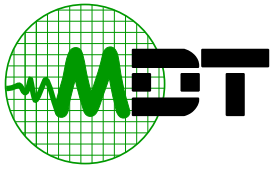
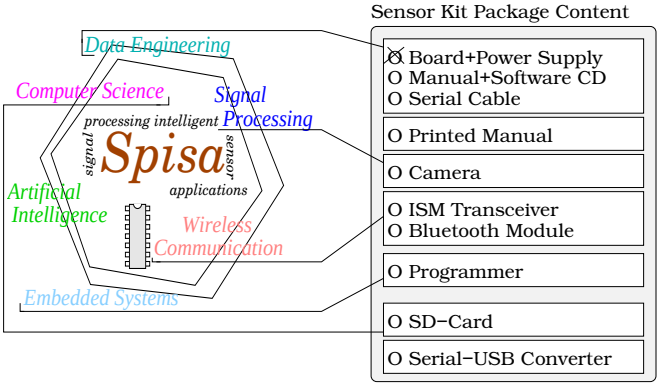


Technische Universität Berlin

Annual Report 2008



Electronic
Measurement and Diagnostic Technology

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Dear ladies and gentlemen,
dear colleagues and friends,

traditionally we would like to give you a review of the year's events. In March we started the new project "NoSI - Nonlinear System Identification" funded by the Investitionsbank Berlin. Some details about this project, an overall view of the other projects

- *Modelling, Simulation, and Automated Analysis of Shifting Processes of Double Clutch Transmissions*
- *Modelling and Prediction with Stochastic Methods*
- *Wavelet Application Group*
- *Nonlinear System Identification - NoSI*
- *Modelling and Simulation of Faults in Electric Drives*

and a summary about our teaching activities you will find in this annual report.

A special highlight of the year 2008 was the conference "Simulation and Test (SuT)" carried out in a cooperation with the IAV GmbH. On this scientific conference the approximate 130 experts could reminisce on the field of the modelling, simulation, and the automated software test. In May 2010 it will be continued with a fourth meeting.

In the meantime we prepare the fifth international conference "Design of Experiments (DoE) in Engine Development" also in cooperation with the IAV. On the 29^{th} and 30^{th} of June scientists and developers from all around the world will discuss modern development methods for combustion engines here in Berlin.

We welcome Prof. Stephan Völker in our Department of Energy and Automation Technology. Since April 2007 he is the head of the Chair of Lighting Engineering. He researches also on the field of the car engineering, however, with the emphasis on lighting engineering. Furthermore, we hope that we can find Prof. Obermeier's (Microsensor and Actuator Technology), Prof. Kalkner's (High Voltage Engineering) and Prof. Bernet's (Power Electronics) successors in order to meet the future challenges in both, teaching and research.

I would like to thank all partners and the whole MDT-Team. All of them did an excellent job in different research projects and in teaching. I wish you and your families a blessed Christmas and a Happy New Year,

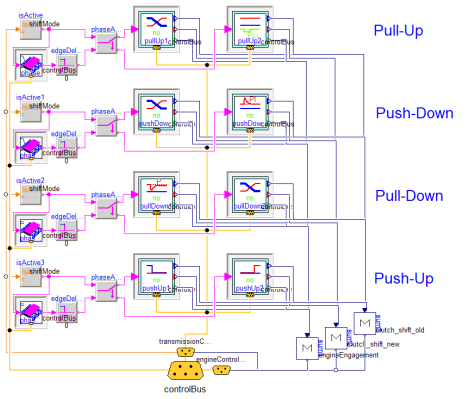
Clemens Gühmann

Modelling, Simulation, and Automated Analysis of Shifting Processes of Double Clutch Transmissions

Henrik Isernhagen (Publications 2008: [1, 2, 3, 4])

Nowadays, more and more new cars are assembled with double clutch transmissions because of efficiency, drive comfort, and uninterrupted power shifts. Such uninterrupted power shifts are possible by reason of the two different clutches with the accordant shafts. The first clutch opens and the second clutch closes simultaneously during the shifting process, resulting in an uninterrupted power transmission. The correct control of the two clutches is very important for the different shifting processes. At this point it is necessary to distinguish between upshifts and downshifts as well as pulling power and pushing power of the power train. Control and calibration errors can result in bad shifting, for example in form of rotational speed droppings, break outs, or oscillations. These faults are sensed by the driver as uncomfortable. According to this, the longitudinal vehicle driveability is an important aspect in the vehicle development process.

