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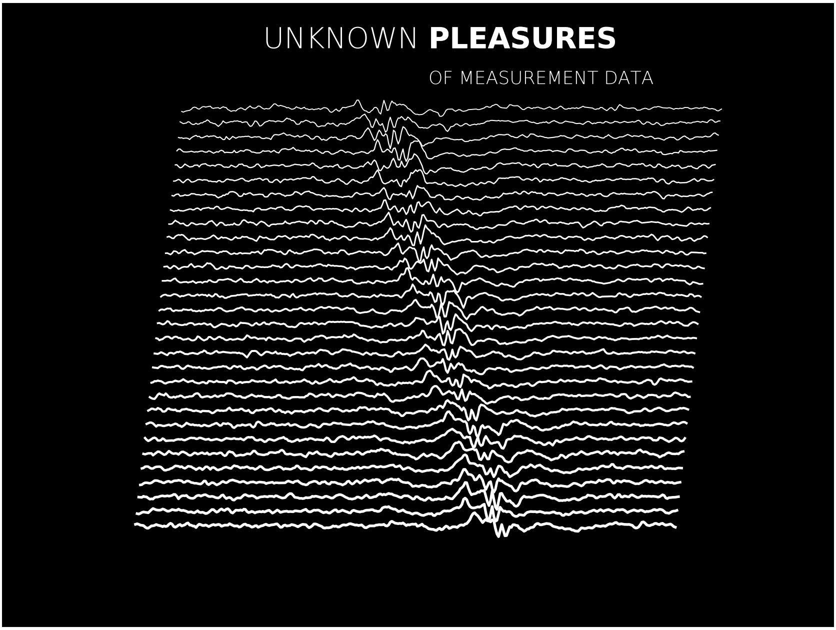

Annual Report 2022

Electronic Measurement and Diagnostic Technology

Dear ladies and gentlemen,
dear colleagues and friends,

until not so recently, most of us certainly could not have imagined that there could be such a brutal and cruel war in Europe again. Due to the aggression of the Russian state against Ukraine, many people have died or been injured unnecessarily, have been displaced, live in constant fear and the infrastructure of a state is being destroyed in large parts. In addition to the depressing individual fates that we witness as citizens of the city of Berlin and as employees or students of the TU Berlin, we are in a crisis of energy that we are trying to control through austerity measures and by changing policies.

At the TU Berlin, too, sensible energy-saving actions are being taken to this end, enabling us to maintain research and teaching operations almost without restrictions, despite the adverse circumstances.

But why did it take this catastrophic war for us to take more serious measures to reduce energy consumption than ever before? We are currently experiencing a boom in the installation of heat pumps or photovoltaic systems. In industry, too, immense efforts have been taken in recent months to become less dependent on fossil fuels.

However, the effects of climate change have been known for decades and we seem to be unable to preserve creation. The lack of technology cannot have been the reason in the past. As early as the nineties of the last millennium, for example, engineers, and technicians developed the 3-liter production car (3-litre Lupo and Audi A2), which could have been a basis for a considerable reduction in CO_2 Emissions from car traffic. Instead, we have witnessed the development of large heavy vehicles for private use.

As another example, the large-scale electric vehicle trial on Rügen from 1992 to 1996 should be mentioned. The result was that the pollutant balance was worse than for conventional drives due to the electricity mix at the time, which consisted largely of electricity produced from coal-fired power plants. Unfortunately, the wrong conclusion was drawn from this and the development of e-vehicles was massively reduced. From today's perspective, of course, an even greater expansion of renewable energies to improve the balance of pollutants in electricity generation would have been the wiser, more far-sighted decision.

The solution to the energy, climate and environmental problems will certainly only succeed if we continue to research and educate at a high level, but get much more involved in socio-political decision-making processes. To this end, we must empower our students more strongly through a broader education.

Nevertheless, the MDT team has also researched and taught very successfully in the past year. By tradition, we would like to give you an overview of last year's events and projects **Research Projects**

- Data-driven Modelling, Fault Diagnosis, and Remaining Useful Life Prediction for Ball Bearing
- SicWell - Influence of SiC Inverters on the of Traction Batteries
- Journal Bearing Wear Prediction using Neuronal Networks
- Wear Prediction of Journal Bearing Systems
- I^2G - Standardized Integral Instrumentation of Gas Foil Bearings for Condition and Operation Monitoring
- Unsupervised Feature Extraction of Multivariate Timeseries Data Using Autoencoder Followed by a Classification on the Autoencoder Representation from an Automotive System with Sparse Error Class
- Unsupervised Domain Adaption on Time Series Data for Remaining Useful Lifetime Estimation
- Development of a Scalable Databased Diagnostic Concept Using Vehicle Measurement Data
- BerDiBa - Digitalization of Rail Transport for Automatic Train Operation
- Probabilistic modelling of railway point machines for fault diagnostics
- Defending against Adversarial Attacks on Timeseries with Selective Classification

To be able to seamlessly transfer our research results into industrial applications in the future, we have founded the Innovation Centre for Electronic Measurement and Diagnostics with our cooperation partner GWT (Gesellschaft für Wissens- und Technologietransfer).

The focal points of the MDT Chair are reflected in this centre. We are eagerly awaiting a successful cooperation.

