Design and Control of a Lego Unicycle

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Abstract

Your abstract.

Contents

1 Author's note **2**

2 Introduction **2**

3 Construction **2**
- 3.1 Ev3 . . . 2
- 3.2 Sensors . . . 2
  - 3.2.1 HighTechinic Gyro Sensor . . . 2
  - 3.2.2 HighTechinic Accelerometer Sensor . . . 4
  - 3.2.3 AbsoluteIMU-ACG . . . 5
- 3.3 Reaction wheel . . . 7
  - 3.3.1 Attachment between the reaction wheel and EV3 Large Motor . . . 8
- 3.4 Motors . . . 9
  - 3.4.1 EV3 Large Servo Motor . . . 9
- 3.5 Prototypes . . . 12

4 Modeling **12**
- 4.1 Lateral Balance . . . 12
  - 4.1.1 Mathematical model . . . 12
  - 4.1.2 Simulink model . . . 12
- 4.2 Medial Balance . . . 12
  - 4.2.1 Mathematical model . . . 12
  - 4.2.2 Simulink model . . . 12

5 Implementation **12**
- 5.1 Programs . . . 12
  - 5.1.1 Lejos . . . 12
  - 5.1.2 NXC . . . 12
- 5.2 Sensors . . . 12

6 Results **12**

1 Author's note

2 Introduction

Your introduction goes here! Some examples of commonly used commands and features are listed below, to help you get started. If you have a question, please use the help menu ("?") on the top bar to search for help or ask us a question.

3 Construction

3.1 Ev3

The EV3 is the third generation of Lego Mindstorms platforms, the specification of this platform can be seen in the table 1. Furthermore some options for programming platforms are listed in the table 2. Lastly can a picture of the EV3 also be seen in figure 1

Processor	ARM9
OS	Linux- based
Sensor ports	4 , analog, digital (up to 460.8 Kbit/sec)
Motor port	4, with encoders
SD- card	Micro SD- Card Reader, (up to 32 GB)

Table 1: Specifications for the EV3 platform found at [3].

Programing platforms
Lejos (extension of JAVA)
RobotC (similar to C)
NCX (similar to C)

Table 2: Some of the optional programing platforms for the EV3.

3.2 Sensors

3.2.1 HighTechinic Gyro Sensor

The Gyro sensor gives the rate of change in x, y and z orientation in radians per second. More specified details about the sensor can be seen in the table 3. The first row shows how long time it takes for our program to fetch a sample, second row shows how accurate the sensor is given by specification by the manufacturer and the last line shows the update time of the sensor also given by the manufacturer.
In nature all gyroscopes has a drift and offset, both are unwanted. The drift means that the rate of change will increase with time even though the sensor is stationary as can been observed in the figure 3. Secondly the offset is the

Figure 1: Shows how the hardware platform EV3 looks like which was used in the project.

property that give a constant value although the sensor is stationary. How we dealt with these problems will be explained in later sections. Lastly can we see the gyro sensor in figure 2.

Refresh time in program	10 ms (average)
Accuracy	±1 degree [5]
Update of value	300 times / second [5]

Table 3: Specifications for the gyro under the name NXT Gyro Sensor (NGY1044).

Figure 2: Shows the gyro sensor which was used in the project.

