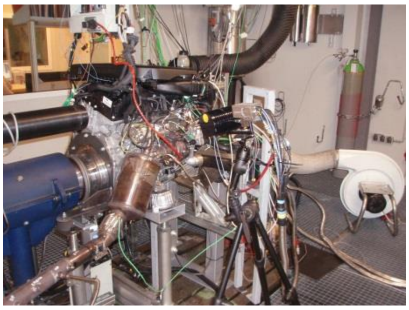
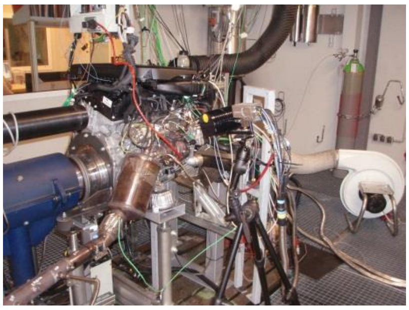
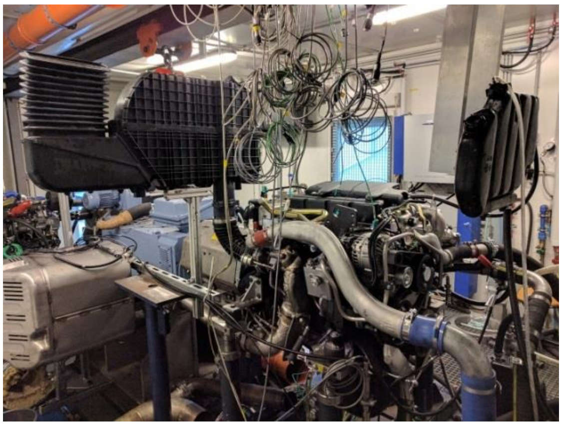
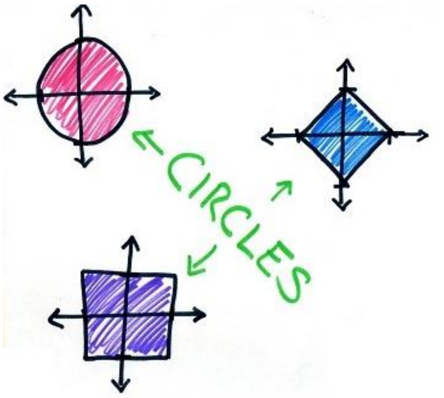
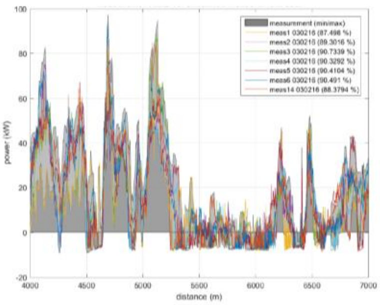
Bachelor Thesis	**Analysis and Correction of the influence of environmental conditions on diesel engine emission models**
Background	Exhaust emissions of modern passenger car engines depend on various and only partially controllable influences. During laboratory experiments these conditions are typically well controlled but for real world driving scenarios large differences from the lab conditions can occur. For control purposes and diagnosis it is important to have models which describe these effects. At the institute emission models for soot and NOx are already available which cover the engine behavior in nominal conditions. However, the effect of external influences is not yet covered. From experimental results it is observed that the variation of the conditions can lead to deviations between estimation and measurements. 
Goal	This thesis aims at improving the exhaust emission models by investigating effects of intake air humidity and intercooler temperature. To achieve this goal two steps are necessary: First the experimental data should be analyzed to clarify these effects on NOx and Soot emissions. Second, based on these analyses, for available emission models (NOx and optionally soot), a data based correction should be developed to cover these effects.
Optional	Additionally, other influences, such as fuel temperature or back pressure in the tailpipe can be investigated
Additional information	It is not necessary to have expert knowledge in combustion engines and emission formation. Already several (transient and steady state) measured datasets are available for analysis. Theory 20%, Simulation 40%, Practice/Experiments 40%
Scientific Advisor	Martin Großbichler

