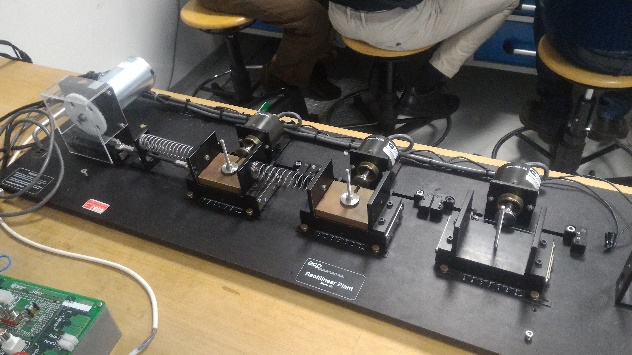
Title:



* A DC direct drive brushed motor
* Three carts with anti-friction ball bearing
* Three springs connecting the carts and the motor
* Several weights to put upon carts
* Three optical incremental digital encoders for the position
* An encoder for the motor
* A PoliArd board with an Arduino Due microcontroller

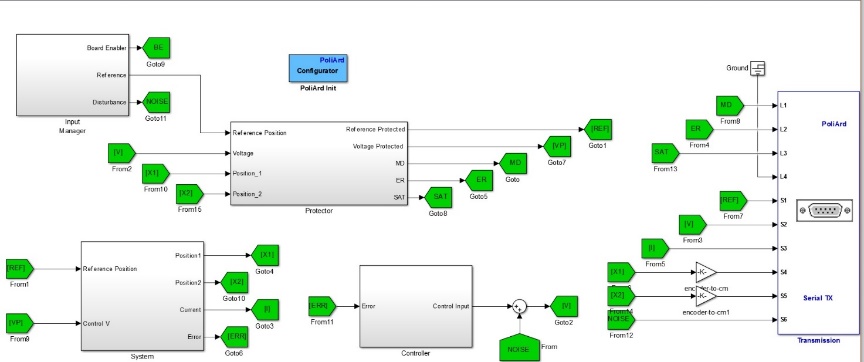
1. System: brushed motor, 3 carts, 3 springs, weights, 4 encoders, PoliArd/Arduino

Preliminary issues

* + Arduino saturation limits measured motor current to ±5A
  + For ,  is not constant; assumed: 
  + Encoder signal: Arduino to and fro cm; measurement of the ratio

Protection system - four macroblocks:

* + Input Manager: selects input, control input noise and reference
  + Protector: saturates voltage, displacement and reference; synchronizes Arduino and signal starting time; triggers alert
  + System: motor and encoder feedback
  + Controller: controls + pulls control voltage to 0 when alert has been triggered



1. Modelling

**Motor**:  where

: back-emf effect, : torque constant 

**Pinion/rack**:  where

load torque transmitted to the carts

inertia of motor, pinion and rack

 non linear motor friction

**Each cart:**  where

: total damping (viscous + spring) of the i-th cart

Putting and neglecting nonlinear friction

 where

1. 1 dof

 state of the motor (current)

 position of the cart

 velocity of the cart



Put 

1 DOF: 

1. 2 dof

Lagrangian approach: where 

State space model: 

With suitable definitions of M, C, K, B

Analogously for 3 dof

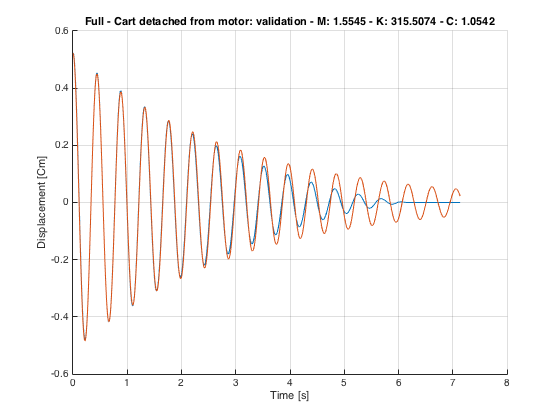
1. White box identification: detached system – cart and springs

The cart was released from a fixed position and allowed to oscillate:

*  ; : time difference between first and second peak
* ,;: amplitudes of first and second peaks
* : for each spring two experiments, with and without load: 

varies with (ball bearing friction?): 