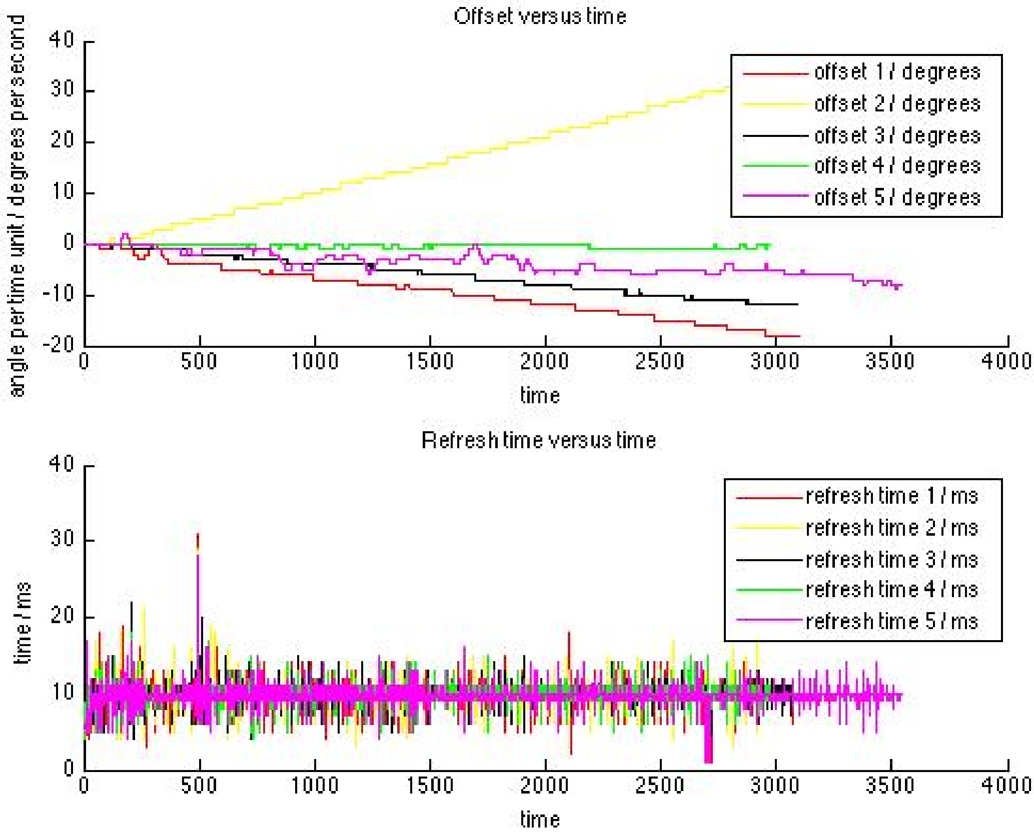

Figure 3: Shows the gyro sensor's offsets and refresh times when beeing stationary.

3.2.2 HighTechinic Accelerometer Sensor

The accelerometer measure acceleration in x, y and z direction relative to the sensors specified directions given by the manufacturer. The specifications of the accelerometer can be seen in the table 4 which shows the the time for it to give a sample to our program respectively number of times the sensor can update a value. On the other hand this sensor also comes with unwanted properties which is that the value is (very) noise however when it is not noise it gives reasonable good data. We can also see how this sensor looks like in the figure 4 and the refresh time for a longer of time can be seen in the figure 5

Refresh time in program	20 ms (average)
Update of value	100 times / second [4]

Table 4: Specifications for the accelerometer under the name NXT Acceleration (NAC1040).

Figure 4: Shows the accelerometer sensor which was used in the project.

