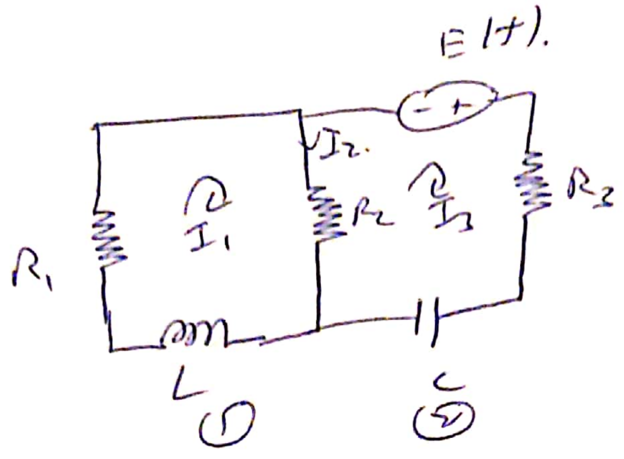
Final Exercise

1.) Given Circuit



a.)

Inputs of system :-

$E(t)$ ⇒ Voltage signal.

Constants of system :-

R_1, R_1, R_3 ⇒ Resistance

L ⇒ Inductance.

C ⇒ capacitance.

Variables of system :-

$E(t)$ ⇒ Input signal

$I_1(t)$ ⇒ current in loop1 and charge $q_1(t)$

$I_3(t)$ ⇒ current in loop2 and charge $q_3(t)$

$I_2(t) = I_1(t) - I_3(t)$

output of system :-

States of system. {

$q_3(t)$ ⇒ charge in capacitor

$I_1(t)$ ⇒ current in loop1.

b).

To derive equations,

Consider loop 1

by kirchoff's law

$$-I_1R_1 - I_2R_2 - L\frac{dI_1}{dt} = 0$$

$$I_1R_1 + I_2R_2 + L\frac{dI_1}{dt} = 0$$

$$L\frac{dI_1}{dt} = -I_1R_1 - I_2R_2.$$

$$\boxed{I_2 = I_1 - I_3}$$

$$L\frac{dI_1}{dt} = -I_1R_1 - (I_1 - I_3)R_2.$$

$$= -I_1R_1 - I_1R_2 + I_3R_2.$$

$$L\frac{dI_1}{dt} = -(R_1+R_2)I_1 + I_3R_2$$

Now $I_3 = \frac{dq_3}{dt}$ which is our state variable

So

$$L\frac{dI_1}{dt} = -(R_1+R_2)I_1 + \frac{dq_3}{dt}R_2.$$

Simply

$$\boxed{L\dot{I_1} = -(R_1+R_2)I_1 + \dot{q_3}R_2.} \quad -(1)$$

Now consider loop ②.

$$E(t) - I_3 R_3 - \frac{q_3}{C} + I_2 R_2 = 0$$

$$I_2 = I_1 - I_3$$

$$E(t) - I_3 R_3 - \frac{q_3}{C} + (I_1 - I_3) R_2 = 0$$

$$E(t) - I_3 R_3 - \frac{q_3}{C} + I_1 R_2 - I_3 R_2 = 0$$

$$E(t) - I_3 (R_2 + R_3) - \frac{q_3}{C} + I_1 R_2 = 0.$$

$$E(t) - \frac{q_3}{C} + I_1 R_2 = I_3 (R_2 + R_3)$$

Now $I_3 = \dot{q}_3 = \frac{dq_3}{dt}$

$$\dot{q}_3 = \left(\frac{R_2}{R_2 + R_3}\right) I_1 - \frac{1}{(R_2 + R_3)C} q_3 + \frac{1}{(R_2 + R_3)} E(t) \quad \text{--- ②}$$

Substitute ② in ①.

$$L\dot{I}_1 = -(R_1 + R_2) I_1 + R_2 \left[\frac{R_2}{R_2 + R_3} I_1 - \frac{1}{(R_2 + R_3)C} q_3 + \frac{1}{(R_2 + R_3)} E(t)\right]$$

$$L\dot{I}_1 = \underline{I_1\left(-R_1 - R_2 + \left(\frac{R_2^2}{R_2 + R_3}\right)\right)} - \frac{R_2}{(R_2 + R_3)C} q_3 + \frac{R_2}{R_2 + R_3} E(t)$$

$$\dot{I}_1 = \frac{\left(-R_1 - R_2 + \frac{R_2^2}{R_2 + R_3}\right)}{L} I_1 - \frac{R_2}{(R_2 + R_3)LC} q_3 + \frac{R_2}{(R_2 + R_3)L} E(t) \quad \text{--- ③}$$

Equations 2 and 3 represent the differential equations of system.