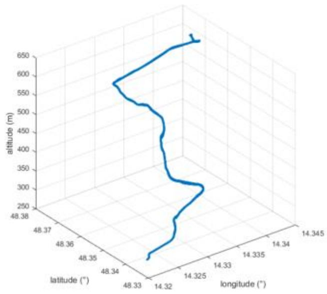
Bachelor Thesis	Numerical optimization of the injection profile for a Diesel engine and a given maneuver
Background and motivation	Modern passenger car Diesel engines have many degrees of freedom in combustion and air system control, such as multiple injections with variable timing, or variable geometry turbochargers. During calibration many tradeoffs of the control system are already fixed and it is not possible to address varying conditions or optimize for certain maneuvers. However, due to this fixed tradeoff, which should ensure a desired engine behavior above the whole operation range, some potential in performance during a specific transient maneuver is sacrificed. 
Goal	The goal of this thesis is to determine the best case of a specific transient engine maneuver. This can be achieved by using several injection control inputs combined with a meaningful objective function (including e.g. torque, emissions…) in a numerical optimization framework. The first step is to establish a meaningful objective function and to perform a sensitivity study for a defined maneuver. The maneuver will be characterized by a fixed time, start and end conditions and a given energy demand. Second, a suitable numerical optimization method should be used to solve the stated problem.
Optional	The choice of the optimization method or approach can be varied, e.g. by defining base functions for the profiles.
Additional information	The optimization will be carried out directly at the engine testbench, however, expert knowledge in combustion engines and emission formation is not required. A setup to manipulate the inputs and measure the emissions will be provided. Theory 40%, Simulation 20%, Practice/Experiments 40%
Scientific Advisor	Martin Großbichler

Bachelor Thesis	**Modeling of a Selective Catalytic Reduction (SCR) system of a heavy-duty Diesel engine**
Background	Modern Diesel engines feature special exhaust gas after-treatment systems in order to reduce emissions that are harmful to the environment or to human health. One of such systems is Selective Catalytic Reduction (SCR), which is used to reduce the amount of NOx emissions by dosing of Diesel exhaust fluid (DEF). Such an SCR exhaust after-treatment system is installed on the institute's heavy duty engine test bench. For (optimal) control of the system an accurate model is useful for control design but also for testing different control approaches in simulation before applying it to the real system.  **Engine test bench at the institute**
Goal	This thesis aims at improving an existing model of a similar SCR system for control purposes. In doing so, first an available gray box model of an older SCR system should be adapted and parameterized to the new SCR system such that the mismatch between plant and model is below a given threshold when applying the engine's default control strategy to the system for different predefined transient test cycles. Second purely data-based model approaches should be investigated and compared against the physically based model to find the most suitable model structure/parameter set of the tested approaches when comparing it to the real system using the same assessment metrics as for the gray box model.
Additional information	Interest in the topic of physical and data-based modeling for automotive applications is appreciated. Theory: 30%, Simulation/Modeling 40%, Measurements 30%
Scientific Advisor	Patrick Schrangl

Bachelor Thesis	Analysis of different metrics for system identification
Background	Typically, the *squared* prediction error (least squares method) is minimized when system identification is used for modeling, so the unknown model parameters can be computed in one step in the case of an ARX structure. However, the least squares estimator is only optimal, when certain requirements are met. If the setting deviates from these requirements, it could be more useful to use a different metric as cost function for identification.
Goal	This thesis aims at investigating the influence of using different alternative metrics as the cost function (such as L_1norm, L_∞norm or a combination of both) on the identification result. Accordingly, an evaluation of different metrics used for parameter estimation (identification) with respect to a single predefined validation metric (e.g. fixed linear error tolerance) should be performed. The evaluation should be done using a simulation analysis for a given mathematical class of (practically relevant) known systems, where the statistical properties of the estimated parameters are compared against the true system parameters using for example Monte Carlo simulations.  **Unit circle in different metrics** *[http://mathwithbaddrawings.com]*
Optional	In the case of identification with nonlinear regressors (such as polynomials) regressor selection (reduction of the model on the essential terms) plays an important role. The use of different metrics could also be analyzed for the regressor selection part.
Additional information	Interest in the field of system identification is appreciated. An evaluation with real data of an engine test bench should be performed. Theory 30%, Simulation 60%, Practice 10%
Scientific Advisor	Patrick Schrangl

