FRTN40 Project Proposals 2017

1. Balancing suitcase

Introduction. As an impressive demonstration of feedback control, we propose the construction of a briefcase that can balance on one of its short edges. We suggest one of the following two actuation mechanisms to solve the stabilization problem:

A. Reaction wheel
   This is option is *relatively* easy to implement, but can only stabilize the bag in upright position.
B. Moving the center of mass
   By using a pulley system and two weights, this approach can stabilize the bag in a wide range of angles, and also handle larger disturbances than approach A.

Modeling. Derive dynamics of the actuated suitcase; this might be a good use for your knowledge of Lagrangian mechanics, or a good opportunity to learn it.
Design. You will design robust hardware, electronics, which can be put small and lightweight suitcase.
Goal. Get the suitcase to balance on one of its short edges.
Prerequisites. Willing to do mathematical modeling, build hardware, integrate electronics, develop control algorithms, and getting everything to work. Some experience of the above is desirable but not necessary. More experience is recommended for those who want to take approach B.

2. Balanduino on rocky road

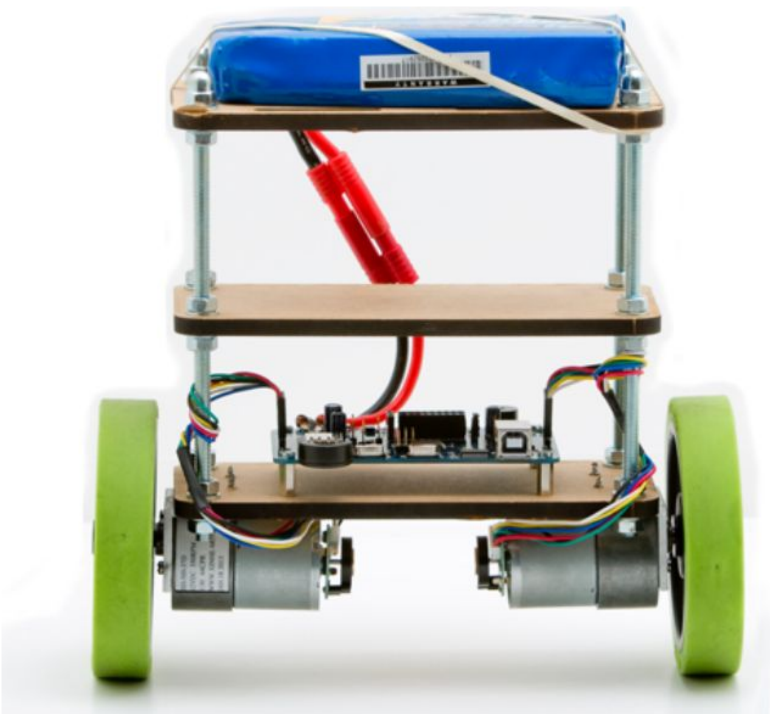
Introduction. In this project, the Balanduino segway robot should be controlled in order to autonomously complete a non-flat route. Possible solutions include optimization or learning based methods.

Modeling. In order to control the Balanduino, its dynamics need to be properly modeled. Simulations in Matlab/Simulink are used to validate the proposed models.

Design. The (optimal) trajectories can for instance be calculated using JModelica. In order to follow these trajectories, additional sensors need to be mounted on the Balanduino. The control algorithms could be PID based, or use optimization or learning based methods, such as Iterative Learning Control.

Goals. Get the Balanduino robot to autonomously complete a difficult track as fast as possible.

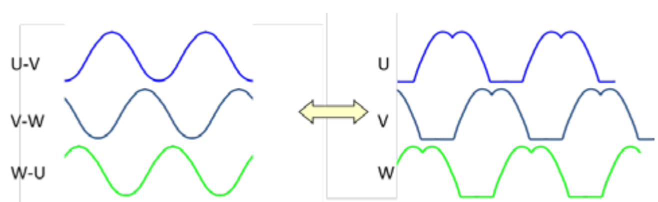
Prerequisites. Interest in mathematical modeling, (embedded) programming skills, basic knowledge of automatic control.