We are also very pleased to welcome Prof. Dorothea Kolossa to our Institute for Energy and Automation Technology. She took over the Chair of Electronic Systems of Medical Engineering (MTEC) in October, and we look forward to a successful collaboration.

In addition, our annual report contains a summary of our teaching activities and the news from our workshops.

Finally, I would like to thank all partners and the whole MDT-Team. I hope you will enjoy our annual report. Please contact us if you have any questions or comments.

I wish you and your families a
blessed Christmas and a Happy New Year,

Clemens Gühmann

Research Projects

Data-driven Modelling, Fault Diagnosis, and Remaining Useful Life Prediction for Ball Bearing

Diwang Ruan (Publication 2022: [6, 7])

This doctoral project focuses on bearing dynamics modelling, fault diagnosis, and remaining useful life (RUL) prediction. Since its initiation in September 2019, it is finally approaching its end this year.

This year, the research focus is laid on developing new methods and improving existing data-driven algorithms for bearing fault diagnosis. The main work finished can be summarized from the following aspects.

- Transfer learning
  On the one hand, with the Modelica model of the whole bearing test bench developed last year, a direct transfer learning from the Simulation model to the real test bench (Case Western Reserve University bearing test bench) is studied, which confirms the positive effect of the physics model in transfer learning, especially when the simulation data is used as auxiliary to experimental data to train the CNN [6]. On the other hand, a new transfer learning framework based on fuzzy-membership labeling is proposed to realize the task transfer learning between two typical PHM tasks, fault diagnosis (classification task) and RUL prediction (regression task) [7].

- Physics-guided CNN network
  The acceleration response of fault bearing has its distinct feature and is different from the signal in image and speech recognition. This means that the experience of CNN design in the image and speech recognition fields does not match the tasks in the PHM field. Therefore, a multichannel Physics-guided CNN (PCNN) is designed, in which the structure and main parameters like input length, input size, and kernel size are determined by derived rules after signal analysis of fault bearing.

- PHM-GUI and online website
  Besides academic research, engineering applications have also become a research topic this year. With cooperation with two project groups, we have developed two ready-made tools, which

consist of a procedure library, a method library, and a parameter library. Users can freely define the procedure, select the method, and configure the parameters to meet their various fault diagnostics tasks, like data acquisition, data preprocessing, feature extraction, feature selection, fault diagnosis, or RUL prognosis. In each step, many widely used methods have been provided. In short, users can achieve these tasks with their measurement data by simply clicking the mouse.

Above is the summary of my research work in 2022. As to the outlook for next year, I will focus on building the bearing test bench and the construction of a bearing fault dataset. The improvement and deployment of the PHM tools will also be concerned.

SicWell - Influence of SiC Inverters on the Lifetime of Traction Batteries

Daniel Weber (Publication 2022: [1, 3])

With an increasing demand for electric vehicles, the lifetime maximization of the traction battery is of great importance. With the emergence of silicon carbide inverters, a vehicle range increase of 5% could be achieved. Many influencing factors like operating temperature and current have been identified for the battery life. However, the influence of high-frequency noise that silicon carbide inverters emit still has to be analysed. The project SiCWell, in cooperation with Daimler AG and Solfas Technologie GmbH, aims to do just that. This year's goal lay in the quantitative validation of the developed state-of-health and state-of-charge battery diagnosis methods and evaluating the application to an online diagnosis system.

The complete approach of the SicWell project and the first results of the battery ageing experiments have been published by all project partners [3].

The dataset used for the quantitative validation consists of 12 automotive-grade lithium battery cells, which have been cycled with two typical driving profiles over more than 200.000 virtual kilometres. Past experiments have demonstrated that the lack of variations of static driving profiles is a significant handicap to the virtual test diagnosis method, which is irrelevant to the practical application. Nevertheless, the results show that the capacity and resistance may be estimated with a mean absolute estimation error of less than 4%. The estimation error even decreases with the furthering ageing process, which is a significant advantage to conventional methods.

The developed system identification method, an essential component of the virtual test diagnosis method, has been further optimized and applied to an embedded system based on a Jetson Nano. With that, the diagnosis method has been successfully validated on an embedded system for the practical online application.

In addition to its utility for battery diagnosis, the system identification method has shown to be a promising tool for the systematic observability analysis of non-linear dynamic systems, which is still an unsolved task. Together with Intelligent Sensori-

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motor Systems of the Friedrich-Alexander-
University Erlangen-Nuremberg, a first step to the solution of this task has been taken [1].

With these results, MDT successfully finished the research project SiCWell with all the cooperation partners.

Journal Bearing Wear Prediction using Neuronal Networks

José-Luis Bote-Garcia (Publication 2022: [2])

Based on the dataset from the year 2021, a diagnosis and prognosis of the wear volume were realized. The dataset consists of data from a total of 24 experiments, which were recorded with 4 different journal bearings. During the experiments, load, rotational speed, temperature, and acoustic emission signal (AE) were recorded on the journal bearing. The wear volume was recorded after each experiment. The RMS value of the AE signal shows a strong correlation with the wear volume.

Neural networks were used for diagnosis and prognosis. For diagnosis, the wear volume can be estimated at runtime at each time step, although the wear volume itself was only measured at the end of an experiment. Here, the correlation between the RMS value of the AE signal and the wear volume is used.

