UNIVERSITY OF TRENTO - Italy
Information Engineering
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**Master Degree in Computer Science**

**Applied Robotics**

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# Identification procedure for Lego Mindstorm motor

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**Abstract**

*Report for the first assignment on Applied robotics. Identification parameters of the motor. In this report we discuss our method of obtaining the data from Lego Mindstorm motor as well as estimation of parameters from the motor data.*

# 1 Collecting motor data

We use 2 methods for collecting the motor data:

1. Using the Bluetooth connection
2. Using USB connection

## 1.1 Bluetooth data collection

We start from the brofist source, and we change message interface to include timestamp. The idea is follows:

1. Send message that tells motor to set up specific power.
2. Send message that requests tacho count from the motor.
3. Receive tacho count with timestamp.
4. Save (timestamp, tacho count) to file.
5. Go to step 2.

You can find code in Bluetooth Collector. But using this methodology we obtain very high latency $\approx 50ms$. So we decided to use USB connection instead.

## 1.2 USB data collection

We use library pyusb to establish USB connection with brick. The idea is follows:

1. Establish connection with brick using pyusb.
2. Setup the motor power on the brick.
3. Send (timestamp, tacho count) from brick.
4. Receive (timestamp, tacho count) at PC.
5. Save (timestamp, tacho count) to file.
6. Go to step 3.

You can find code in USB Collector. Using this methodology we obtain much better performance $\approx 2ms$ latency. Using USB we collect 10 data files with different raw powers.

# 2 Estimating the parameters from the data

To estimate the parameters we filter the data using butterworth filter and then we estimate the parameters using 2 methods:

- Regular method proposed on the lecture
- Regression method

## 2.1 Filtering

We use butterwoth filter of order 1 and and cut-off frequency 0.02. For example fig. 1. You can find code for filtering in Filtering. And plot for all the powers in Filtering Plots.

## 2.2 Parameter Estimation

We need to estimate 3 parameters $q$, $\omega_n$, $\xi$. You can find code in Identification

### 2.2.1 Regular method

For the regular method we use the following formulas:

$$q = \text{Last speed value} \tag{1}$$

$$\xi = \sqrt{\frac{\log(\text{overshot})^2}{\pi^2 + \log(\text{overshot})^2}} \tag{2}$$

$$\omega_n = \frac{\log(\frac{alpha}{100}) - \log(\frac{1}{\sqrt{1-\xi^2}})}{-\text{settling time} * \xi} \tag{3}$$

Using this method we obtain 10 sets of parameters which we can see in table 1.

### 2.2.2 Regression method

Let $\hat{s_t}$ be the speed at time $t$, and $T$ - finish time, and $s_t(q, \xi, \omega_n)$ will be the speed from our model. The result parameters will be:

$$(q, \xi, \omega_n) = arg \max_{q,\xi,\omega_n} \sum_{t=1}^{T} (s_t(q, \xi, \omega_n) - \hat{s_t})^2 \tag{4}$$

Using this method we obtain 10 sets of parameters which we can see in table 2.

Table 1: Parameters obtained using regular estimation

| Power | $q$ | $\xi$ | $\omega_n$ |
|---|---|---|---|
| 20 | 0.1573 | 2.0425 | 0.5320 |
| 30 | 0.1638 | 18.0187 | 0.7611 |
| 40 | 0.1685 | 0.9028 | 0.7799 |
| 50 | 0.1720 | 3.4136 | 0.8462 |
| 60 | 0.1732 | 12.7967 | 0.8444 |
| 65 | 0.1745 | 14.9685 | 0.8597 |
| 70 | 0.1733 | 14.5697 | 0.8046 |
| 75 | 0.1740 | 14.7569 | 0.8493 |
| 80 | 0.1750 | 15.0400 | 0.8083 |
| 90 | 0.1746 | 14.2055 | 0.8638 |

Table 2: Parameters obtained using regression estimation

| Power | $q$ | $\xi$ | $\omega_n$ |
|---|---|---|---|
| 20 | 0.1625 | 28.14 | 0.9996 |
| 30 | 0.1645 | 11.73 | 1.0000 |
| 40 | 0.1691 | 24.80 | 0.9990 |
| 50 | 0.1702 | 24.34 | 0.9993 |
| 60 | 0.1725 | 21.38 | 0.9994 |
| 65 | 0.1740 | 23.19 | 0.9995 |
| 70 | 0.1736 | 21.92 | 0.9994 |
| 75 | 0.1736 | 22.47 | 0.9993 |
| 80 | 0.1752 | 10.52 | 1.0000 |
| 90 | 0.1743 | 10.19 | 1.0000 |

Table 3: Mean of mean square error for all data sets.