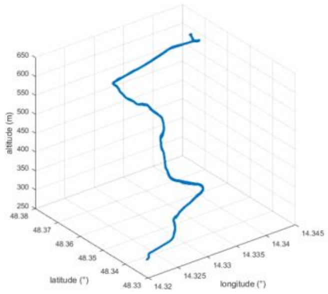
<table>
<tr><th>Bachelor Thesis</th><th>Data based modeling and prediction of a vehicle’s velocity and power demand profile for a given route profile</th></tr>
<tr><td>Background</td><td>To improve real driving emissions and consumption, advance knowledge of the future load profile can be highly beneficial. Unfortunately, this information is hardly available, although in some cases at least the route topology is known in advance. This information can be used to determine a future power demand profile for a known vehicle and a given route.



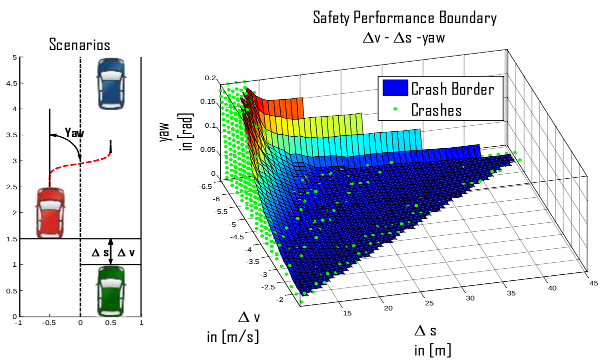

</td></tr>
<tr><td>Goal</td><td>The goal of this work is to find a databased model, which can be used for prediction of the future power demand. The model should only rely on the route data, i.e. x,y,z coordinates of a route. For the development a dataset containing fifty test drives on the same road will be provided. As a comparison the mean power demand deduced from the dataset should be used as a baseline model and the databased models should be evaluated using the relative performance in terms of power prediction.

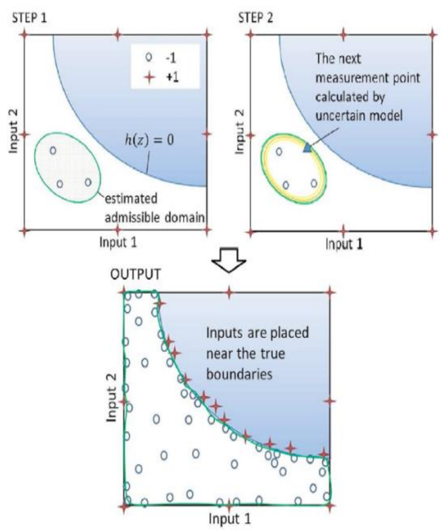
Once a structure for a model is found, it should be investigated if the use of adaption allows for improvement of the power prediction when applied to single trips.</td></tr>
<tr><td>Steps</td><td>• Theory and literature research
• Data analysis to find important quantities (e.g. curvature, gradient…)
• Identification of Models based on important quantities</td></tr>
<tr><td>Additional information</td><td>The main focus will be on data based identification and modeling approaches.

Theory 30%, Simulation 70%</td></tr>
<tr><td>Scientific Advisor</td><td>Philipp Polterauer</td></tr>
</table>

