# Deriving a white-box model of the drive of a RC-Car using Prediction-Error-Method

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## I. Introduction

Model-Driven-Development is a method, often used in the development of embedded systems in which a system, that is supposed to interact with a physical enviroment is simulated with a PC before it is finally tested in real life. For this technique it is of course necessary to have a model of the physical enviroment. In this project the drive of an RC-Car which is used for students projects such as developing driver-assistance systems is modelled. The aim was to derive a model-equation, that describes the speed of the rear wheels which are driven by brushless motor in dependence of different input signals to the brushless motor.

## II. Experimental-setup

The input signal was created by a remote control that sends information of the users throttle input to a reciever on the car, which modulates this information into a corresponding PWM-Signal. The PWM-Signals for different throttle positions were determined by measuring the pulse-width with an osciloscope. The signal width in the neutral position was 1,5 ms. In the following with PWM-Signal, the difference to that neutral signal is meant. The PWM-Signal is fed into the controller of a brushless motor, which then drives the wheels. The RC-Car is equipped with magnetic speed sensors on all four wheels. Using an Arduino Microcontroller step responses to different input-PWM-Signals were measured. During the experiment the car was lifted, so that the wheels were rotating freely in the air. The sample rate was 8.5 ms.

## III. Results and modelling

The results of the measured step responses for different input-signals where used as input and output data. To model the system an ARX-Model of order 2, whicht is described in formula 1, was used in the first iteration. The aim was to estimate the coefficents a and b. For this purpose the matlab function arx_pem, which was provided in the modelling and system identification lecture was used with the input data of the step response of the PWM-Signal with 120 $\mu s$. After the parameters were estimated a continuous-time transfer function was used to simulate the system. The results of the simulation, compared to the measured data can be seen in figure 2.

$$y(k) + \sum_{i=1}^{n} a_i y(k-i) = \sum_{i=1}^{n} b_i u(k-i) \tag{1}$$

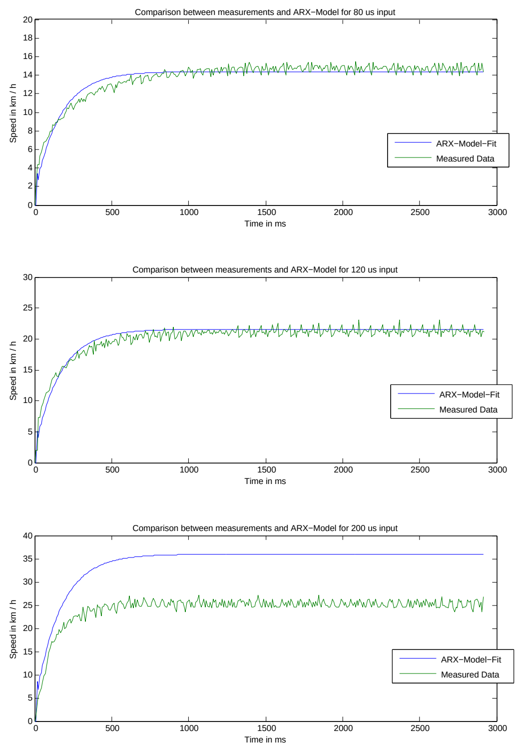


**Figure 1:** *Comparison of the measured data with the ARX-Model-Fit*

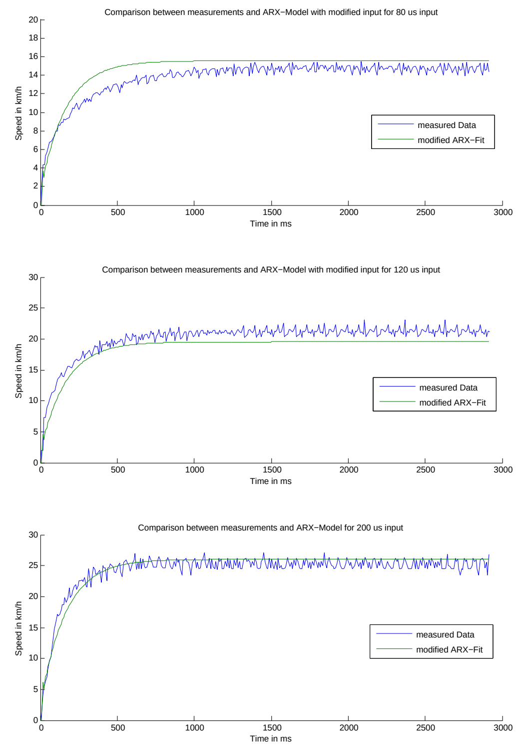


**Figure 2:** *Comparison of the measured data with the modified ARX-Model-Fit*

As one can see, the simulation using an ARX-Model fits nicely for the 80 and 120 $\mu s$ PWM-Signal. However, the fit holds hardly for the 200 $\mu s$ input. This is due to the nonlinearity of the output-signal to the input signal. After the steady state was analyzed for different it showed, that the relation showed a curve which had the form of a logarithmic- or root-function. The idea then was to modify the input signals in a way that the input signal was "flattened out" for higher inputs. This was done using a root function like described in formula 2. In this function the parameter $\alpha$ and $\beta$ had to be found. A function was set up, to calculate the residual between the a simulation using a modified input signal with a given system. This function was then minimized with the lsqnonlin-function. In figure 2 again the simulation with the modified PWM-Signal is shown. It shows that using the modification of the input-signal yields a much better matching of the simulation to the measured data.

$$modifiedPWM = \alpha \sqrt[\beta]{inputPWM} \tag{2}$$

*A thank you or further information