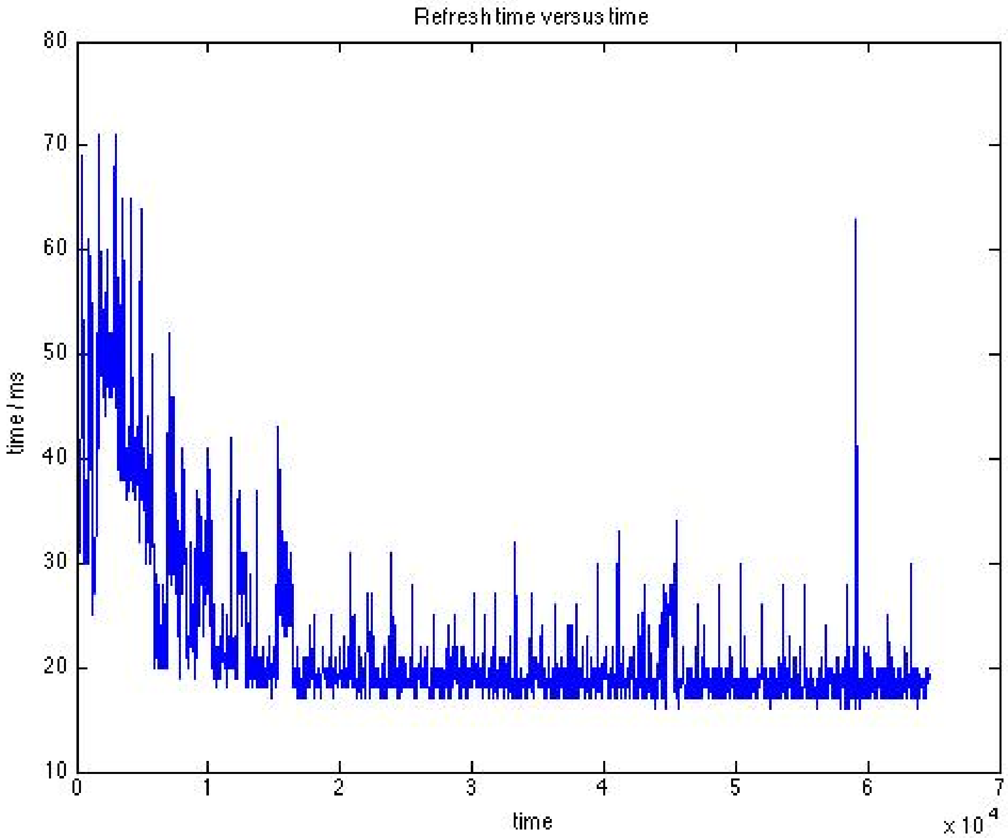

Figure 5: Shows the accelerometer sensor refresh time.

3.2.3 AbsoluteIMU-ACG

The AbsoluteIMU-ACG can gives gyro, accelerometer and compass data but in this project we are only interested in the gyro and the accelerometer therefor we will only discuss those measurements. As discussed previously gives the gyro part the rate of change in x,y and z. The accelerometer part measures the gravity in the x,y and z direction. The interesting part of this sensor is the refresh time versus the previous sensors and the update time can be seen in the figure 6. With this sensor one can also choose to have a smoothing filter for the accelerometer part of the IMU, downside is that this will increase the refresh time of the sensor. Therefor we did two measurements, one with sensitivity 0 and one with sensitivity 4 (figure 7).

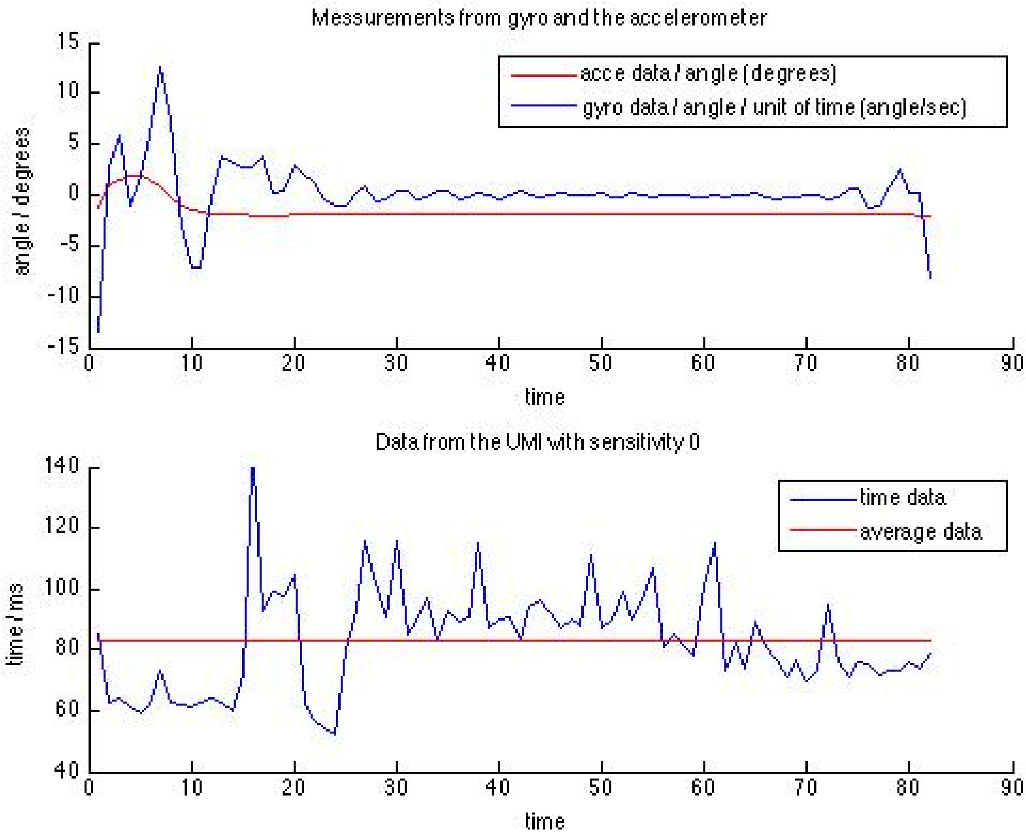

Figure 6: Shows the important properties of the IMU sensor with sensitivity 0.