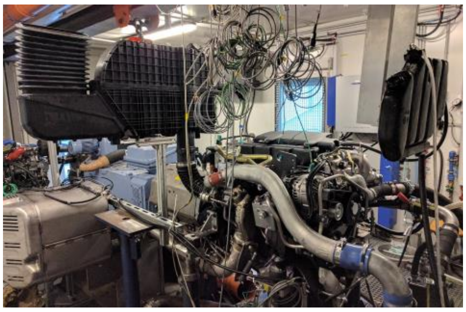
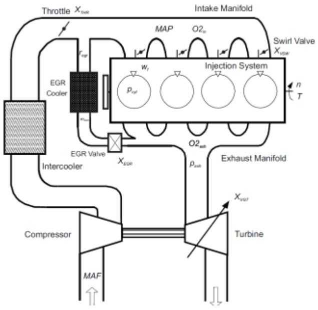
Bachelor Thesis	**Optimization of the vehicle speed profile for given route to minimize fuel consumption with constrained traveling time**
Background	Minimizing fuel consumption is an important topic for individual transportation. Besides environmental effects and overall traffic situation, a strong influence on the consumption of a given vehicle on a given route is given by the operator, i.e. the driver. The action of the human driver, e.g. how fast accelerations are performed, directly influences the consumption. To evaluate the performance of different drivers, but also automated driving functions, a baseline representing the optimal solution is required.  
Goal	The purpose of this work is to determine a speed profile for a predefined route which minimizes the fuel consumption and performs the driving mission in a given time interval, under the assumption of no other traffic participants on the road. Therefore, an inverse vehicle model including dynamics and consumption should be utilized together with optimization methods. Constraints on the vehicle dynamics, such as maximum curve speeds, speed limits and acceleration/deceleration limits need to be considered. For the evaluation a detailed vehicle simulation environment should also be used.
Steps	• Theory and literature research • setting up evaluation environment e.g reduce the complexity of the problem in order to speed up optimization • applying numerical optimization methods • evaluate solution by comparing energy demand of the optimal solution and the on road data
Optional	The evaluation can be performed in a HIL-Setup on the test bench and it is possible to also take emissions (based on simplified models) into account.
Additional information	For the numerical optimization different algorithms can be investigated, the route profile for the driving mission, the constraints and the inverse vehicle model are provided. Theory 50%, Simulation 40%, Practice/Experiments 10%
Scientific Advisor	Ngoc Anh Nguyen

<table>
<tr><th>Bachelor Thesis</th><th>Safety Boundary Identification using Gaussian Process Classification</th></tr>
<tr><td>Background</td><td>During the ADAS/ADF design, it is necessary to evaluate the safety of the whole system. Within our validation concept, the performance limits of the automated vehicles (vehicles equipped with ADAS/ADF) in given situations (scenarios) is employed to estimate the crash rate in real world traffic environment. In this method, one of the most important parts is to find the safety boundary, separating the crash and non-crash subspace, e.g.:

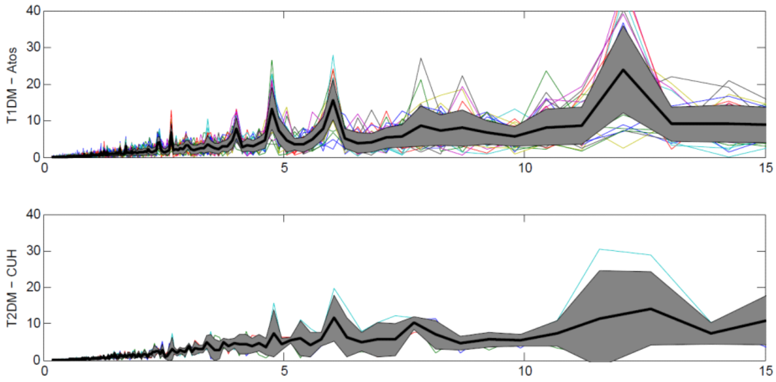


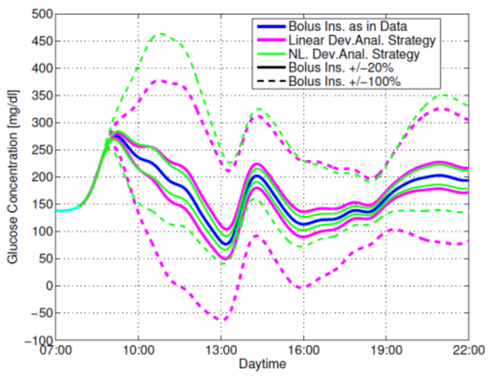
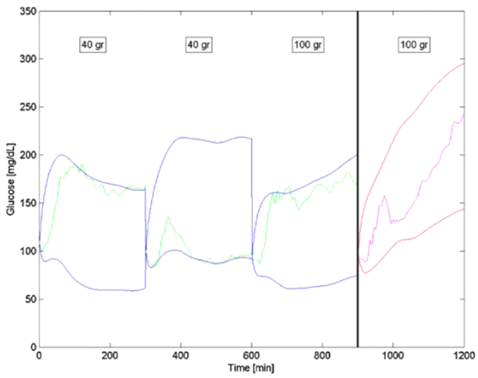
Since the safety boundary can be non-convex, a grid searching method was employed as the first approach. However because of the high dimensionality of test scenarios, millions of points have to be checked to find out the boundary with certain accuracy. This procedure is very time-consuming, especially when a complex vehicle model (in CarMaker) is employed.</td></tr>
<tr><td>Goal</td><td>