The Balanduino robot

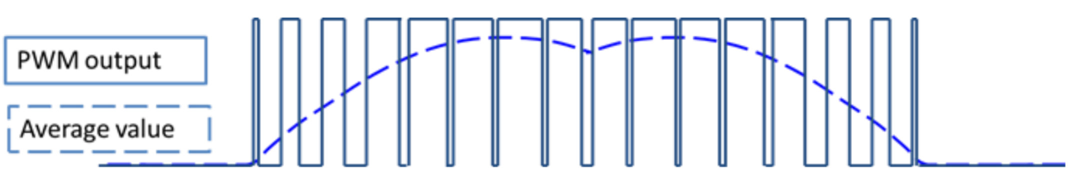
3. Brushless DC motor control

Introduction. Brushless direct current motors (BLDC) have several advantages over normal DC, but do not not handle commutation of its windings automatically. A dedicated hardware driver with a controller is needed for this. Designing such hardware is associated with interesting problems from several domains: control, embedded realtime systems, electronics.
Modeling. A dynamic model of the motor will be used to design an estimator of its angular position based on (the history of) sparse measurements from hall sensors or winding currents. These measurements, together with a model of the motors inertial load, will be used by a feedback controller to update the winding actuation pattern of the motor, making it rotate at a desired speed.
Design. The design will be based on an embedded computer system (e.g. an Arduino/Atmel platform or a Beaglebone). A custom PCB hosting BLDC-specific drive circuitry and FET drivers will need to be designed and ordered. Control for commutating the windings based on an external angular velocity reference and an estimate of angular position and velocity needs to be implemented on the embedded platform.
Goals. The goal is to implement and evaluate a sophisticated controller for BLDC-motors, which can handle both block and sinusoidal commutation patterns. If successful the controller will be used in the department's course lab, and be made accessible online as open source, for others to benefit from.
Prerequisites. Experience in electronics design and programming are strong benefits for this project.



Sinusoidal Voltage from Phase to Phase

Sinusoidal Voltage fromPhase to GND
With 3rd Order Harmonics



PWM Encoded Phase Output and the Average Value

4. Continuous control of batch tank

Introduction. The Batch Process is a multivariable laboratory process developed at the department, which is used in projects in the Process Control course for the B and K programs (see the project manual [1]). It features a number of actuators: two pumps (one for the inlet and one for the outlet), a heater, a cooler, and a stirrer (agitator). The sensors can measure the liquid level and the temperature in the tank. In this project you will explore the possibility to run the tank in continuous mode, thereby emulating a so called Continuous Stirred Tank Reactor (CSTR).

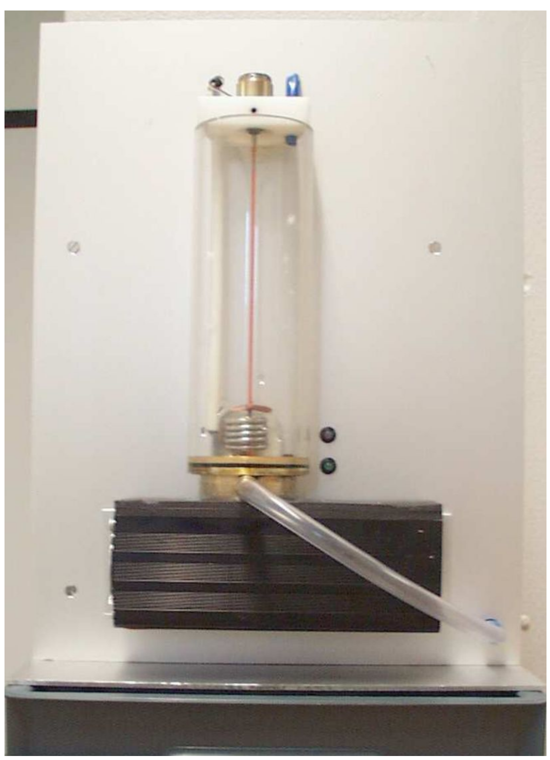
Modeling. Using system identification experiments and/or mathematical modeling, you should model the liquid level dynamics and temperature dynamics of the tank when it is operating with a small and constant continuous flow. A simulated endothermic or exothermic chemical reaction can then be added to the model, to make the control problem more interesting.

