WE E K L Y  R E P O R T S

• Week 17

- It’s been two weeks since the last project meeting and during part of that the whole group took one week off. During the rest of that time we’ve continued working with the control design. We have a PID controller that we are satisfied with. The objective in the design of this controller has been to obtain a simple design which can be used for laboratory exercises in basic control courses. The PID control system is currently implemented with a Kalman filter for state estimation. Although we haven’t looked in to it, it should possible to replace it with an observer derived using pole-placement.

  Our other controller using an LQ filter together with a kalman filter has proven to be more difficult to implement on the robot. Even though everything works fine in simulation the real robot system does not work. Our first response was that we had to tune the controller design variables better. This approach gave no results and after a couple of days of we started looking for other explanations. We started exploring the fact that LQG guarantees basically no robustness. We ran simulations with more model uncertainty by adding random disturbances to the state variables. Neither this could explain the real behavior of the system. Our final resort was to construct the control system with model parameters which we believed to be correct and then we simulated the system with a model using slightly different values on some of the model parameters. This gave us a simulation with the same behavior as the real robot. So our conclusion is that our model has to more accurate with respect to it’s parameters.

  This has lead us to thinking that a system identification is in place. We have started working with the graybox identification routine in matlab and our trying to get acquainted with the system identification toolbox in MATLAB.

  As a small note we have the LQ controllers, regulator and servo, working with a brute replacement for the kalman filter. We use a system that integrates and derivates numerically from the measurement and uses the LQ controller for calculating the control signals.

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• Week 14
- For the past week we’ve worked on regulator using PID and LQG theory. Regarding the PID controller we are using an approximation for the derivation. The LQG controller is composed of a Kalman filter as a state observer and a controller which minimizes the LQ criterion using a weighting matrix. This way we build the controller on the notion that we are only interested in controlling the jaw angle pitch angle and velocity.

For both controllers we have derived a plant for the control system. The PID plant is a SISO state-space model with the pitch angle deviation from zero as input. The LQG plant is a MIMO state-space model with full state feedback and outputs the voltage which is to applied to each motor. These controller are discreet and have been derived using a linearized model. Each controllers performance is further tested using the continuous non-linear model.

Parallel to the control design we have build robust robot.

We also have started our work with implementing the controllers in RobotC. We have tried the code on the robot and are currently occupied with debugging. We are patiently and with great anticipation working towards having the controllers applied on the robot.

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• Week 13

- Last friday we discovered that there was a flaw in our model. We derived the model our selves and compared it to other models using the same states for verification. Unfortunately the flaw in our model went by undiscovered. So for the last couple of weeks we have been working on controllers for a incorrect model and thus they are useless. Since then we have changed our strategy completely.

We’ve put all the work on LQ - controllers to the side for now. We whent back to the drawing board and looked over our modeling of the robot and consulted with other models using articles. We have now verified our new model by comparing it to models derived using other approaches then lagrange method. They derive the same model as us and we are confident that it is correct with in the assumptions and simplifications made. Our new strategy is that we first linearize the model and find a discreet PID regulator for it.

Then we move directly to implementing the non-linear model to se how it responds to the controller. In this step we also simulate the non-linear model without using a controller to se that the system behaves in a physically feasible way. This is where we are now.

Our next step will be to also find a controller based on the liner model using pole-placement and a observer. This is instead of using the LQ - controller with a Kalman filter. The reason for why we changed our strategy regarding the LQG controllers is that we really have no information about the process and measurement disturbances involved. And also it is likely that our linear model can be improved using graybox identification. So we will use
the simpler controllers like PID and pole placement initially to get ahead. Then we will move on to the LQG controller when we have successfully implemented these on the robot.

This is also good in the sense that the ultimate goal of this project is to provide a self-balancing robot implementing controllers that can be used for teaching purposes at the university. We therefore need to have good working controllers for SISO models which are being thought at the basic control courses.

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• Week 12

- Our goal for the past week has been to form a satisfying servo controller for the robot. Also parallel to this we have been working with implementing the non-linear model for the system. We want to test the controllers on this model. The model was implemented using SIMULINK. The next step would be to connect the model with the controllers using simulink and we’ve had some problems doing this. The main difficulty have been to connect the continues non-linear model with the discreet controllers. Our approach to connect them is to sample the outputs from the model and feed them to the controller. The controller then gives the control signal to the model. We are currently trying to work out how to sample the model and therefore we don’t have any simulations on the non-linear model right now.