Refresh time in program	83 ms (average)
Update of value	100 times / second [1]

Table 5: Specifications for the IMU-ACG sensor.

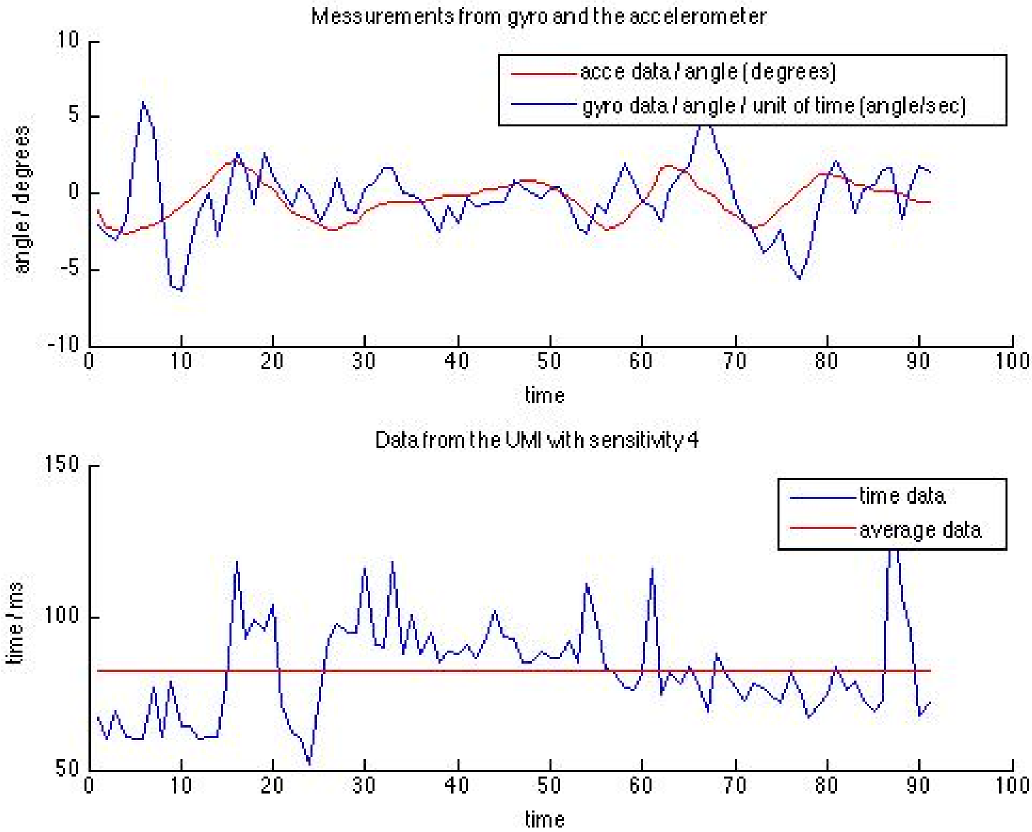

Figure 7: Shows the important properties of the IMU sensor with sensitivity 4.

3.3 Reaction wheel

The reaction wheel modeling is explained in the section 4 and some conclusion can be drawn from that. In this section we will bring up what those conclusion became in reality. Because we want as much weight as possible in the outer ring so nuts screwed in the material was the obvious choice. The choice of material was between plastic and wood, because of the nature of time and availability of personal it became wood. Plastic was preferable wood would also make it work. Due to the heavier weight of wood due to its nature it became a problem but was solved with making circles in the circle of wood so the most of the weight was taken out but leave enough for the circle not to crack under pressure of acceleration. The end product of the reaction wheel can be seen in the figure 9 while the dimensions is shown in the table 6. Meanwhile the design of the initial reaction wheel be seen in the figure 8. Thirdly is wort mentioning that the wholes at the end of the circle in figure 8 is for the nuts to go in and the cross in the middle is for the attachment to the axis going to the EV3 Large Servo Motor. More on this topic under the section 3.3.1