Design. Currently it is difficult to maintain a small but steady flow through the tank due to nonlinearities in the pumps and the lack of flow sensors. A first step could therefore be to mount a flow sensor and regulate the inflow pump. You should then design a multivariable control system for simultaneous control of temperature, liquid level, and the simulated chemical concentration in the tank.

Goals. Based on the outcome, you should conclude whether continuous operation is feasible and what the limitations are.

Prerequisites. It is valuable if you have taken Multivariable Control or Systems Identification, but not necessary.

[1] https://www.control.lth.se/media/Education/EngineeringProgram/FRT110/2015/manual2015_eng.pdf



5. Industrial adaptive controller

Introduction. The MC XC50 from First Control [1] is one of very few industrial controllers on the market today that actually implements adaptive control algorithms. In this project you should try to use the XC50 for rapid prototyping and control of a nonlinear process in different operating points.
Modeling. After selecting a suitable (laboratory) process for the experiments, you should model the process using the Modelica language [2] in (e.g.) Dymola [3]. The model can then be exported to the XC05 development and simulation environment.
Experiments. The XC05 should be used to control the nonlinear process model in simulation mode, testing one of the adaptation algorithms. After successful simulation, you should then try to control the real process and evaluate the results. Can the controller adapt its parameters to different operating points?
Goals. The project will be of exploratory nature. The goal is to try out a few features and evaluate how easy it is to model and program an adaptive control system using the XC50.
Prerequisites. At least one group member should have taken the Predictive Control course. Knowledge in Nonlinear Control is valuable but not necessary.

N.B.: You must have your own laptop with Windows on it to program the XC50 and to run the interactive simulations and experiments.

[1] http://www.firstcontrol.se/embedded-systems/
[2] https://en.wikipedia.org/wiki/Modelica
[3] https://en.wikipedia.org/wiki/Dymola

6. Lego self-balancing unicycle

Introduction. Constructing a self-balancing robot on two wheels (a "mini-segway") is a fairly straightforward task. In this project we will make the task a bit more challenging by requiring the robot to balance on one wheel. The lateral angle should be stabilized by a reaction wheel.

Modeling. The modeling work involves properly dimensioning the robot and the reaction wheel to make the process controllable. The dynamics should be derived and the model should be simulated in e.g. Simulink.

Design. Using sensor data from accelerometer and/or gyroscope, a Kalman filter should be designed to estimate the angular position and velocity in two dimensions. State feedback or PID controllers can then be used to stabilize the process. The Lego processor can be programmed in a number of different programming languages.

Goals. To successfully balance the unicycle. If time permits, a remote control could be added to the system.

Prerequisites. Interest in mathematical modeling and programming skills. Knowledge in Multivariable Control and/or Real-Time Systems are valuable but not necessary.

7. Lego trailer system

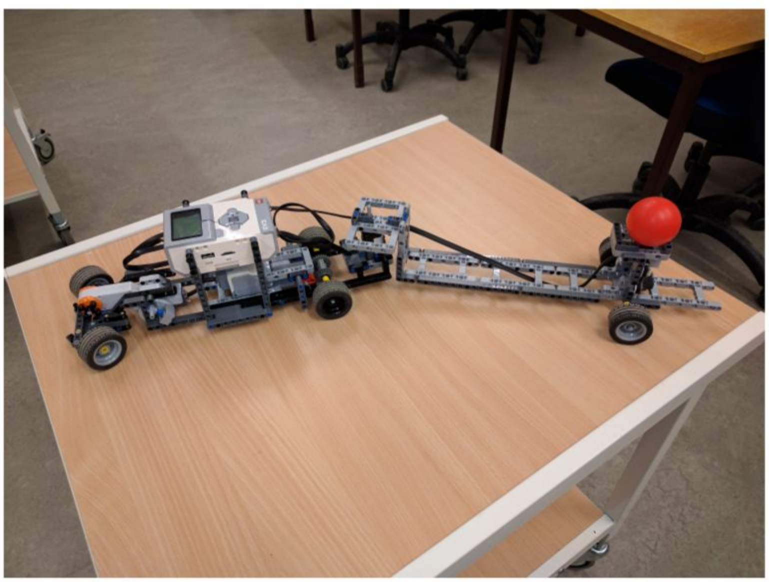
Introduction. This project is connected to the research topic of autonomous vehicles. As parking and reversing of a trailer system is a complicated task even for experienced drivers, it is an interesting scenario to automate. Here the trailer system will be designed and built in Lego from scratch.