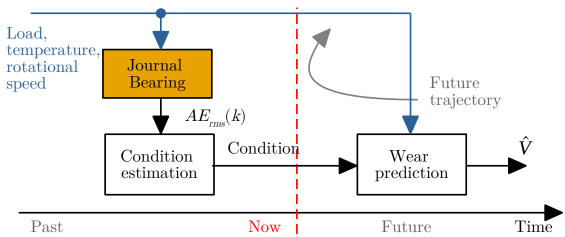


Figure 1: Simulation Results

For prognosis, the difficulty is that the AE signal, which correlates with wear volume, is not available. Therefore, an approach was chosen that allows estimating the wear volume for a specific journal bearing based on data (AE signal, load, speed, etc.) of its past.

In the diagnosis, an RMSE value smaller than $1\,mm^3$ was obtained for the estimation. In the prognosis, an RMSE value of less than $3\,mm^3$ was achieved, which is a good result compared to the result of a simpler approach, where the estimation is based only on load, speed, and temperature, with an RMSE value greater than $5,5\,mm^3$.

Wear Prediction of Journal Bearing Systems

Ongun Türkcüoglu

I have started my teaching and research duties at the MDT team this year in March and decided to contribute to the research project "Journal Bearing Wear Prediction using Neuronal Networks". I had written my Master's thesis on the subject and the test bench, where I had implemented a control algorithm which is capable of inducing mechanical wear on the bearing without interfering with the built-in safety measures.

Currently, I am working on reimplementing the LabVIEW test system, to get insights and generate ideas for the exact direction my research is going to go. The new test system should also allow me to modify some underlying controls, which will hopefully unlock new capabilities.

Gefördert durch
DFG Deutsche Forschungsgemeinschaft

I²G - Standardized Integral Instrumentation of Gas Foil Bearings for Condition and Operation Monitoring

Martin Kliemank

A key component of more efficient operation of machines is the available data about them that allows for optimization of usage and operation. Since machine elements tend to be located close to places where such data can be collected, the DFG priority program 2305 "Sensor-Integrated Machine Elements pave the way for Widespread Digitalization" puts those in the focus. The idea is, that by integrating sensor systems into standardized machine elements it will become easier for manufacturers and users of machines to collect and use data from their machines without additional development effort, thus boosting digitalization.

The priority program is made up of ten projects located at different universities across Germany, each focusing on a different machine element. At the Department of Electronic Measurement and Diagnostic Technology, we are focusing on gas foil bearings. For that, we have joined forces with the department of Engineering Design and Product Reliability (Prof. Liebich) from Faculty V, who are experts on this type of bearing.

Figure 3: Gas foil bearing

Gas foil bearings work similarly to hydrodynamic journal bearings, however, instead of oil, they use gas (e.g. air or whatever gas the machine interacts with) as the lubricant. While this means they can only support relatively light rotors, it also means they run very efficiently up to extreme velocities and can be applied in areas where oil contamination would be problematic. This makes them a perfect fit for the air compressor for fuel cell systems or for cooling turbines for air conditioning, but they are also used in other turbo machineries.

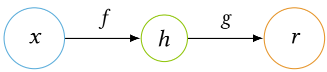
The goal of the project is to integrate a sensor system into the gas foil bearing that provides the current rotational velocity, state of friction, and temperature as wireless data to an outside receiver. It is supposed to be powered from the bearing itself via energy harvesting and must not change the workings of the bearing. This also means that nothing can be attached to the rotor, which means many of the values need to be interpreted indirectly from vibrations.

The project has just started this spring. Currently, we are working to establish a test stand for reference measurements and trying out the first options for the velocity estimation algorithms. We are also manufacturing the first prototype of the sensor system to collect insights into power consumption, processing power, and integration in general.

Unsupervised Feature Extraction of Multivariate Timeseries Data Using Autoencoder Followed by a Classification on the Autoencoder Representation from an Automotive System with Sparse Error Class

Jonas Köhne

Within the project „Automatic Selection of Features for the Diagnosis of Mechatronic Processes", which started in September 2019 in cooperation with IAV GmbH, new deep learning approaches for machine diagnosis are being examined. The following research targets will be evaluated during this PhD study: Classification or detection of sparse error class and deterioration effects of a mechatronic system which provides large multivariate timeseries data using a deep learning approach; also the partial automation of the necessary preprocessing and feature selection by a human expert who has a priori knowledge of the system. This should be achieved by using, amongst others, a type of artificial neural network which is called autoencoder. The resulting compressed representation of the system together with the reconstruction error should be used to classify, identify a sequence or detect abnormal behaviour of the system and possibly determine the precise condition of the equipment. The figure below shows the general structure of an autoencoder: the mapping of an input x to an output, which is called reconstruction r, through an internal representation h (Source: Own representation based on Goodfellow et al. 2018, pp. 503).



One of the main challenges in the diagnosis and predictive maintenance of a mechatronic system, particularly in the commercial vehicle sector, is the sparse amount of data from the error component or deteriorated part. The intentional destruction of the component is challenging and is especially very time-consuming with newly used components. Other challenges are the a priori knowledge and expertise of the specific component needed for developing a robust diagnosis, not even considering a prediction of the future condition. A new approach for labelling sequences of operation points called ABIMCA (Autoencoder-based Iterative Modelling and Multivariate Time-Series Subsequence Clustering Algorithm) is being published and made publicly available as a Python package. In this context, a new clustering metric for multivariate time-series, which takes the time space variations like curvature, acceleration or torsion in a multidimensional space into consideration, was developed and made publicly available.