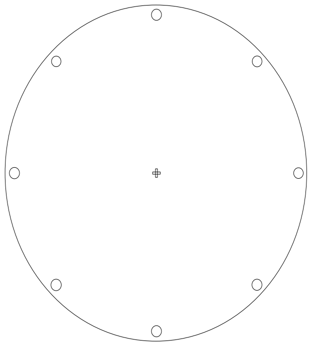

Figure 8: Shows the initial design for the reaction wheel.

Diameter	30 cm
Thickness	8 mm

Table 6: Shows the dimensions of the end product of the reaction wheel.

3.3.1 Attachment between the reaction wheel and EV3 Large Motor

Due to the attachment of the sensors on the current prototype we build in one small circular block to the reaction wheel which also had wholes matching the attachment directly to the EV3 Motor attachment. The specific attachment pattern is shown in figure 10. By using that specific pattern we achieved more stability of the reaction wheel but still there were problems with leaning of the reaction wheel relative to the full scale prototype. We also experienced wobbling of the reaction wheel when it was set to use. Therefore we rebuild the reaction wheel once more relative to the initial design with one more circular block on the other side of the reaction wheel which meant that we now had two circular blocks coming out from the reaction wheel at both ends. The prototype holding up the reaction wheel was also rebuild due to rebuilding of the reaction wheel, more on rebuilding of the full prototype can be seen in section 3.5. Thus in the end leading to a full stable reaction wheel relative to the full scale prototype. The end attachment of the reaction wheel is shown in figure 11

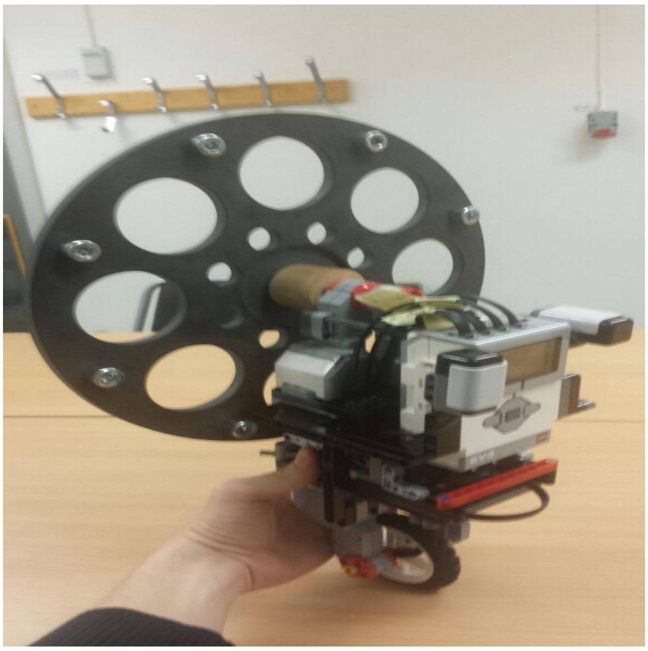

Figure 9: Shows the end product of the reaction wheel with the whole prototype at one stage.

Figure 10: The red rectangle specifies the attachment pattern on the EV3 motor.

3.4 Motors

3.4.1 EV3 Large Servo Motor

This is one of the strongest motors there is for LEGO and the specifications for this motor can be seen in the table 7. One experiment was done to get the connection between the torque and the power which is the parameter that