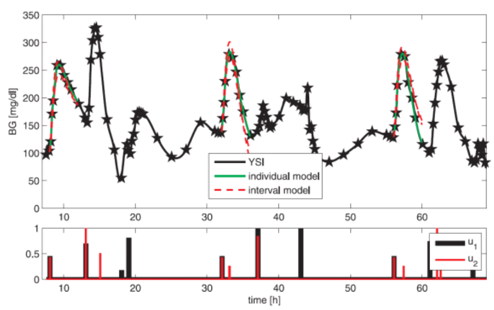
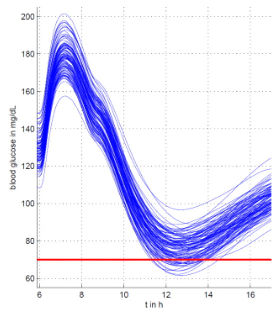
This thesis aims at finding an efficient method for the safety boundary identification problem. This method makes use of the design of experiment strategy (DoE) based on the Gaussian Process Classifier (GPC) with the expectation propagation (EP). Evaluation of the proposed method throughout various scenarios in Matlab with a complex vehicle model in Carmaker should clarify the efficiency of this method in terms of non-convexity and high dimensionality.</td></tr>
<tr><td>Additional information</td><td>Theory/Implementation 70%, Simulation 30%</td></tr>
<tr><td>Scientific Advisor</td><td>Jinwei Zhou</td></tr>
</table>

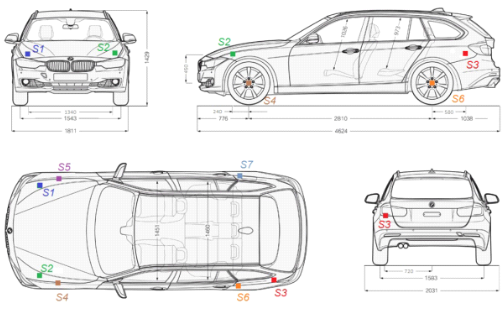
<table>
<tr><th>Bachelor Thesis</th><th>Development of a Mean Value Airpath Engine Model (MVEM) of a Heavy Duty Diesel engine</th></tr>
<tr><td>Background</td><td>To develop and test control strategies mean value engine models are often used. These describe the main dynamics of the fuel and air system of an engine by combining nonlinear static relations with simplified dynamics for the air system of an engine. These models provide insights in the main dynamics but are still computationally efficient and allow verifying control strategies within a simulation environment.
 
</td></tr>
<tr><td>Goal</td><td>In this work a mean value model of a 4-cylinder heavy duty Diesel engine should be set up. Therefore special experiments need to be designed, which explore the permissible input domain of the engine. A main focus will be on the air system and its actuators (EGR, Wastegate, Throttle), whereas other influences, such as environment conditions, will be kept constant.</td></tr>
<tr><td>Optional</td><td>Investigation of automatic engine mapping approaches or alternatives to the currently available strategy.</td></tr>
<tr><td>Additional information</td><td>It is not necessary to have expert knowledge in combustion engines or modeling. A formerly developed semi-automatic algorithm for light duty engine will be provided and needs to be adapted and improved in this work to the heavy duty engine.