Within this PhD study, these research questions are examined: is a representation learning approach possible to convert unsorted raw sensor data into a representation with well-separated factors of variation that describes the observed mechatronic system? If so, how feasible is it to use these separated factors as an input for a classification algorithm to diagnose the observed mechatronic systems within a possible out-of-distribution input? How well would this approach compare to a mathematical or physical modelling approach with expertise and experienced knowledge of the mechatronic system? How big is the effort of obtaining a good representation and training a classifier compared to a standard and widely accepted modelling approach? What types of Autoencoder architectures are feasible for multivariate time-series data from a mechatronic system?

Unsupervised Domain Adaption on Time Series Data for Remaining Useful Lifetime Estimation

Tilman Krokotsch (Publication 2022: [4])

There is a severe data imbalance in Predictive Maintenance (PDM) applications, i.e. having large amounts of data from healthy machines and only a small amount from worn down ones. Methods of Unsupervised Domain Adaption (UDA) can alleviate this imbalance by transferring knowledge from a trained model to a new unlabelled dataset. We use deep neural networks as prediction models because their learned representations have proven highly adaptable in other domains.

Remaining Useful Lifetime (RUL) estimation is a sub-field of PDM where the data imbalance is especially severe. The label information for RUL estimation (the remaining operational cycles until breakdown) can only be calculated after a machine breaks down. Therefore, conventional, supervised training methods can only be used once a sufficient number of machines failed. UDA can enable the application of PDM much earlier in the machine life cycle by using the unlabelled machine data and a related labelled dataset (e.g. same machine under different operating conditions) for training.

This year, we published a semi-supervised learning method in the International Journal of Prognostics and Health Management (IJPHM). Semi-supervised learning is a special use case of UDA where both labelled and unlabelled data come from the same domain. We have shown that self-supervised pre-training using labelled and unlabelled can improve the RUL prediction performance of a neural network. The pre-training task was predicting the number of time steps between two feature windows from the same time series. We achieved favourable results by using as few as three fully degraded machines for labelled data. Because, as mentioned before, semi-supervised learning is a special use case of UDA, our approach should be generalizable to UDA as well. The research here is ongoing.

To make our research reproducible and transparent, we always release our code publicly. Unfortunately, not all researchers are able to do so. To further reproducible research, we are working on an open-source library that contains common UDA approaches for RUL estimation. We will use this library to conduct a survey and benchmark of these approaches to gauge if the field is making progress. Additionally, we are working on a companion library that provides easy access to popular benchmark datasets. The development progress can be observed here:

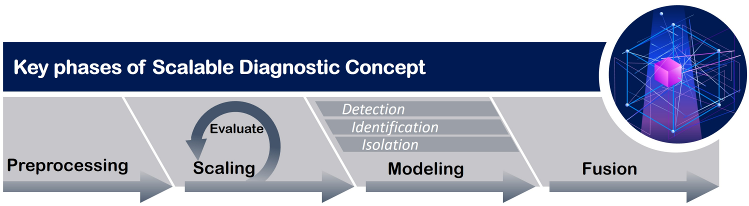
RUL Adapt : `https://github.com/tilman151/rul-adapt`

RUL Datasets : `https://github.com/tilman151/rul-datasets`

Development of a Scalable Databased Diagnostic Concept Using Vehicle Measurement Data

Andreas Schmitz

The aim of this Ph.D. thesis is the development of a diagnostic concept, which is scalable about statistical and information-theoretic criteria. The project is in cooperation with IAV GmbH. There are several ways to develop a diagnosis for an arbitrary system, and most of them can be either classified into model-based or data-based methods. Also, the combination of model- and data-based methods is possible, called hybrid methods. All approaches have special advantages and disadvantages, which could be combined into a scalable inductive inference concept. Generally, the diagnosis task has three main parts: Fault Detection, Fault Identification, and Fault Isolation, as can be seen in the modeling step in the figure.
The key phases of the diagnostic concept include four steps. The preprocessing for preparing the data is followed by scaling, where different databased methods are compared via specific metrics. In the modeling step, one diagnostic method is chosen and trained to fulfill the diagnostic tasks. Finally, a fusion strategy can be used to combine two or more approaches if needed.



Besides the aim to combine different methods out of data-based approaches in a scalable way, the difference between the online- and offline-system-performance which is needed to do the diagnostic, is considered. In the concept it should be also reflected, that specific requirements could be given depending on the diagnostic task, e.g. maximum accuracy or maximum performance. Currently, the development of the phases, especially the scaling part, takes place. Furthermore, each step is evaluated and tested with real vehicle measurement datasets. The next step is the extension of real experiments and the integration of statistical and heuristical thresholds for scalability, to answer the research questions: which metrics and thresholds are suitable to the different diagnostic methods (also regarding the real experiments)? Which areas could be identified for the different diagnostic methods, regarding the specified metrics? Which diagnostic capabilities of the individual methods can be classified depending on the fault severity and type of fault?