Modeling. A key component to model is how the truck and trailer will move, based on the current velocity and steering angle.

Design. In order to automate the parking and/or reversing of the truck, you will create trajectories and design and implement control algorithms to follow them. An important issue is how to design the positioning system that keeps track of the Lego trailer. A possible implementation platform is Java+LeJOS.

Goals. The goal is to design and implement a (multi-) Lego trailer system with support for autonomous parallel parking and/or backing. The Lego processor can be programmed in a number of different programming languages.

Prerequisites. Interest in mathematical modeling, (real time) programming skills, basic knowledge of automatic control



Last year’s truck

8. Magnetic levitation system

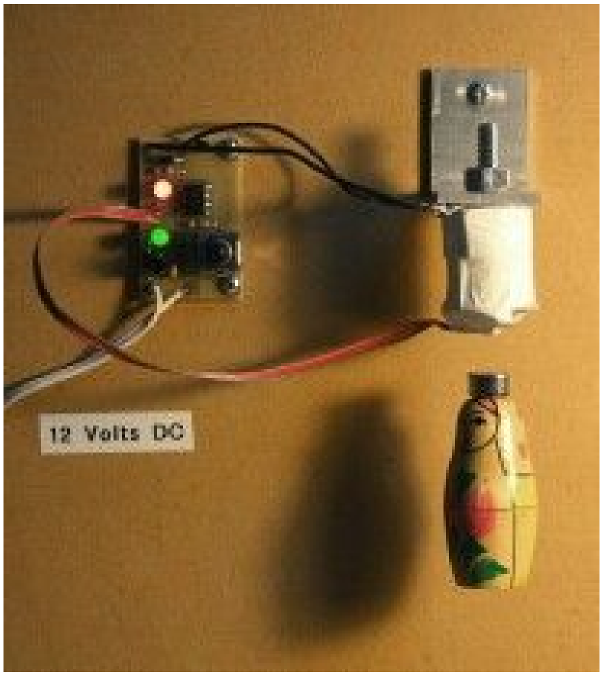
Introduction. The magnetic levitation system is a classic demonstration of automatic control. In this project you should design, build and control your own electromagnetic levitation system from scratch. A hall sensor is used for position measurement, while the current through the electromagnet acts as control signal.

Modeling. The process should be dimensioned, modeled, and simulated. Linearization around a stationary point can then be used as a starting point for linear controller design.

Design. The linearized system can be controlled by a PID controller. A nonlinear controller with e.g. gain scheduling can be used to give the system a slightly larger workspace.

Goals. The system should be able to balance a small metal object and move it around in the workspace of the system (following a position setpoint).

Prerequisites. At least one project participant should be knowledgeable in electronics design. Knowledge in Nonlinear Control or Predictive Control is beneficial but not necessary.



9. Quadcopter attitude estimation

Introduction. The problem of estimating the attitude of the quadcopter central to enabling robust control methods [1]. Using simple methods of complementary filters are often insufficient, and nonlinear complementary filters such as the Mahony filter [2] is often used instead. This project is done in three parts in chronological order, derivation of an algorithm for estimating the UAV attitude, implementation and tests of the algorithm (in Matlab/Simulink/Julia), real-time tests of an embedded implementation using the Crazyflie platform [3] (in C).

Modeling. The modelling part consists of implementing UAV dynamics to test the algorithms, either in Matlab, Simulink or Julia.

Design. The design part consists of implementing known algorithms, such as standard complementary filters, the Madgwick/Mahony-methods [2][4], or some algorithm of your own devising.

Goals. The goal is to implement useful algorithms in UAV attitude estimation and explore how they may be improved.

Prerequisites. Programming and embedded systems, mathematical interest and ability, familiarity with rotational transformations and their parametrizations.