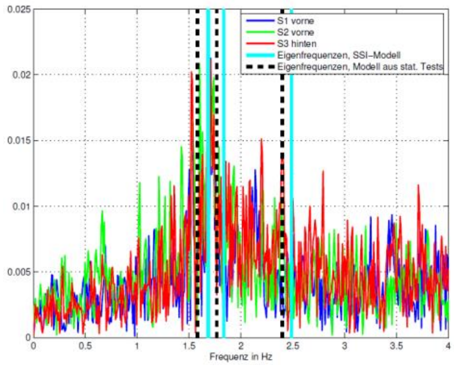
Theory 10%, Simulation 20%, Practice/Experiments 70%</td></tr>
<tr><td>Scientific Advisor</td><td>Harald Waschl</td></tr>
</table>

Bachelor Thesis	**Analysis of CGM Signals in the Frequency Domain**
Background	In order to inform diabetic patients about their blood glucose dynamics it is becoming more and more common to use continuous glucose monitoring (CGM) systems for this purpose which supply patients with glucose values at a high measurement frequency. However, it is believed that so far the full potential of CGM devices is not yet tapped. So far analysis of CGM data is limited to observing glucose values and trends in the time domain. It is thought that additional information could potentially be gained by analyzing signals in the frequency domain. Analysing CGM signals of clinical trials in the frequency domain reveals significant differences between patients with type 1 and type 2 diabetes (see picture below).
Goal	The goals of this work are twofold: First, simulation studies should help to better understand the peaks of CGM signals in frequency domain. For this purpose simulations with a complex computer model of the glucose metabolism of diabetic patients (UVa/Padova simulator) should help to identify correlations between day-to-day variations in life style as well as the stage of the diabetes disease (extend of the beta cell failure) and the extend and positions of peaks in the frequency spectrum. In a next step the analysis of real CGM data in the frequency domain using a sliding time window for analysis (methods from Fault Detection and Isolation, see e.g. [Pichler et al, „Monitoring procedure in frequency domain using...“, SYSID 2009]) should be used to try to analyze the correlation between the characteristics of CGM signals in the frequency domain and the risk of very low or high glucose values to occur (hypo-/hyperglycemias). Such a correlation between the high frequency content of CGM signals and the risk of hypoglycemias was already suggested in [Reiterer et al 2016 – chapter in Springer book].
Optional	Design of a real-time capable algorithm for the early detection of impeding hypoglycemias / hyperglycemias (if possible).   **Remark: For this work the student needs to get access to CGM datasets!**
Prerequisites	The student should be interested in the topics of biomedical engineering, data analysis and modeling of physiological systems Theory 20%, Data Analysis 40%, Modelling/Simulation 40 %
Scientific Advisor	Florian Reiterer

Bachelor Thesis	**T1DM: Coupling of Interval Identification with Deviation Analysis**
Background	The most common way of estimating the performance of new insulin dosing schemes for type 1 diabetes mellitus (T1DM) consists in performing a simulation study using a complex, physiological model of the human glucose metabolism, e.g. the UVa/Padova simulator. As an alternative, several methods have recently been proposed that try to extrapolate the effect of a modified insulin therapy using real measurement data together with models of insulin action. These methods are referred to as „Deviation Analysis“ strategies. The drawback of those methods is that the quality of the evaluation results depends strongly on the quality of the model used for describing insulin action and the assumptions behind it. An improvement is expected for the case of not just predicting one single glucose trajectory (the „most probable“ one), but to predict an envelope of possible future trajectories that reflect the intra-patient variability. Such envelops can be identified and formed using methods from interval analysis.
Goal	The goal of this work is to combine a recently proposed nonlinear Deviation Analysis approach (paper submitted to the ACC 2017 conference) for the computation of glucose trajectories for insulin dosing different from the one in the data with methods from interval identification. Those methods from interval identification should be used to obtain suitable estimates of the effect of intra-patient variability on glucose trajectories. Using the methodology from [Laguna et al 2014] estimates of parameter intervals of a physiological model should be identified from data. The identified parameter intervals can then be used in the next step for performing an interval prediction in the Deviation Analyses. Main goal is to obtain in the end a validated methodology for a combined analysis of intrapatient variability (by means of interval identification) and prediction of possible glucose trajectories by means of Deviation Analyses.
Optional	Using the newly proposed methodology for analyzing the performance of specific control strategy (Adaptive Bolus Calculator - ABC) in simulation studies.   **Remark: For this work the student needs to get access to CGM datasets!**
Prerequisites	The student should be interested in the topics of biomedical engineering, system identification and modeling / simulation of physiological systems Theory 40%, System Identification 30%, Modelling/Simulation 30 %
Scientific Advisor	Florian Reiterer