A huge amount of measurement data is collected, often in endurance tests, which needs to be automatically evaluated. For this, in cooperation with the IAV GmbH a software was developed for an automated analysis of vehicle measurement data. The automated measurement analysis system is used for the evaluation of shifting processes of different quality. There exist different evaluation modules, e. g., an analytical signal description or a frequency detection. The focus of this work is the analysis of transmission measurement and control signals, but not the objectification of subjective ratings.



Because measurement data is often unlabelled the system parametrisation is difficult. The data contains measurements of several shifting processes, but information on good or bad examples is often missing.

As a solution we developed the model of a double clutch transmission within a vehicle model and an appropriate transmission controller in Modelica®/Dymola®.

The aim of this work is the simulation of shifting processes with different levels of detail. Here, the focus is on the differentiation between good and bad shiftings. According to this, it is possible to verify on the one hand the physical level of detail and on the other hand the control of the shifting process. With the simulation results of this work we can parametrise the automated measurement data analysis system for the evaluation of shifting processes.

Modelling and Prediction with Stochastic Methods

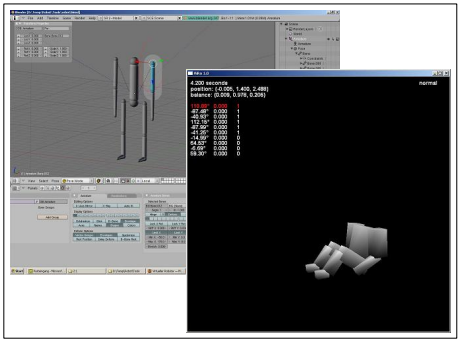
Steffen Kühn (Publications 2008: [5, 7, 6])

The years 2006 and 2007 were dominated by the development of a new stochastic sequence detection and recognition technique. This year finally some time was available to investigate and develop two new algorithms.

The first algorithm concerns the question, how it is possible to generalise the well known statistic concept of prediction intervals for high dimensional and non-trivial data [5]. In real life the behaviour of a complex technical system is often non-linear and ambiguous and it is not easy to predict its reactions for a certain input only on the basis of sample data. A new probability measure - the significance level distribution - which extends cumulative density functions was introduced to solve this problem. The advantage is that the criterion provides probabilities - even for real-valued data like measurement values from current or voltage. The significance level distribution can be computed easily with the new algorithm from a given probability density function.

The second algorithm is a numeric optimisation method to find the global optima or the modes of kernel densities [6]. The difficulty is that the weighted sum of kernels leads to numerous local maxima. Traditional numeric optimisation methods deliver in the most cases only one of these. The practical value of this new algorithm is that the most probable system response for a given set of input values can be found with linear time complexity, when the system behaviour is modelled by a complex (but powerful) kernel density estimation.

Both new methods aim at unsupervised system identification of very complex systems. The dynamics of a vehicle can be taken as an example for a system with a medium complexity. One article describes how the developed methods can be combined into a system which learns autonomously the behaviour of a vehicle power train. The obtained model can then be used for control algorithms [7]. For further experiments a virtual physically-realistic biped robot model framework was developed.

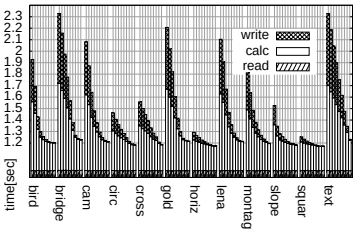


Besides these theoretical considerations applied research and development was performed this year. On the one hand the quality of the sequence recognition technique for the fault detection of weldments based on infrared images was examined in cooperation with the Inpro GmbH. On the other hand we have studied in detail its quality for the detection of knocking combustions in presence of environment noise. Furthermore, a low cost embedded hardware for the sequence recognition method was developed.

