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Identification procedure for Lego Mindstorm motor

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Abstract

Report for the first assignment on Applied robotics: getting and identification parameters of the Lego NXT motors.

In this report we discuss our method of obtaining data from Lego Mindstorm motors as well as estimation of parameters from the motor data.

1 Tools and definitions

1.1 General definition

- `Lego Mindstorms NXT`: LEGO Mindstorms NXT is a programmable robotics kit released by LEGO in late July 2006. The main component in the kit is a brick-shaped computer called the NXT Intelligent Brick; it can take input from up to four sensors and control up to three motors[1].

- `nxtOSEK`: nxtOSEK is an open source platform for LEGO MINDSTORMS NXT; it can provide C/C++ programming environment and API for NXT Sensors, Motor, and other devices[2].

1.2 Used tools

To collect the data from the motor, we used our pc, with 2 types of connection: bluetooth (Based on brofist) and usb wired (based on pyusb library). From the Lego terminal we instantiated a server on our pc, and a client on the NXT brick connected to the motor. In this way it was simply comunicate with the motor, define an angular velocity(determined by the power gived to the motor by the centraline), and then pick up the data. We use R to plot, filter and estimate parameters from collected data.

2 Collecting motor data

Have been used 2 different methods to collect motor data:

1. Bluetooth connection
2. Usb connection

It is important get the minimum time gap between measures, but it require an extra check to detect if the tachometer sensor is fast and precious as the used transmission. For this report we decided to use USB connection getting 10 different data files with different raw powers.

[1]Lego Mindstorms NXT - Wikipedia, the free encyclopedia, `https://en.wikipedia.org/wiki/Lego_Mindstorms_NXT`

[2]nxtOSEK, `http://lejos-osek.sourceforge.net/whatislejososek.htm`

2.1 Bluetooth data collection

Given by the lab the code to comunicate between our PC and the NXT brick, we learned how it works and we implement the interface to include also the current measure NXT timestamp. The procedure to get data with bluetooth is the following:

1. Send message from PC to brick that define motor power(that determines the speed)
2. Send message from PC to brick that requests tachometer count from the motor
3. Receive message from brick with tachometer count and relative timestamps
4. Save timestamps and tachometer count in a file.txt
5. Repeat all from step 2

Using this methodology there is a very hight latency $\approx 50ms$. It is possible to force the speed connection, but using USB connection it results more reliable and fast. Code is available here: Bluetooth colection

2.2 USB data collection

To establish a connection between PC and NXT brick is it possible use a specific Pyton library called "pyusb". The procedure to get data with this method is the following:

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

Using this methodology is it possible to obtain much better performance in terms of $\approx 2ms$ latency. Code is available here: USB colection

3 Estimating the parameters from the data

To estimate the parameters we filter the data using butterworth filter and then we estimate the parameters in two different way:

- Regular method proposed on the lecture
- Regression method

3.1 Filtering

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

3.2 Parameter Estimation

We need to estimate 3 parameters q, ω_n, ξ. You can find code in Identification

3.2.1 Regular method

For the regular method we use the following formulas:

steady state

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

damping

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

period

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

Using this method we obtain 10 sets of parameter which can be seen in table 1.

3.2.2 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 parameter which can be seen in table 2.

Table 1: Parameters obtained using regular estimation

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

Table 2: Parameters obtained using regression estimation

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

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

3.2.3 Methods Comparison

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

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

integral squared error

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.

4 Conclusion

As discussed in the second chapter "Collecting motor data", USB connection gives a better and faster connectivity. Thanks to the quantity and quality of the collected date, it is possible to compare them to the estimated date. To do it, it is needed to filter the collected date and match them to the estimated ones. With filter is possible to get hight readability plots and better result.