Bachelor Thesis	Robust Control of Glucose Levels in Type 1 Diabetes Using Set-Theoretic Methods
Background	Patients with type 1 diabetes mellitus (T1DM) need to inject insulin in order to control their blood glucose levels. This control task requires to keep the glucose level as much as possible within a clinically safe target range. This is a very demanding task and many diabetics fail to achieve this goal. Therefore, a device which autonomously decides on the correct insulin dose (a so-called „Artificial Pancreas“) would mean an immense reduction of the burden of the disease in day-to-day life. The problem of designing an appropriate control algorithm is associated with the large variability of glucose dynamics in diabetic patients (larger inter-patient and intra-patient variability). In the framework of this bachelor thesis, set-theoretic concepts in robust control should be analyzed more closely, where the uncertainties of the glucose metabolism are first quantified and then considered directly in the control task.
Goal	Goal of this work is to control the glucose level by means of a robust control algorithm. This so-called convex lifting based method aims to steer the state into a suitable region around an equilibrium glucose level. First, a linear time-invariant model of the glucose dynamics should be used to design a suitable controller. Second, another given linear time-varying model will be deployed to design a robust controller stabilizing the glucose level based on the same method. Finally, results should be evaluated and compared to one another.
Optional	Testing the proposed control strategy using real patient data in Deviation Analyses (**Remark: This optional task would require the student to get access to CGM datasets!**).   
Prerequisites	The student should be interested in the topics of biomedical engineering and modeling and control of physiological systems Theory 50%, Modelling/Simulation 50 %
Scientific Advisor	Ngoc Anh Nguyen

<table>
<tr><th>Bachelor Thesis</th><th>Identification of Damping Ratios from Output-Only Data</th></tr>
<tr><td>Background</td><td>Operational Model Analysis (OMA) summarizes methods to identify modal properties of a system using only measured output data during normal operation, but no information about input data. In previous works a methodology has been proposed to identify natural frequencies from accelerometer data of passenger cars and to use this information in order to generate a model of the vehicle suspension. In this methodology data is recorded during a ride with constant speed over a rough, but relatively flat and straight country road (changes in speed and turns/curves are not accounted for in the methodology). The problem with the current methodology is that the natural frequencies are hardly influenced by the damping of the car, and therefore additional measurements are required to obtain information about damping parameters and to complete the suspension model. However, in case one would be able to identify also the damping ratios in the OMA, this would enable to skip the subsequent additional measurement step and to directly obtain a fully parametrized model of the vehicle from the OMA data.</td></tr>
<tr><td>Goal</td><td>In pre-analyses it turned out to be much more difficult to identify the damping ratios using OMA compared to the identification of natural frequencies. However, it also showed to be feasible under certain conditions. The goal of this work is to systematically check and quantify those conditions and to propose a methodology for the reliable identification of damping ratios and natural frequencies of passenger cars from accelerometer data. Besides the methods from Stochastic Subspace Identification (SSI) that are currently in use for this purpose, also alternative methods operating in the frequency domain should be evaluated. Analyses should first be performed using simulation data and results then verified and extended in real experiments using the model of a quarter car (available at our institute’s lab). In a last step, the methodology should be validated using data recorded with a real passenger car.</td></tr>
<tr><td>Optional</td><td>Based on the findings of the simulation studies and the analysis of experimental data of the quarter car, a new experimental protocol for the application of OMA on real passenger cars can be proposed and verified with the institute car (BMW 320d) and already available measurement equipment (accelerometers).



</td></tr>
<tr><td>Prerequisites</td><td>The student should be interested in the topics of automotive engineering, system identification and data analysis
Theory 20%, Simulations: 20%, Experimental Work 20 %, System Identification / Data Analysis 40%</td></tr>
<tr><td>Scientific Advisor</td><td>Philipp Polterauer</td></tr>
</table>