BerDiBa - Digitalization of Rail Transport for Automatic Train Operation

Daniel Thomanek, Daniel Weber, Daniel Adam

The key to sustainable and environmentally friendly mobility is the digitalization of rail transport. With BerDiBa ("Berliner Digitaler Bahnbetrieb"), the MDT department is working on an innovative research project dealing with this topic. The project includes 12 project partners and is funded by the innovation support program ProFIT.

The main focus of the project is the research and testing of technologies for automated driving on a rail. One main topic of autonomous trains is the ability to monitor their health state and likewise the health state of their environment. Furthermore, these health states need to be predicted in the future to ensure safe and optimal operating conditions.

The Department of Electronic Measurement and Diagnostic Technology is working on several topics.

Together with our project partners, we have developed a maintenance optimization algorithm to improve the work plan. Our department developed a multibody model of a mechanical train door. In the model, we integrated the wear of various mechanical components. With this wear model, door openings are simulated and different stations, routes, and passengers are considered. This data can then be used to predict their failure as precisely as possible. This provides the opportunity for our project partner, the Zuse-Institute of Berlin, to optimize the maintenance and thus the work schedule.

For the simulation of railroad operations, we developed a scene simulator. The simulator reproduces the mechanical train, the rail, and the control of the train. This simulator was developed as a Simulink library and allows the assembly of individual routes. The track profiles can include curves, slopes, gradients as well as damaged sections. Furthermore, railroad switches and railway signals can be configured to accurately represent a rail network. A controller is required to operate the train in the simulation. This governing of the model and thus the adjustment of the target speed is done via 2 PID controllers for motor speed and brake load. This simulation can now be used to generate the velocity and acceleration data of the train along the track. However, more importantly, it can be applied to simulate different forces.

Next year we will start the 2nd phase of the project. We will then also work on new topics in the research area of railroad infrastructure monitoring.

The first topic is the diagnosis of sleeper lowering. For this purpose, the effects of sleeper lowering on the train are to be investigated simulatively. From this, the remaining service life and the state of health are to be determined. This load model of the rail is then also to be integrated into the scene simulator and different stations, routes, and passengers can be simulated.

Figure 4: Image of the Environment (left) and 3D-Reconstruction (right)

Not only the track will be monitored, but also the so-called structural gauge. One of the major challenges is to monitor the railway environment and model the plant growth along the railway tracks to predict the violation of the structural gauge over a long period of time. For this purpose, images taken from a monocular camera mounted frontal on the Train (driver's view) are used to recognize the vegetation. Within these images, the vegetation along the track is detected and reconstructed (Figure 4). The growth of the reconstructed vegetation can now be simulated and the violation of the structural gauge can be predicted. To determine the expected growth, a test bench is constructed in that the growth of a common species along the railway tracks can be examined under optimal conditions. Figure 5 shows the inside of that test bench.

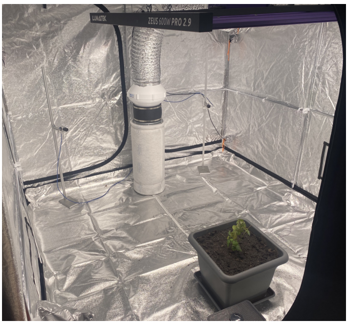


Figure 5: View inside the greenhouse testbench

This research project should make rail traffic safer and increase the punctuality of trains, thus creating sustainable and environmentally friendly mobility.

Kofinanziert von der
Europäischen Union

Probabilistic modelling of railway point machines for fault diagnostics

Susanne Reetz - DLR

Switches and their point machines, commonly powered by electric motors, are critical elements of the railway infrastructure. Therefore, the motors are often monitored by measuring the electric current during the transition process. Many aspects of the switch behaviour are reflected in these current curves (cf. Figure 6) so that this data constitutes a good basis for condition monitoring.

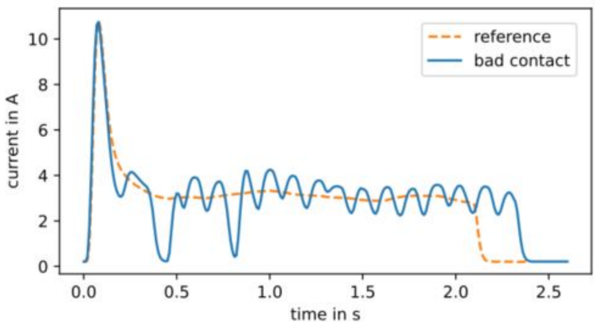


Figure 6: Current curve of a point machine with a bad contact in the power supply, and healthy reference curve

In the area of anomaly detection, i.e. the automated detection of any atypical behaviour in target assets via the regular assessment of measurement data, the monitoring of railway switches based on current curves is a common practice. The next step, once an alert is issued, is to automatically identify the root cause(s) behind the abnormal behaviour (i.e., fault diagnosis). As large quantities of labelled historic fault data are often hard to come by, the following approach is based on expert knowledge, manual feature engineering and experimental data. Bayesian networks are probabilistic graphical models that can represent complex probabilistic relations between different random variables transparently, allowing for human-interpretable reasoning. The switch drive, its influencing factors and current curve features are implemented in the Bayesian network based on their causal relations (cf. Figure 7). In application, measurement data features and other known information (e.g., environmental factors) are entered into the model as soon as they are available. Based on these evidences, the model automatically calculates the most likely fault causes as states of the respective network nodes