Wavelet Application Group

Stephan Rein and Stephan Lehmann (Publications 2008: [8, 9])

Summer School: In summer 2008, two student groups from University of Michigan joined the MDT research laboratory. The program (sponsored by IAV) was mentored by Volker Sick (University of Michigan) and Clemens Gühmann.



The exchange aimed to give the students insight into German culture, engineering and industry. After an introduction class held by Frank Baeumer, where the students learnt how to build the chair's sensor node, Stephan Lehmann taught the students how to develop their

own sensor application using a filesystem and a camera. Finally the students performed a wavelet transform using one of the chair's latest algorithms.

MDD'08: The wavelet group organised the *Mobile Developer Days* at TU Berlin, a three-day conference that concerns the development of mobile applications for phones and sensors. The event was attended by 88 researchers from industry and academics.

Filesystem: The chair's filesystem for sensor nodes was made freely available in [8]. Stephan Lehmann conducted an extensive performance evaluation to verify the system's ability to operate on very limited platforms while read access is in the range of a few milliseconds. Write access is reasonably fast if it is not done at random. The system is now the basis for two novel algorithms for image compression.

Fractional Filter: One of the latest algorithms of the group is the *fractional wavelet filter* [9]. This filter allows a fixed-point wavelet transform of a picture with 256x256 pixels only allocating 1.3 kByte of random access memory (RAM). Previous algorithms required 10 times more of RAM and were not applicable to low-cost micro controllers.

Wi2l Coder: The latest algorithm of the group is the *wavelet image two-line* (Wi2l) coder [10], which achieves compression rates competitive to Jpeg2000 while it is conceptually very simple. The coder can compress a picture with 256x256 pixels with only 1.5 kBytes of RAM and thus can be employed on simple micro controller architectures. In the past these architectures were considered to be not sufficient for wavelet image compression. The recursive Wi2l coder uses the chair's fractional filter and thus only requires integer calculations. Encoding times for 9 different picture qualities ranging from 25 to 59 dB are given in the plot. The measurements are categorised by access and computing times and were conducted by Stephan Lehmann on the chair's sensor node Spisa.

Nonlinear System Identification - NoSI

Jan Malte Riedel and Nivin Ghamry (Publications 2008: [11])

As the classic approaches to engine measurement (e. g., grid-measurement) have difficulties in keeping up with the shortening of development cycles the industry is moving on to statistical methods

like "Design of Experiments". DoE tries to maximise the covering of the experiment space with a given number of data-samples without losing relevant information about the system. To gauge the amount of information inherent in one data-sample engine models are used. Dynamic measurements are being made to minimise/avoid the slow settling in operating points which in turn requires dynamic models to reproduce the measured results. Physical models mostly contain a set of differential equations which require a large amount of computing time. One alternative are data-based methods which use "black-" or "grey-box" models.

The aim of the NoSI Project is to analyse the features of modelling nonlinear dynamic systems with data-based methods. The different methods will be tested on different sub-parts of a spark-ignition engine to find the appropriate one with a fitting dynamic behaviour for each part respectively. After the initial research of already existing models the project is coming to its core task, the testing of the data-driven methods.

Already some student projects and theses are on their way:

Ms. Liu is researching the possibilities of the use of wavelets under the guidance of Dr. Nivin Ghamry a guest researcher at MDT. Mr. Blankenburg, Mr. Liu and Mr. Wang are looking into the identification of state space systems via subspace methods.

Modelling and Simulation of Faults in Electric Drives

Dietmar Winkler (Publications 2008: [4, 13, 14])

In automotive applications the number of electric motors used is increasing rapidly. Most of them are doing their work in the background unnoticed by the car owners/users. Whilst a power window is quite an obvious application for an electric motor, the active controlled throttle valve might not be. And with more and more tasks going to be performed *by-wire* (e. g., braking, steering) the number of electric motors used is due to increase even more. But not only *small* electric motors are present. With the electric motor being used for active propulsion in hybrid electric vehicles (HEV) also the power rating of motors used grows bigger.