**Validation**: real output vs simulation (identified parameters): fit=0.9449±0.0263

 Loss of accuracy on the long run

1. White box identification: motor only

Resistance only: voltage pulses to motor: steady state measurement of 

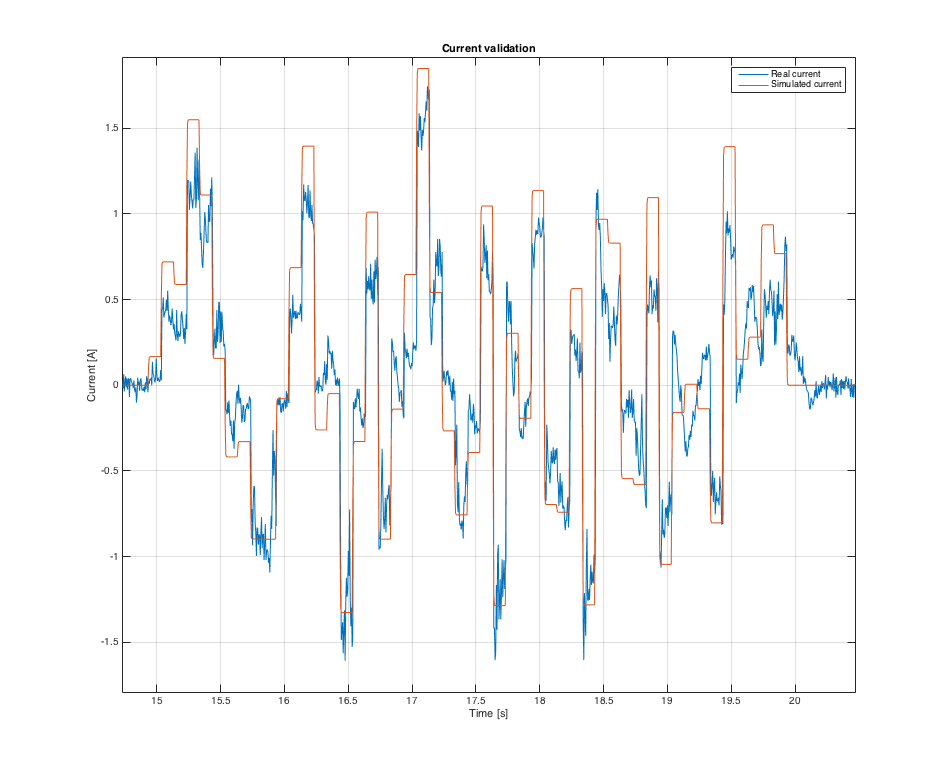
Resistance and inductance: experimental input/output data given to Matlab tfest (first order)

;back-emf neglected because 

,

Nominal values from motor datasheet ,

**Validation**: real output vs simulation with input = N(0,9/4): fit=0.8142±0.0364



1. Overall system identification: cart attached to motor

Same tests and same techniques used for detached parts. Results:

System mass: ; Motor mass: 

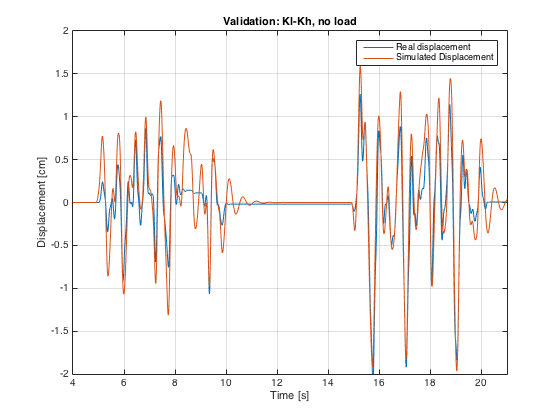
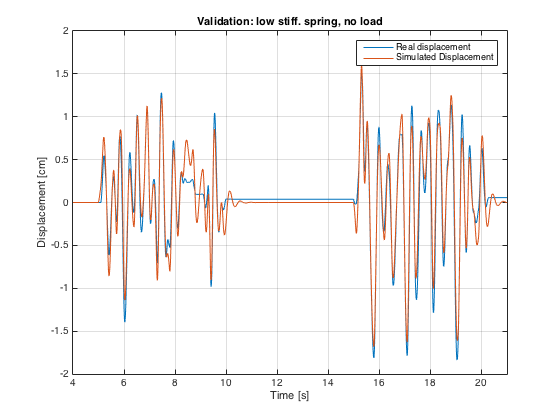
System springs: ,,

System damping(load/no load):  , ,, ,,

Linear torque constant: 

**Validation**: real output vs simulation with input , where:

Fit: 1 dof: (85.42±1.68)%, 2 dof (2 combinations: Kh-Km, Kl-Kh): (86.54±4.68)%



1 dof 2 dof

Tempo 30 secondi a slide 7x3=21 -> 21x30=500= 10,5 minuti

Tempo 45 secondi a slide 7x3=21 -> 21x45=945= 15,75 minuti