Tire Pressure Monitoring

4588745 2384618

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Contents

All of the matlab exercises can be run by running script.m.

Authors info

- 4588745 Email
- 2384618 Email

D1

Three Point estimates in Minutes

Task No.	Best Case	Likely Case	Worst Case
D1	10	25	40
D2	60	80	160
D3	80	150	200
D4	40	80	160
D5	30	70	150
D6	50	100	160
D7	40	70	120
D8	30	50	120
D9	40	60	100
D10	30	60	120
D11	40	60	100
D12*	40	70	100
D13*	20	40	60
D14*	30	50	70
Sum (min)	540	965	1660
Sum (hours)	9	16.08	27.67
Result (min)	1010		
Result (hours)	16.83		

D2

Files: findRadius.m, script.m

The values of the curve.mat file have to be stripped for the required values. Then the `findRadius()` function located in `findRadius.m` is called to determine the curve radius of the car.

```
b=2.65;
w=1.53;
```

```
vrl = matrix.vrl;
vrr = matrix.vrr;
vfl = matrix.vfl;
vfr = matrix.vfr;
tv = matrix.tv;
sw = matrix.sw;

vrl_simulink = [tv, vrl];
vrr_simulink = [tv, vrr];
vfl_simulink = [tv, vfl];
vfr_simulink = [tv, vfr];


% Get radiuses
[R_RR, R_RL, R_FR, R_FL] = findRadius(vrl, vrr, vfl, vfr, w, tv, sw);
```

Given the formulas

$$R_{RR} = W + R_{RL}$$

and

$$\frac{V_x}{V_y} = \frac{R_x}{R_y}$$

and velocities for all the wheels during the entire duration of the test data one can determine the curve radiuses easily as such:

$$R_{RL} = \frac{W}{\frac{V_{RR}}{V_{RL}} - 1}$$

$$R_{RR} = \frac{R_{RL} \cdot V_{RR}}{V_{RL}}$$

$$R_{FR} = \frac{R_{RL} \cdot V_{FR}}{V_{RL}}$$

$$R_{FL} = \frac{R_{RL} \cdot V_{FL}}{V_{RL}}$$

Another approach is the pythagoras formula which we ended up using in our final version.

$$R_{RL} = \frac{W}{\frac{V_{RR}}{V_{RL}} - 1}$$

$$R_{RR} = R_{RL} + W$$

$$R_{FR} = \sqrt{W^2 + R_{RR}^2} \cdot signum(R_{RR})$$

$$R_{FL} = \sqrt{W^2 + R_{RL}^2} \cdot signum(R_{RR})$$

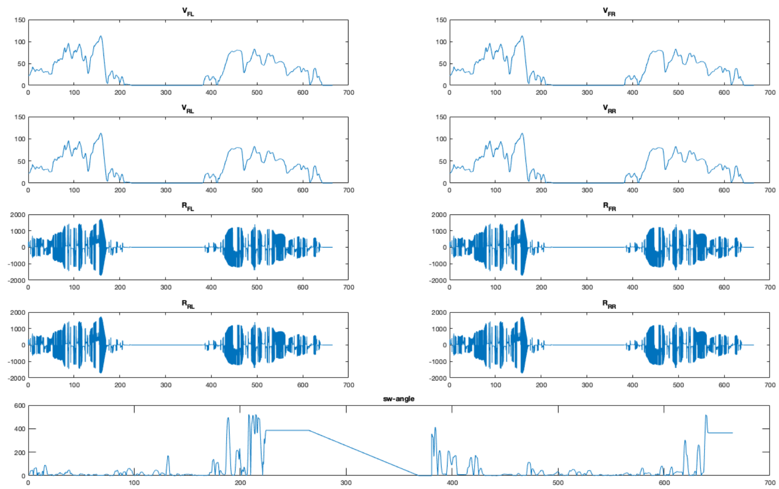
In `randomNumberGenerator()`:

```
w_m=zeros(size(tv));
w_m(:,1) = w;
R_RL=(w_m./((vrr./vrl)-1));
R_RR=R_RL+w;
% sign function ensures that all signs are the same
R_FR=(sqrt(w^2 + R_RR.^2)) .*sign(R_RR);
R_FL=(sqrt(w^2 + R_RL.^2)) .*sign(R_RR);
```