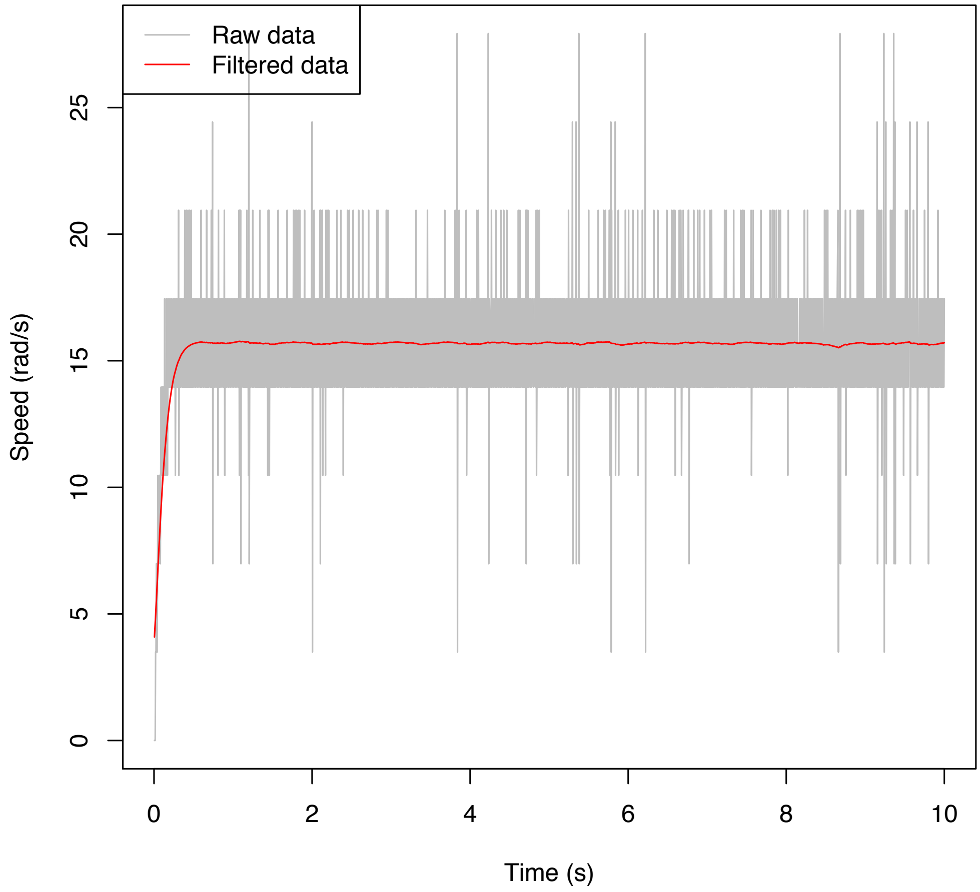

Figure 1: Filtered and raw data for motor power = 90.