| Power | Regular Method | Regression Method |
|---|---|---|
| 20 | 60.71 | 50.53 |
| 30 | 49.81 | 49.47 |
| 40 | 73.30 | 46.96 |
| 50 | 50.96 | 46.40 |
| 60 | 45.30 | 45.32 |
| 65 | 44.51 | 44.55 |
| 70 | 45.07 | 44.80 |
| 75 | 44.76 | 44.78 |
| 80 | 44.24 | 44.07 |
| 90 | 44.52 | 44.49 |

#### 2.2.3 Methods Comparison

For every set of parameters we plot how modeled data and filtered data ax example fig. 2, you can find all the plots in Model comparison plots. For every set of parameters we also compute mean of mean square errors for all data sets.

$$\text{result in cell} = \frac{1}{10}\sum_{i=1}^{10}\frac{1}{T}\sum_{t=1}^{T}(s_t^i(q,\xi,\omega_n) - \hat{s_t^i})^2 \tag{5}$$

And we get a result which is in table table 3 (Power is from which data set we obtain a parameters, second column for regular method and third for the regression method). From table 3 we can see that optimal parameters is obtained from (power = 80) data and regression method. We plot filtered data and modeled data with optimal parameters, for example fig. 3. You can find other plots in Result plots.

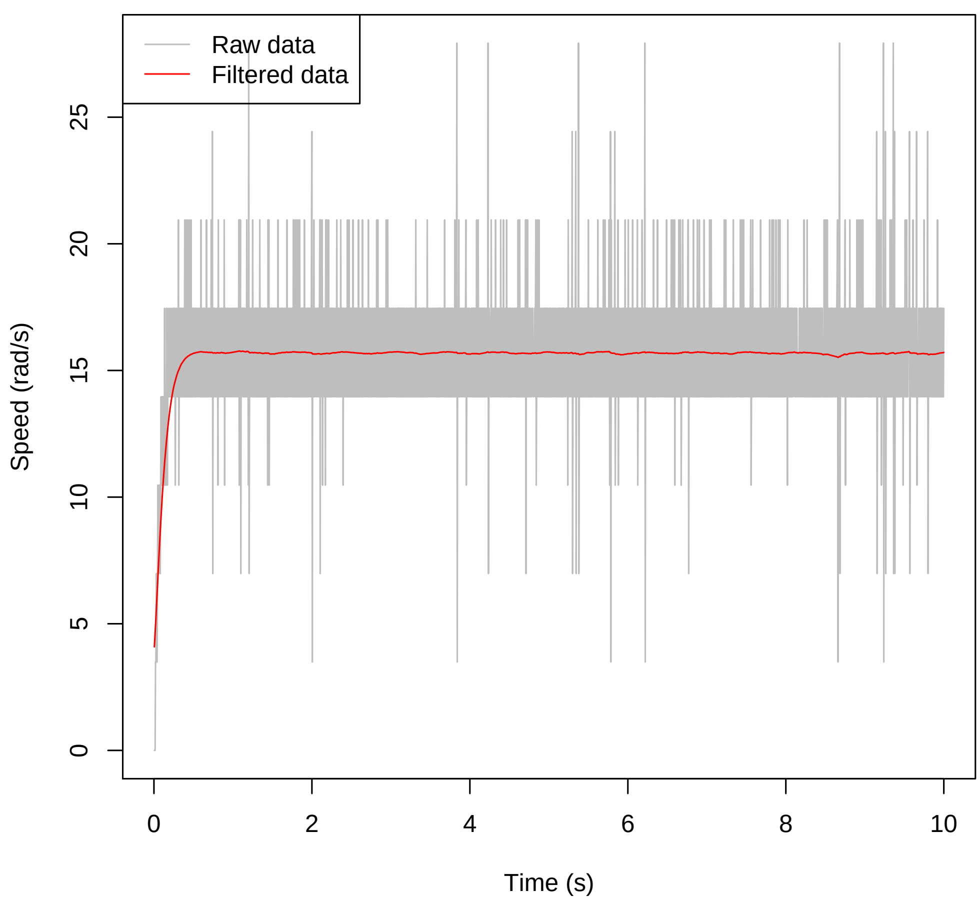


Figure 1: Filtered and raw data for motor power = 90.