To prevent errors, bad values like inf an NaN are replaced with 0.

```
% Filter bad values
R_RR(isnan(R_RR)|isinf(R_RR)) = 0.0;
R_RL(isnan(R_RL)|isinf(R_RL)) = 0.0;
R_FR(isnan(R_FR)|isinf(R_FR)) = 0.0;
R_FL(isnan(R_FL)|isinf(R_FL)) = 0.0;
```

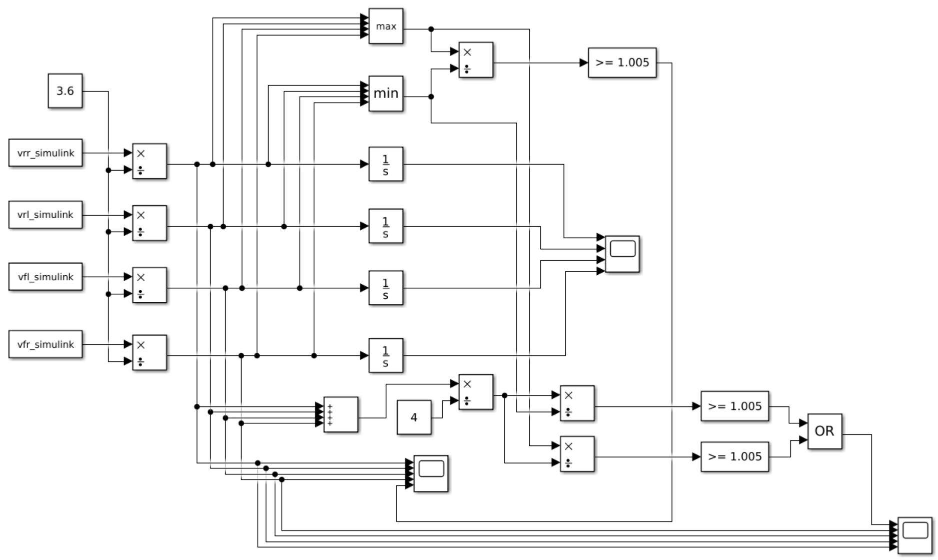
The resulting radiuses for each wheel together with their speeds and steering wheel are pictured below.



D3

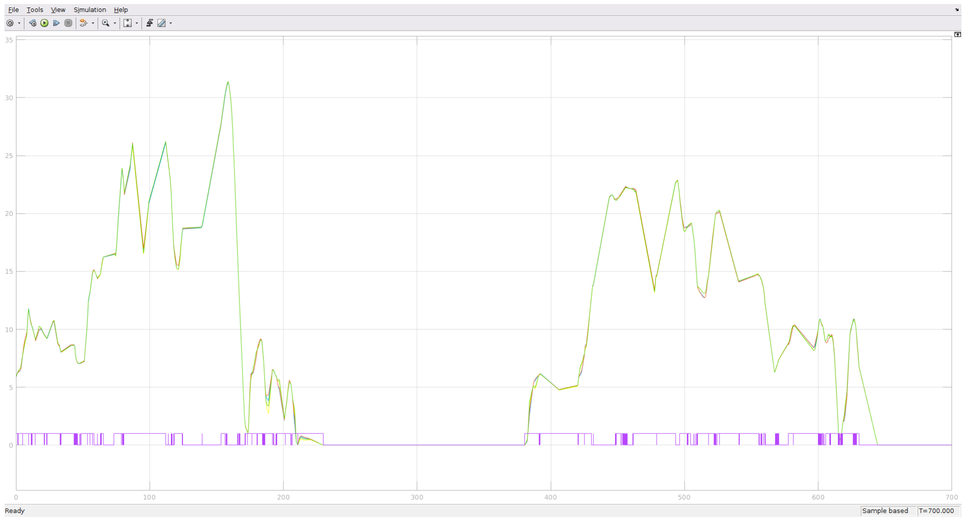
Files: D3.slx, script.m

The simulink model for D3 is provided with the velocities of the respective wheels of the vehicle. It converts the values that are given in $\frac{km}{h}$ into $\frac{m}{s}$ by dividing by 3.6. As to the Requirement R2, we think there are at least two interpretations of the word "imbalance". Both are present in the simulink model.