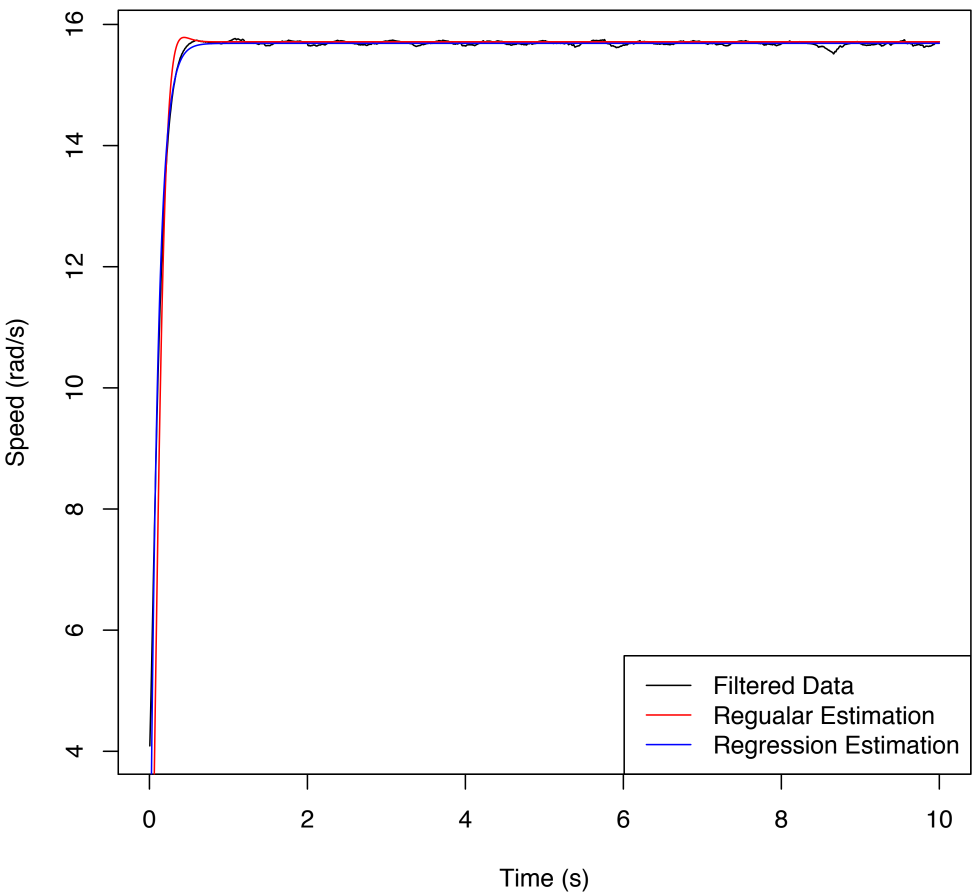

Figure 2: Filtered and modeled data for motor power = 90.

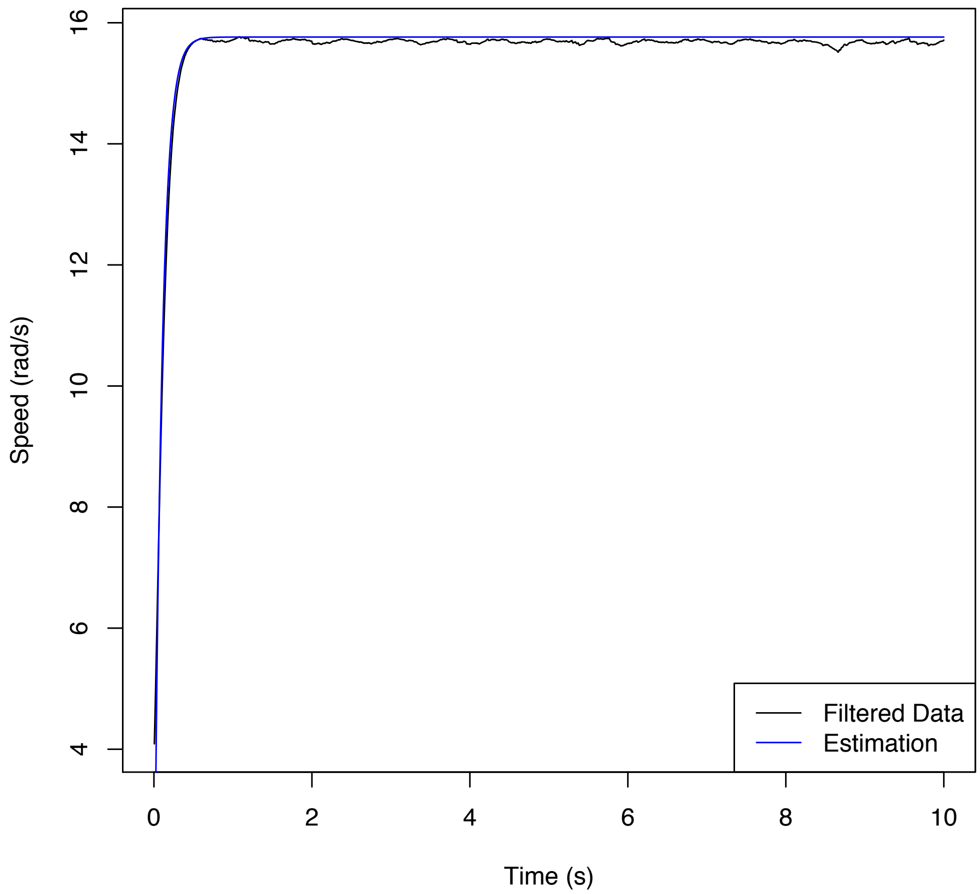

Figure 3: Filtered and modeled data (with result parameters) for motor power = 90.