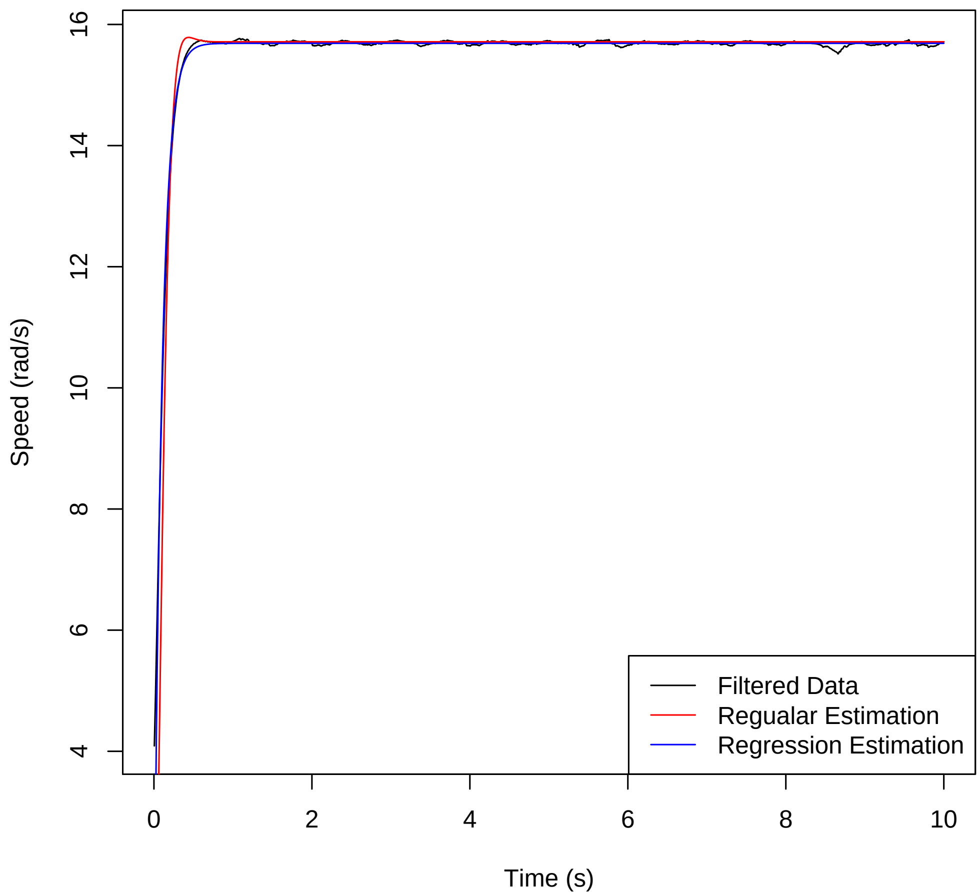


Figure 2: Filtered and modeled data for motor power = 90.

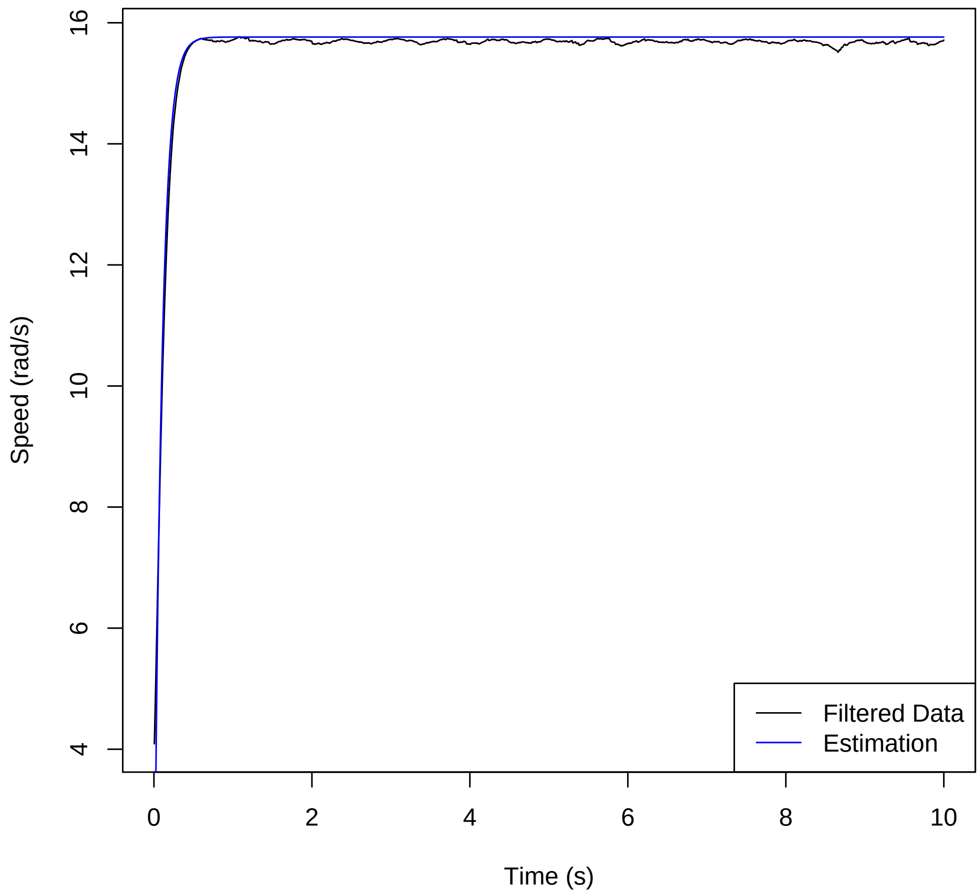


Figure 3: Filtered and modeled data (with result parameters) for motor power = 90.