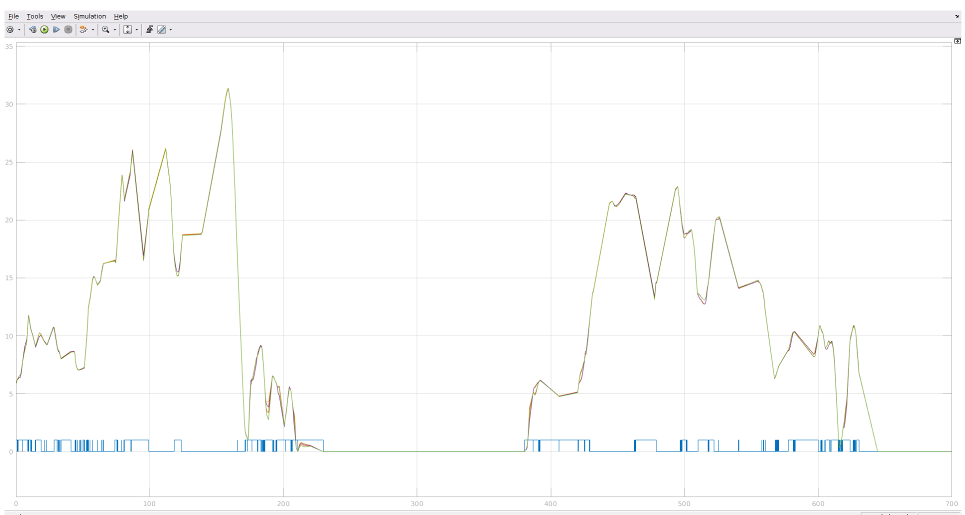
First Interpretation

If any two tires differ by 0.5% in their velocities, a drop is detected. This method is implemented by taking minimum and maximum values of the four velocities at any time and dividing them to see if the two most exteme wheels differ by 0.5%. A “1” in the blue/purple signal denominates if a tire pressure drop has been detected. The other signals represent the speeds of the respective wheels. This produces the following result:



Second Interpretation

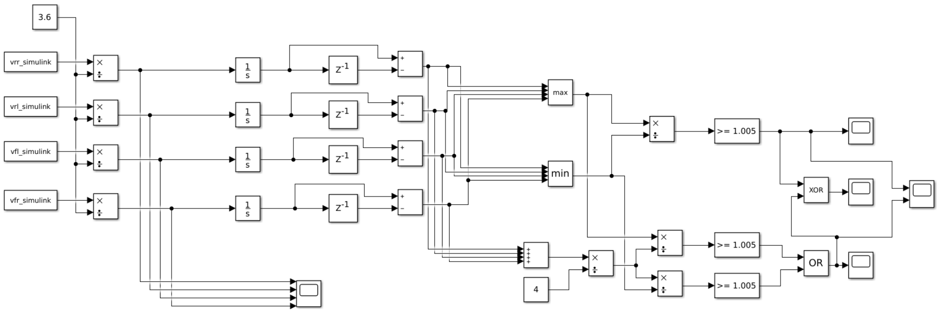
The maximum and minimum velocities are compared to the average of all velocities. If either the minimum or maximum velocity differs by 0.5% an imbalance is detected. This produces the following result:



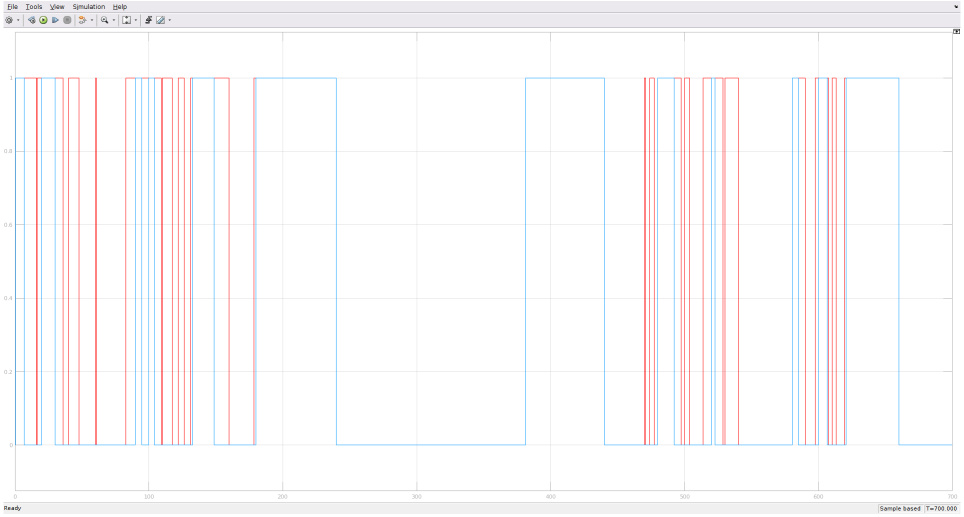
D4

Files: D4.slx, script.m

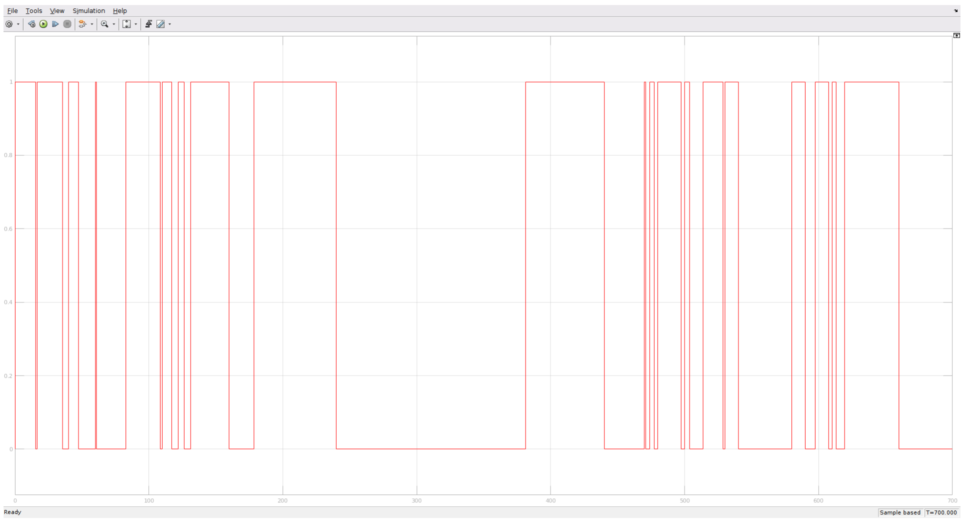
If the difference between the maximum distance and the minimum distance is greater then 0.5% the system will detect tire pressure drop. This is essentially the same as D3 but with the travelled distance of the wheels instead of their velocities. A delay block is used to get a $\delta S = S(t) - S(t-10)$ which is the travelled speed in the last 10 time units. As in D3 there are two approaches to detecting an "imbalance" both of which can be seen below.