Regarding the servo controller we have been going back and forth with what system outputs reference signals to use and thus what signals to feed to the controller. The controller system consists of a kalman predictor system, an integrator system and a LQ controller. We’ve had some difficulties with this control system since there are a lot’s of parameters to consider for the ”tuning” of the controller and the results have been vastly varying. At the moment we would have to say that we still only have a working PID-controller and a LQ regulator.

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• Week 11

- We have been working on analysis of the LQR controller. The performance of the controller in terms of reaching the desired state is very good comparing to the PID regulator, also it more stable once it’s reached the desired state.

We’ve also introduce some disturbances how the controller acts when these enter the model. The results where very much the same except, (obviously this depend on how much
disturbance was introduced). The main difference was in how ”strong” the input signals needed to be in order to reach desired states in a certain time.

Also we wanted to look at how process and measurement disturbances affected the system in terms of stability. This can be done by looking at the sensitivity and complementary sensitivity function. We tried to implement this in Matlab but had some difficulties. More on this will follow. We’re putting up working with the robot until we have found a working servo controller.

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• Week 10

- Our tasks for this week has been to continue the design of controllers and to prepare for a presentation. Topics were supposed to be ”promising results” from the research field ”two wheeled inverted pendulum”. Our approach was to read published papers and compare the performance results if implementation of different methods for control. The most commonly used controllers where derived using a kalman predictor to estimate state parameters and LQ criteria to find an optimal controller. Although the performance of this approach is very good there are other methods which give even better results, e.g ”partial feedback linearization” and Slide Mode Control, (SMC). We chose to present the SMC.

The work done on our on controller this week resulted in a reasonably good performing PID controller and an LQR controller. Our next task will be to implement the servo problem using the LQ criteria for the controller and also if needed add an integrator to get rid of the error in between the the feedback and the reference signal, i.e an improved control signal. We also need to analyze the performance of these LQ controllers.

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• Week 9

- During the last week we have continued working on the modeling of LegoWay. We have worked out a model, although not really formalized, which seems to be working. We have tried to validate the model using a simple simulation of the system in MATLAB. Based on these simulations our model seems to be valid and we are going to move forward with what we have for now. Also simulations have been made for some control methods like PID and LQG, (we choose to not say anything more about them for now). There are still some “issues” with the model that have to be worked out, but we are hoping that with the use of some identification methods these “issues” will be resolved in the feature.
Before moving on to the next stage of our project, which would be to work with Lego and RobotC, we are going to formalize our results so far. So our goal for the next week is primarily to write a “memorandum” on our model and the simulation results. If time allows us we will look into the programing environment and Lego.

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• Week 8

- For this week we’ve been mostly reading articles on the subject, “two-wheeled inverted pendulum” and focus have been on the physical and mathematical modeling of the system. Most articles derive the same models but they reach them in different ways. All the articles we have found useful are posted on our wiki-page, [http://user.it.uu.se/~pejo1781/pmwiki/pmwiki.php?n=Main.Inbyggda](http://user.it.uu.se/~pejo1781/pmwiki/pmwiki.php?n=Main.Inbyggda) under the headline “Modellering”. Some use Newtons equation of motion and an approach called Kane dynamics. Here the physical model consists of all the parts of the system decouple showing all the forces and torques acting on them. The mathematical models is derived using Newtons second law. The other approach was using Lagrange dynamics. This approach is much more elegant and is the approach we ha decided to take. The physical model here consists of a diagram showing all the generalized coordinates of the system and the relations between coordinates and other constraints. The mathematical model uses the idea of describing the motion of the centre of mass by means of the systems kinetic, rotational and potential energies. Using the Lagrangian and Euler/Lagrange-equations a system of equations describing the motion can be derived fairly simple. Although the idea behind this is simple we were not equipped with the theoretical background for reasoning about the problem, (having non-conservative forces and non-holonomic constraints). Thus we’ve also been reading up using some literature about Lagrange Dynamics. Some good material can be found on our wiki-page under the headline “Teori/Bakgrund för Modellering”. Our goal is to have finished the modeling by next week and perhaps having started with some basic testing and validation.

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