But how do all these little and large motors work together? How should the manufacturer develop the controller? What happens if there is a fault in the system? Will the faults cause serious damage

or just minor inconveniences?

All these questions could be answered by using simulations to investigate the normal and faulty behaviour. This project continues work which started off as the "Test Bench of the Future" project and is now focusing on the development of a "free Field-Oriented Control library" (`freeFOClib` [12]) in Modelica®. During 2008 the library could be further extended by new battery models and improved machine models. One important aspect that is left is the verification of the model parameters and the simulation behaviour in general. This shall be the final step before releasing the library to the public in Spring 2009. A test bench consisting of an asynchronous induction machine (the test object) as drive and a DC-machine as load is being set up. Faults such like winding short-cuts (e. g., by over temperature) or power failure in part of the windings (cut-off of supply connectors) can then be simulated, verified and interpreted.

Publications in 2008

[1] H. Isernhagen and C. Gühmann. Modelling of a Double Clutch Transmission with an Appropriate Controller for the Simulation of Shifting Processes. In *Proceedings of the 6th International Modelica Conference*, pages 333–339, Bielefeld, Germany, 2008.

[2] H. Isernhagen and C. Gühmann. Modelling, Simulation, and an Automated Analysis of Shifting Processes of a Double Clutch Transmission. In *7th International CTI Symposium "Innovative Automotive Transmissions"*, pages 613–626, Berlin, Germany, 2008.

[3] H. Isernhagen, T. Liebezeit, S. Rebeschieß, H. Neemann, and C. Gühmann. Softwaretest in Verbindung mit einer automatisierten Messdatenauswertung. In C. Gühmann, editor, *Simulation und Test in der Funktions- und Softwareentwicklung für die Autmobilelektronik II*, pages 378–387, Berlin, Deutschland, 2008. expert verlag.

[4] H. Isernhagen, D. Winkler, and C. Gühmann. Diagnostic and Fault Simulations of Automotive Applications Using Modelica. In C. Gühmann, editor, *Simulation und Test in der Funktions- und Softwareentwicklung für die Autmobilelektronik II*, pages 166–177, Berlin, Germany, 2008. expert verlag.

[5] S. Kühn. Generalized Prediction Intervals for Arbitrary Distributed High-Dimensional Data, 2008. http://arxiv.org/abs/0809.3352.

[6] S. Kühn. Kernel Regression by Mode Calculation of the Conditional Probability Distribution, 2008. http://arxiv.org/abs/0811.3499.

[7] S. Kühn and C. Gühmann. Modeling and Control with Local Linearizing Nadaraya Watson Regression, 2008. http://arxiv.org/abs/0809.3690.

[8] S. Lehmann, S. Rein, and C. Gühmann. Filesystem for Sensor Node with scarce Resources. In *Proc. of the ACM Mobimedia'08*. Association for Computing Machinery, 2008.

[9] S. Rein, S. Lehmann, and C. Gühmann. Fractional Wavelet Filter for Camera Sensor Node with external Flash and extremely little RAM. In *Proc. of the ACM Mobimedia'08*. Association for Computing Machinery, 2008.

[10] S. Rein, S. Lehmann, and C. Gühmann. Wavelet Image two-line Coder for Wireless Sensor Node with extremely little RAM. Technical report, a, 2009. submitted to data compression conference'09.

[11] J. Riedel, W. Baumann, and K. Röpke. Einsatz von RBF-Netzen zur Modellierung am Dieselmotor. In C. Gühmann, editor, *Simulation und Test in der Funktions- und Softwareentwicklung für die Autmobilelektronik II*, pages 33–41, Berlin, Deutschland, 2008. expert Verlag.

[12] D. Winkler, E. Bakhach, F. Döring, S. Rinderer, and F. Andre. `freeFOClib` - A free Field-Oriented Control library for Modelica. unreleased, see `www.freefoclib.org` for any news., 2009.

[13] D. Winkler and C. Gühmann. Modelling of Electric Drives using freeFOClib. In *Proceedings of the 6th International Modelica Conference*, pages 215–220, Bielefeld, Germany, 2008.