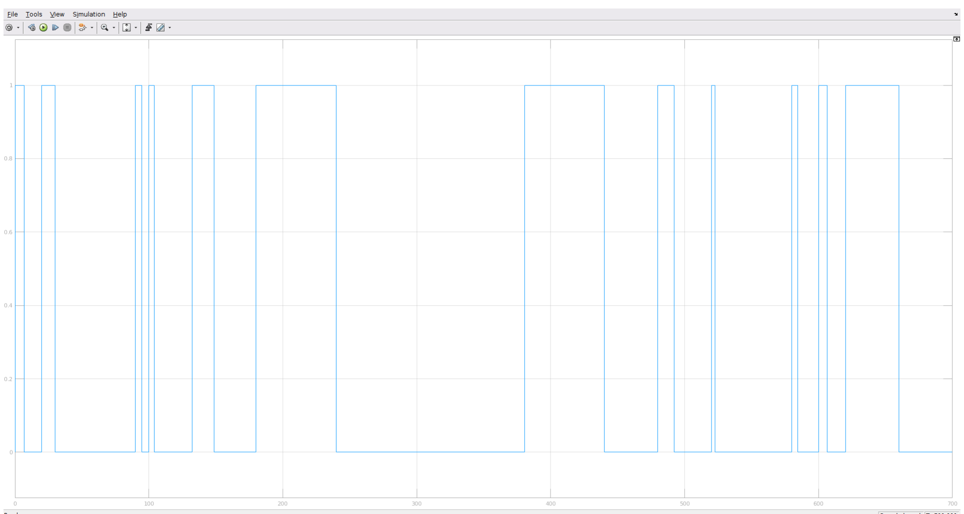


Again, using these two different approaches to detecting the imbalance as discussed in D3 we gets two different results. The first approach is pictured in red and the second is pictured in blue. A "1" means that a pressure drop has been detected.



Here they are seperately:





D5

Files: randomNumberGenerator.m, script.m

The m and c parameters of the given random number generator are the upper and lower limit for the values generated. An initial value has to be chosen and functions as seed.

```
%randomNumberGenerator.m

function [dataset] = randomNumberGenerator(a, c, m, seed, n)
% Generater random test data for D5
% seed = X(0)
% n = length
% a,c,m according to formula of task D5

% Preallocate return array
dataset = zeros(1, n);
% Set seed
dataset(1) = seed;

for i = 2:1:n
    dataset(i) = mod(round((a * dataset(i-1) + c)), round(m))
end
```

According to wikipedia for a random sequence of data, the parameters for a congruential number generator have to be chosen according to these rules:

1. c and m are relatively prime
2. a-1 is divisible by all prime factors of m
3. a-1 is a multiple of 4 if m is a multiple of 4
4. c is nonzero

Using these rules one can quickly determine four combinations for each wheel which fulfill all requirements.

a	c	m
21	23	80
7	13	81
31	17	90
39	11	76

The seed can be chosen arbitrarily as there is no rule concerning it. ____

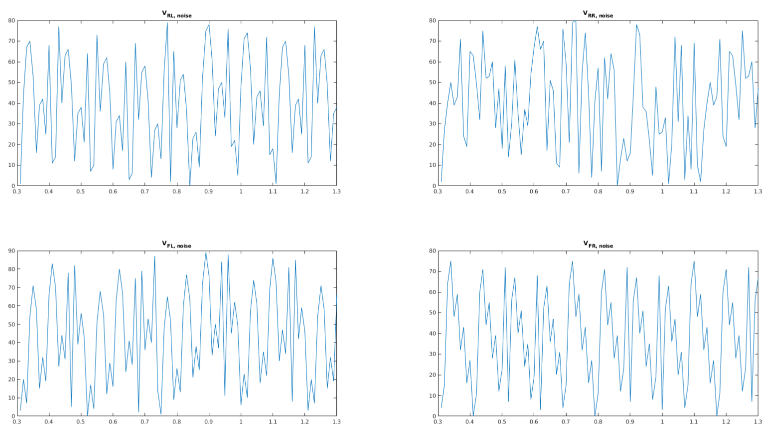
```
% Generate own tire velocity data for testing using randomNumberGenerator()
```

```
% Will generate data up to 80 km/h per wheel

% Amount of data points
n = 100;

% Create random test data
vrl_simulink_noise = randomNumberGenerator(21, 23, 80, 1, n);
vrr_simulink_noise = randomNumberGenerator(7, 13, 81, 2, n);
vfl_simulink_noise = randomNumberGenerator(31, 17, 90, 3, n);
vfr_simulink_noise = randomNumberGenerator(39, 11, 76, 4, n);
```

Plotted on a graph, the pseudo-random noise looks like this:



D6

Files: D6.slx, script.m

D6.slx is merely a copy of D4.slx that uses the variables `vx_simulink_noise` instead of `vx_simulink`.

D12

D13

Using the steering wheel angle and lateral acceleration provided it should be possible to remove bias in the wheels speeds caused by curve driving. However, seeing as there are almost always significant intervals of straight driving, it would be easier to just use these to measure (relatively) unbiased wheel speeds for pressure monitoring.

D14