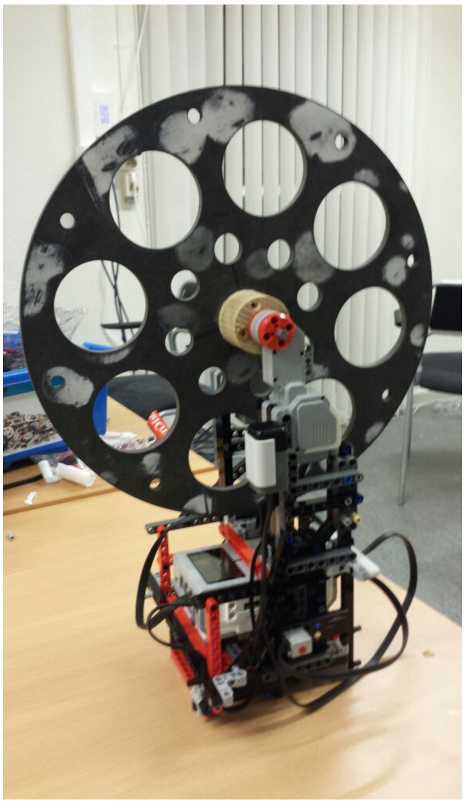

Figure 11: Shown the end product of the attaching of the reaction wheel with the two engines.

control the PWM that goes to the motor. The power goes from -100 to 100. The result can be seen in the figure 12.

RPM	160 - 170 [2]
Running torque	20 N/cm [2]
Stall torque	40 N/cm [2]

Table 7: Specifications for the EV3 large motor server.

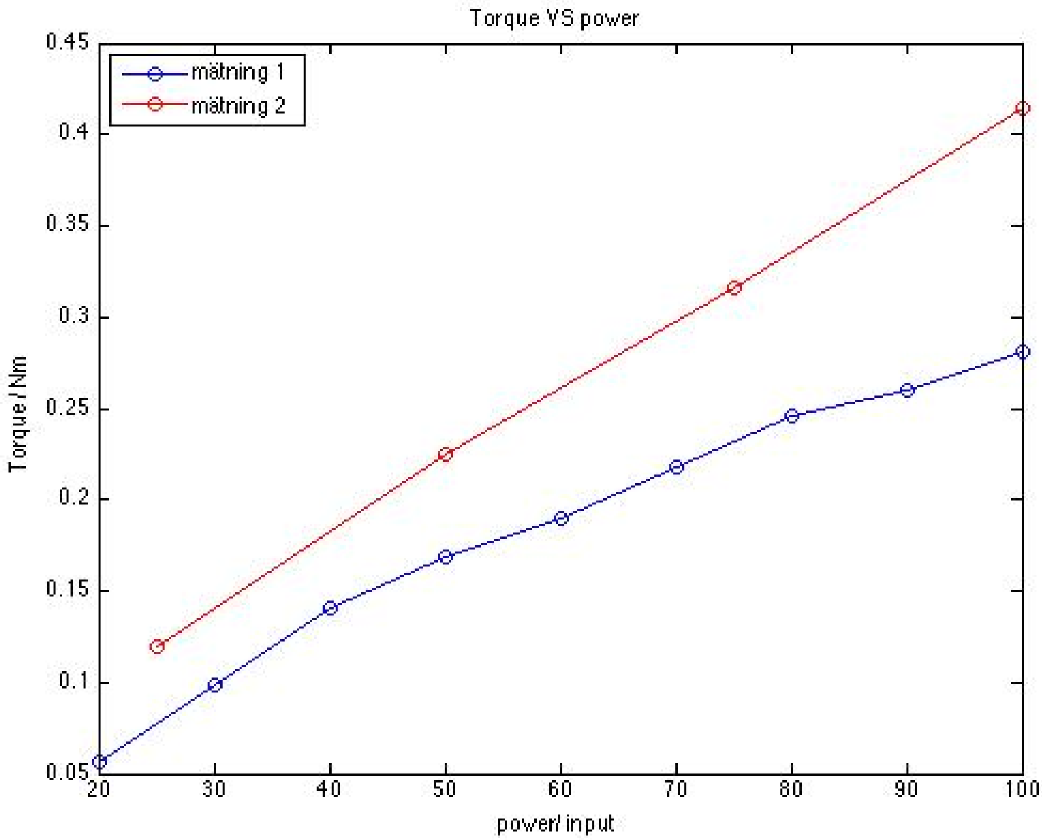

Figure 12: Shows the relation between the power and the torque of the motor.

3.5 Prototypes

4 Modeling

4.1 Lateral Balance

4.1.1 Mathematical model

4.1.2 Simulink model

4.2 Medial Balance

4.2.1 Mathematical model

4.2.2 Simulink model

5 Implementation

5.1 Programs

5.1.1 Lejos

5.1.2 NXC

5.2 Sensors

6 Results

7 Discussion and Conclusion

References

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