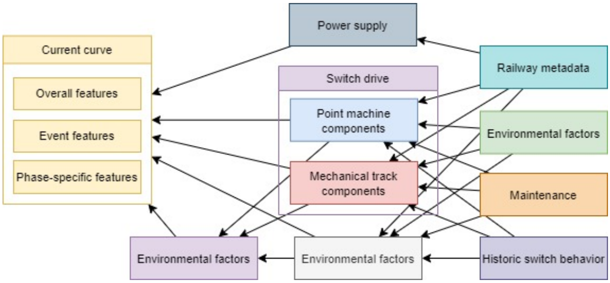


Figure 7: Overview over the presented diagnostic model for switch drives. The full model comprises 66 nodes, 178 states, 105 links and 661 free parameters

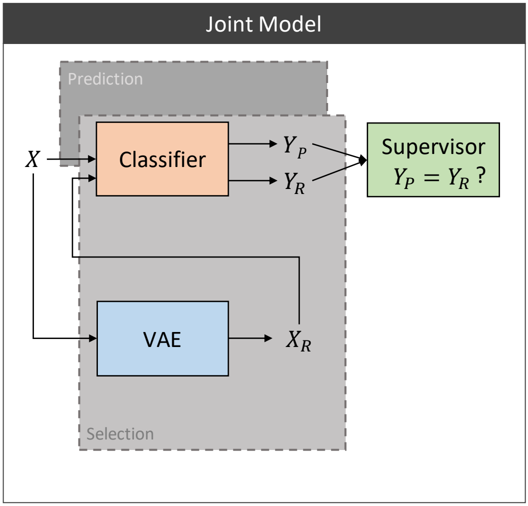
This work (including used information sources, development process, scenario-based evaluation and entropy analysis of the presented model) is currently submitted as a research paper (status in review).

This PhD project is carried out in cooperation with DLR.

Defending against Adversarial Attacks on Time-series with Selective Classification

Joana Kühne (Publication 2022: [5])

Despite their many advantages, deep learning models are known for their poor performance on input data that is from another distribution than the training data. Adversarial attacks intentionally perturb the input data to test the model's robustness. High robustness is crucial for many applications, especially if safety aspects need to be considered. This study combines adversarial training and selective classification to counteract adversarial attacks.



The idea of selective classification is to only predict input samples for which the model is confident and to reject the samples otherwise. For the study, four different selective approaches are evaluated:

- **Softmax Response**. This approach estimates prediction confidence as the maximum Softmax value activation for the input sample.

- **Variational Autoencoder (VAE) Reconstruction Loss.** This method introduces a VAE which is trained on the same data as the target classifier. The reconstruction loss is used as a measure for the confidence.

- **Joint Model.** This method also relies on the usage of a VAE. However, instead of computing the reconstruction loss, the reconstructed sample is fed to the classifier and an additional prediction Y_R is conducted. If the first and second predictions, Y_P and Y_R, are not identical, the sample is rejected. The model structure is displayed in the figure.

- **Selective Net.** This approach is a neural network with an integrated reject option, developed by Geifman et al. in 2019. In addition to the prediction, the confidence is given as the output of the model for each sample.

The selection approaches are tested on unmodified time series as well as with adversarial attacks applied such as: Gaussian Noise, Fast Gradient Sign Method (FGSM), Basic Iterative Method (BIM), Projected Gradient Descent (PGD), and Deep Fool (DF). Moreover, the selection approaches are combined with PGD training, where the classifiers are exposed to perturbed samples already during training. The results show that selective prediction can successfully decrease the risk of adversarial attacks. Moreover, all the classification algorithms can be easily combined with adversarial training, which leads to a further reduction of the risk. However, the task of sustaining the risk as low as for clean input data could not be achieved yet. This aspect is focused on in the ongoing studies. Another interesting field of research is the combination of selective classification algorithms with other defences against adversarial attacks.

This PhD project is carried out in cooperation with IAV GmbH.

Electronic and Mechatronic Workshop

News from Our Workshops: Electronic Service and Mechatronic Workshop

Frank Baeumer

Fortunately, after the two Corona years and the hacker attack in 2021, a bit of normality returned in 2022. Nevertheless, there was still a lot of work on our IT infrastructure and the further development and modification of our test stands. Our Electronic Service uniformly installed a new Linux operating system on our existing servers. Furthermore, our department bought a new server for the research work of our scientific staff. Our Mechatronic Workshop supported various research projects. In the BerDiBa research project, a greenhouse was set up in one of our rooms, in which various parameters such as e.g. humidity or light intensity can be changed. The growth of the plants is monitored by sensors and cameras. You can find more about this in this brochure in the report by Mr. Thomanek and Mr. Adam.

Investment: MDT IT Infrastructure

Because of growing requirements concerning calculation speed and memory size, our chair invested in the MDT IT infrastructure and bought one new high-performance server. The configuration of this server enables tasks to be operated at high speed. Thanks to the excellent teamwork between the research assistants and the Electronic Service we managed to order, install and operate the new system. We think that this investment will be a good support and basis for our existing and coming research projects.