[14] D. Winkler and C. Gühmann. Simulation of Electric Drives using freeFOClib. In *Proceedings of IEEE International Conference on Sustainable Energy Technologies*, Singapore, 2008. IEEE.

Our Team

Head of Chair

Prof. Dr.-Ing. Clemens Gühmann

Sekr. EN 13

Ms. Brigitte Auerbach

Research Assistants

Dipl.-Ing. Henrik Isernhagen
Dipl.-Ing. Steffen Kühn
Dipl.-Ing. Stephan Rein
Dipl.-Ing. Jan Malte Riedel
Dipl.-Ing. Dietmar Winkler

Doctorands

Dipl.-Ing. Stev Gerson (IAV GmbH)
Dipl.-Ing. Wei Hu (Robert Bosch GmbH)
Dipl.-Ing. Nicolas Lewkowicz (Continental)
Dipl.-Ing. Felix Matthies (IAV GmbH)
Dipl.-Ing. Adrian Nessler (IAV GmbH)

Conferral of Doctorate

- On 18th of September 2008, Lai Geng successfully held his graduation talk with the title "Black-Fault Tolerant Position Control of SM-PMSM in an Electro-Mechanical Brake Actuator Against AMR Angle Sensor Failure" in order to gain his doctorate (PhD).

- On 1st of December 2008, Thomas Habath successfully held his graduation talk with the title "Messtechnische Untersuchungen der Netzqualität in einem Industrienetz" in order to gain his doctorate (PhD).

Guest Researchers

Ms. Dr. Nivin Ghamry

Visiting Lecturers

Dr.-Ing. Jörg Beilharz, Dr.-Ing. Carsten Haukap
Dr.-Ing. Thomas Offer, Dr.-Ing. Thieß-Maguns Wolter

Tutors Measurement Laboratory

Mr. Mounir Bellouch, Mr. Fabian Fehres, Mr. Mahmoud Felk,
Mr. Sven Kriener, Mr. Lahoussine El Mekhantar,
Ms. Amra Mujagic, Mr. Daniel Smolin, Mr. Reinhard Stornowski,

OWL - Student Assistants

Mr. Stephan Lehmann, Mr. Sebastian Nowoisky,
Mr. Alexander Wiener

Student Research Assistants

Mr. Eduard Bakhach, Mr. Felix Böckelmann,
Ms. Alexandra Mehlhase

Offices

Ms. Edeltraud Esser (EN 3 – EMSP)
Ms. Brigitte Auerbach (EN 13 – MDT)

Institute Engineers (EMSP & MDT)

Dipl.-Ing. Frank Baeumer
Dipl.-Ing. Rüdiger Seidel

Electronic Service (EMSP & MDT)

Mr. Michael Hackbarth
Mr. Hans-Ulrich Timm

Mechatronic Workshop (EMSP & MDT)

Mr. Peter Jaeck
Mr. Uwe Kurlbaum

Courses

summer term 2008

Lecture	Measurement Data Processing
Project Course	Measurement Data Processing with Wavelets
Laboratory	Electronic Measurement Techniques (MT I)
Laboratory	Measurement Data Processing
Lecture	Introduction to Automobile Electronics
Laboratory	Introduction to Automobile Electronics
Lecture	Control and Regulation of Automotive Power Trains
Seminar	Mobile Phone Programming
Seminar	Graduation seminar Measurement Technique
Projects	Measurement Data Processing, Simulation, and Technical Diagnostics

winter term 2008/2009

Lecture	Basics of Electronic Measurement Techniques (MT I)
Tutorial	Basics of Electronic Measurement Techniques (MT I)
Laboratory	Basics of Electronic Measurement Techniques (MT I)
Lecture	Modelling and Real-Time Simulation
Lecture	Pattern Recognition and Technical Diagnostics
Project Course	Pattern Recognition and Technical Diagnostics
Seminar	Mobile Phone Programming
Seminar	Graduation seminar Measurement Technique
Projects	Measurement Data Processing, Simulation, and Technical Diagnostics

Combined organised courses of Prof. Obermeier and Prof. Gühmann

Laboratory	Electronic Measurement Techniques
Laboratory	Measurement Data Processing
Laboratory	Sensors