[1] http://folk.ntnu.no/skoge/prost/proceedings/ecc-2013/data/papers/0927.pdf
[2] http://ieeexplore.ieee.org/abstract/document/1582367/
[3] https://www.bitcraze.io/crazyflie-2/
[4] http://x-io.co.uk/res/doc/madgwick_internal_report.pdf

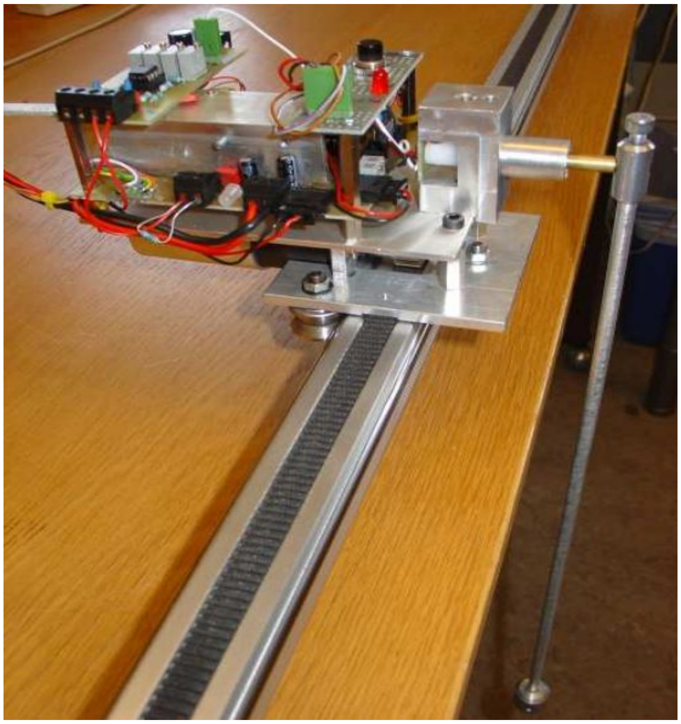
10. Reflow oven control

Introduction. Modern printed circuit boards are soldered in a temperature controlled oven. All the components are placed on the board and fixed using a sticky paste containing the solder. For good results, the temperature inside the oven should follow a pre-programmed profile.
Modeling. In this project, we will modify a hot air oven so that its fan and heater can be controlled individually, while the temperature in the oven is measured. A model describing the oven dynamics will be derived, and its parameters identified using the actual oven.
Design. A micro computer, for example a Raspberry Pi, will be used to control the heater and fan, and to obtain temperature measurements. A temperature controller will be implemented, and a user interface for starting, stopping, and monitoring the oven will be written. The interface needs to accommodate for changing the temperature profile reference.
Goals. The goal is to make to oven function reliably enough for routine use in the departments workshop.
Prerequisites. Basic automatic control, programming and embedded systems.

11. Time-optimal control of inverted pendulum

Introduction. In this project you should develop new hardware and control software for an inverted pendulum on a linear servo. An existing process is used in the Nonlinear Control course [1].
Modeling. The process should be dimensioned, modeled and simulated.
Design. The embedded controller contains its own feedback loops that need to be designed besides the cart and pendulum control system.
Goals. Demonstrate time-optimal nonlinear control of the pendulum with (at least) as good performance as the old system.
Prerequisites. You need a background electronics as well as mechanics and embedded systems programming for this project. Nonlinear Control is beneficial but not necessary.

[1] https://youtu.be/QRrGaWAoMZ4



12. Static ultra wideband positioning

Introduction. Ultra wideband (UWB) positioning, a form of indoor GPS positioning, is a hot research topic and widely used in navigation of general robotics [1]. This project explores modern methods of static positioning in the plane on an embedded platform. The project is done in three parts in chronological order, derivation of any algorithm in [2], implementation and tests of the algorithm (in Matlab/Simulink/Julia), real-time tests of an embedded implementation using the Decawave platform [3] (in C).

Modeling. The modelling part consists of creating a simulation environment to test the algorithms, either in Matlab, Simulink or Julia.

Design. The design part consists of implementing known algorithms in [2], such as the LL/WLS/ML-methods with potential improvements, for instance taking non-isotropic radiation and outliers into account.

Goals. The goal is to implement state-of-the-art algorithms in positioning and explore how they may be improved.

Prerequisites. Programming and embedded systems, mathematical interest and ability.

[1] https://pdfs.semanticscholar.org/38a2/6c53a39f69735e73bb15a91b0e028018af15.pdf
[2] http://ieeexplore.ieee.org/document/5722410/
[3] https://www.decawave.com/products/dw1000