Modernization of the gear wheel test stand and the motor test stand

Our MDT department operates a gear test stand in which a motor drives the gears while a magnetic powder brake can generate a variable braking torque. Software and hardware for controlling and regulating this test stand have been updated. The same applies to our motor test stand, in which an asynchronous motor drives the shaft and a DC motor including a load resistor generates a braking torque.

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[2] José-Luis Bote-Garcia and Clemens Gühmann. Wear volume estimation for a journal bearing dataset. *tm - Technisches Messen*, 89(7-8):534–543, July 2022.

[3] Erik Goldammer, Marius Gentejohann, Michael Schlüter, Daniel Weber, Wolfgang Wondrak, Sibylle Dieckerhoff, Clemens Gühmann, and Julia Kowal. The Impact of an Overlaid Ripple Current on Battery Aging: The Development of the SiCWell Dataset. *Batteries*, 8(2), February 2022.

[4] Tilman Krokotsch, Mirko Knaak, and Clemens Gühmann. Improving semi-supervised learning for remaining useful lifetime estimation through self-supervision. *International Journal of Prognostics and Health Management*, 13(1), 2022.

[5] Joana Kühne and Clemens Gühmann. Defending against adversarial attacks on time-series with selective classification. In *2022 Prognostics and Health Management Conference (PHM-2022 London)*, pages 169–175, 2022.

[6] Diwang Ruan, Yuxiang Chen, Clemens Gühmann, Jianping Yan, and Zhirou Li. Dynamics modeling of bearing with defect in modelica and application in direct transfer learning from simulation to test bench for bearing fault diagnosis. *Electronics*, 11(4):622, 2022.

[7] Diwang Ruan, Yuheng Wu, Jianping Yan, and Clemens Gühmann. Fuzzy-membership-based framework for task transfer learning between fault diagnosis and rul prediction. *IEEE Transactions on Reliability*, 2022.

[8] Nino Sandmeier. *Optimization of adaptive test design methods for the determination of steady-state data-driven models in terms of combustion engine calibration*. Number 10 in Advances in Automation Engineering. Universitätsverlag der TU Berlin, 2022.

Bachelor Theses in 2022

[1] Nadir Ekrek. Drahtloses Messsystem zur Erfassung von Raddrehzahlsignalen .

[2] Mahmoud El Hage. Unterdrückung stochastischer und deterministischer Störungen in Sensorsignalen mittels Wavelet-Transformation in Echtzeit.

[3] Felix Felchner. Entwicklung einer Visualisierung für den simulierten Zugverkehr.

[4] Dogan Gülcemal. Drahtloses Messsystem zur Erfassung von Raddrehzahlsignalen .

[5] Vivien Lisa-Marie Kosow. Konzeption, Aufbau und Inbetriebnahme eines automatisierten Lebensdauerprüfstandes für elektrische Heizelemente in Waschgeräten.

[6] Ines Kueta Notsa. Modellierung und Simulation idealer und nichtidealer Analog-Digitalumsetzer mit Modelica.

[7] Yanbing Liu. Modellierung und Simulation eines Biegebalkens und einer DMS-Messbrücke zur Gewichtsbestimmung mit Modelica.

[8] Alexander Lähns. Modellierung und Simulation der Interaktion zwischen Schiene und Radsatz zur Verschleißvorhersage.

[9] Hassan Mohammadi. Implementierung von Algorithmen für Situationsanalyse und Bremslogik im Parkhaus.

[10] Jason Osayi. Programmierung von CNC-Werkzeugmaschinen mittels Computer-Aided-Manufacturing-Software am Beispiel des 5-Achs-Simultan-Fräsens und des Laser-Auftragsschweißens.

[11] Christian Rompas. Data-Driven Sensor Models – How the Identification of Significant Influences on Perception Pipelines Allows Testing Automated Vehicles More Efficiently.

[12] Christian Schlegel. Automatisierte Getriebeapplikation am Prüfstand.

[13] Freia Siegel. Programming, Calibration and Commissioning of a 5-Hole Probe.

[14] Odeidah Awni Salim Smadi. Verfahren zur Unterdrückung stochastischer und deterministischer Störungen in Sensorsignalen mittels Wavelet-Transformation.

[15] Johannes Stoeckle. Entwicklung und Simulation eines Alterungsmodells für Wicklungen elektrischer Maschinen am Beispiel einer permanenterregten Synchronmaschine.

[16] Zhengyan Zhu. Verfahren zur Unterdrückung stochastischer und deterministischer Störungen in Sensorsignalen mittels Wavelet-Transformation.

Master Theses in 2022

[1] Abdullah Al Asaad. Wear detection and prediction of journal bearings using acoustic emission signal with convolutional neuronal networks.

[2] Björn Fischer. Detektion von Energieeffizienzdefiziten in industriellen Anlagen durch automatisierte Zustandsklassifikation anlagenspezifischer Messreihen.

[3] Oleksandr Gozman. Parking scene understanding with Classifying and Localizing Surroudings.

[4] Runkai He. Conceptual Design and Implementation of Smart Parking System.

[5] Viet Hoang Lai. Photonische Sensoren und maschinelles Lernen zur automatisierten Temperaturbestimmung.

[6] Yi Li. Modeling of the Race Roughness for Ball Bearing based on Fractal Theory and Fourier Series.

[7] Hanwen Liu. Development of Vehicle Domain Controller Prototype and Body Domain Testbench.

[8] Hannes Lorkowski. Entwicklung eines datenbasierten Ansatzes zur frühzeitigen Erkennung von Radschäden am Beispiel von Hochgeschwindigkeitszügen.

[9] Lin Ma. Improvement in similarity-based RUL prediction for bearing by Monte Carlo Methods.

[10] Sabrine Maiz. Modeling and Simulation of railway operations for use in optimization.

[11] Fabian Menzel. Condition Monitoring and Prognosis of Degradations of Rotating Machines.

[12] Cheng Peng. Control Algorithm Implementation for Electric Motors in a Circuit-based Model.

[13] Felix Saalfrank. Multi-Sensor Ramp Detection and Localization for Autonomous Valet Parking.

[14] Yi Sun. Remaining Useful Life Prediction for Bearings based on Wiener Processes.

[15] Pei Tang. Diagnosability Evaluation for Measurement Data in Bearing Fault Diagnosis.

[16] Jiaoying Wang. Modeling of Vibrations produced by Bearings with Defects and its Application in Construction of a Bearing Digital Twin.

[17] Jin Wang. Efficient physics-driven convolutional neural network design for bearing fault diagnosis.

[18] Yikai Wang. Development of Autonomous Emergency Braking System Controller Based on Ethernet Swith.

[19] Hao Wu. Modellierung und Entwicklung einer Energiemanagement-Strategie für Brennstoffzellen-Hybridfahrzeug.

[20] Yifan Zhao. Improvement of softmax layer and label encoding of CNN for bearing fault diagnosis.

[21] Mengjie Zhu. Probability-based labeling for unlabeled data over the aging process and Its application in bearing fault diagnosis.

Courses

Despite the severe restrictions due to the Corona pandemic, we were able to offer all courses as in previous years.

Summer term 2022

Measurement Data Processing	Lecture & Lab
Control and Regulation of Automotive Powertrains	Lecture
Graduation seminar on Measurement Technique	Seminar
Measurement Data Processing	Projects
Pattern Recognition and Technical Diagnosis	Lecture & Lab
Simulation and Technical Diagnostics	Projects
Machine learning for error diagnosis and prognosis	Lecture & Lab

Winter term 2021/2022

Basics of Electronic Measurement Techniques	Lecture & Lab
Basics of Electronic Measurement Techniques	Tutorial
Introduction to Automotive Electronics	Lecture
Modelling and Real-Time Simulation	Lecture
Modelling and ECU Optimization	Lab
Graduation seminar on Measurement Technique	Seminar
Measurement Data Processing	Projects
Simulation and Technical Diagnostics	Projects
Machine learning for error detection	Lecture & Lab

Our Team

Head of Chair

Prof. Dr.-Ing. Clemens Gühmann

Offices

Ewa Heinze	(EN 13 – MDT)
Elisabeth Schwidtal	(EN 3 – MTEC)

Research Assistants

M.Sc.	José-Luis Bote-Garcia (until May 2022)
Dipl.-Ing.	Jonas Köhne
M.Sc.	Tilman Krokotsch (until August 2022)
M.Sc.	Diwang Ruan
M.Sc.	Daniel Thomanek
M.Sc.	Daniel Weber
M.Sc.	Daniel Adam
M.Sc.	Ongun Türkcüoglu (since March 2022)
M.Sc.	Martin Kliemank (since April 2022)

Doctorands

M.Sc. Joana Kühne (IAV GmbH)
M.Sc. Christian März (IAV GmbH)
M.Sc. Andreas Schmitz (IAV GmbH)
M.Sc. Susanne Reetz (DLR)
M.Sc. Patrick Laufer (IAV GmbH)
M.Sc. Russell Sabir (SEG Automotive Germany GmbH)
M.Sc. Mateusz Grzeszkowski
M.Sc. José-Luis Bote-Garcia
M.Sc. Tilman Krokotsch
M.Sc. Dengfeng Shen

Not Permanently Employed Lecturer

Dr.-Ing. Mirko Knaak	Seminar Measurement and Technical Diagnosis
Dr.-Ing. René Knoblich	Automotive Control Systems for Drivelines and Introduction in Automotive Electronics - Lecture and Lab
Dr.-Ing. Benjamin Baasch	Machine learning for condition monitoring of technical assets and systems - Lecture and Lab

Tutors Measurement Laboratory

Emil Thaon de Saint André
Gert Ruka
Michael Böttge
Laurin Angel
Armin Kalabic

Institute Engineers (MTEC & MDT)

Dipl.-Ing. Frank Baeumer
B.Eng. André Göttlicher

Electronic Service (MTEC & MDT)

B.Sc. Felix Piprek
B.Sc. Sebastian Binder

Mechatronic Workshop (MTEC & MDT)

Peter Jaeck
Patrick Schulz

Technische Universität Berlin
Prof. Dr.-Ing. Clemens Gühmann
Electrical Engineering and Computer Science
Chair of Electronic Measurement and Diagnostic Technology
Sekr. EN 13, Einsteinufer 17
10587 Berlin, Germany
Phone: +49 30 314-22280
http://www.mdt.tu-berlin.de