$$\dot{I}_1 = \left(\frac{-R_1 - R_2 + \frac{R_2^2}{R_2+R_3}}{L}\right) I_1 - \left(\frac{R_2}{(R_2+R_3)LC}\right) q_3 + \frac{R_2}{(R_2+R_3)L} E(t)$$

$$\dot{q}_3 = \left(\frac{R_2}{R_2+R_3}\right) I_1 - \left(\frac{1}{(R_2+R_3)C}\right) q_3 + \left(\frac{1}{R_2+R_3}\right) E(t)$$

1.c

Please refer Matlab code and plots

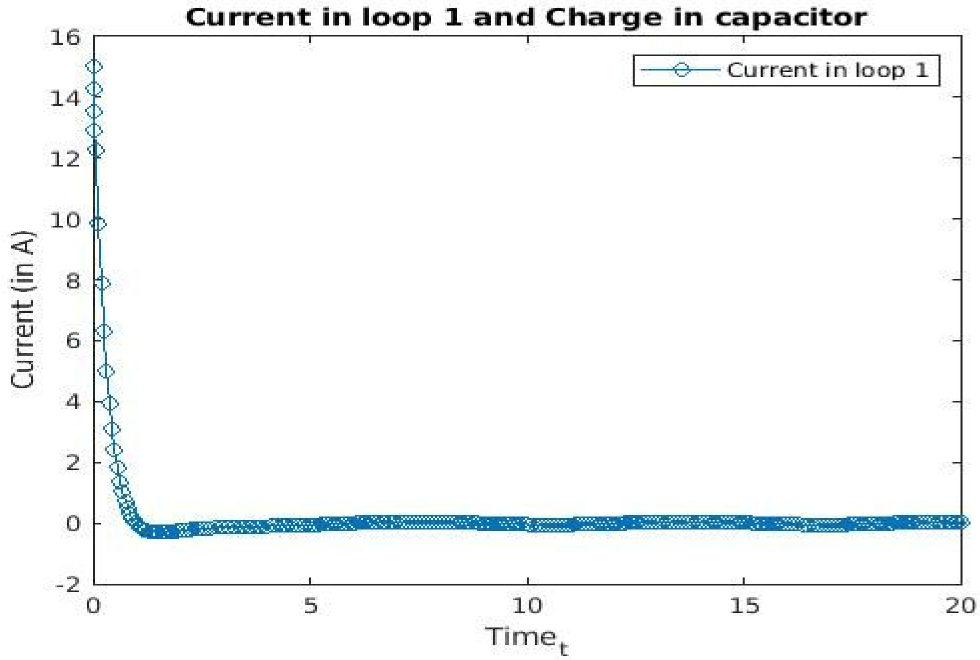
1.d

Please refer matlab code and plots

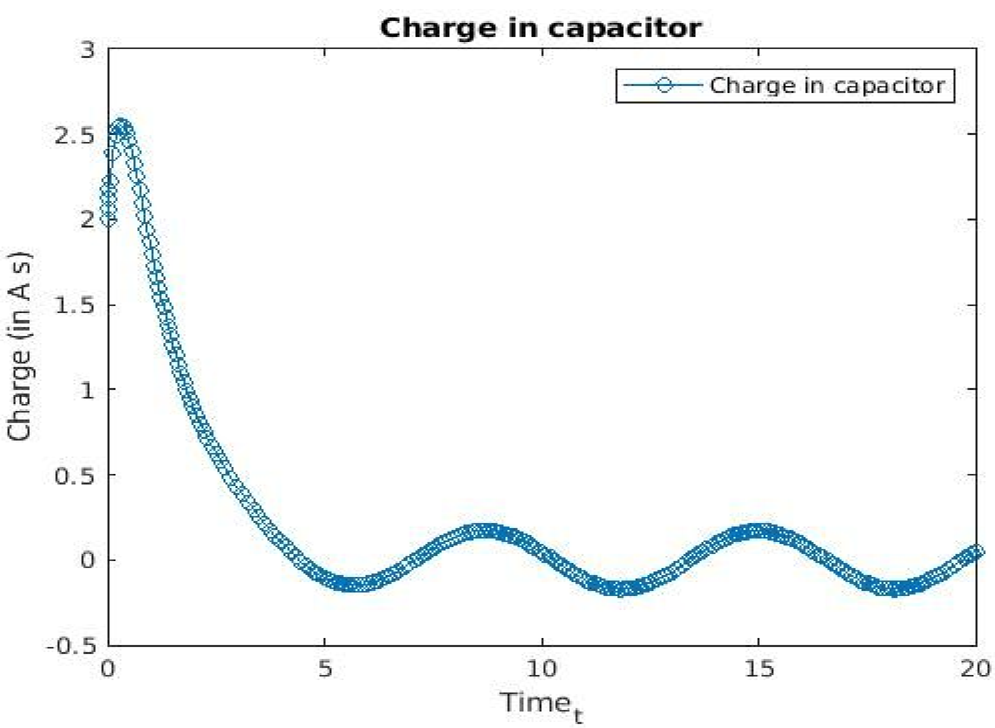
Solution 1:

1.c:

The plots of Current in first loop,



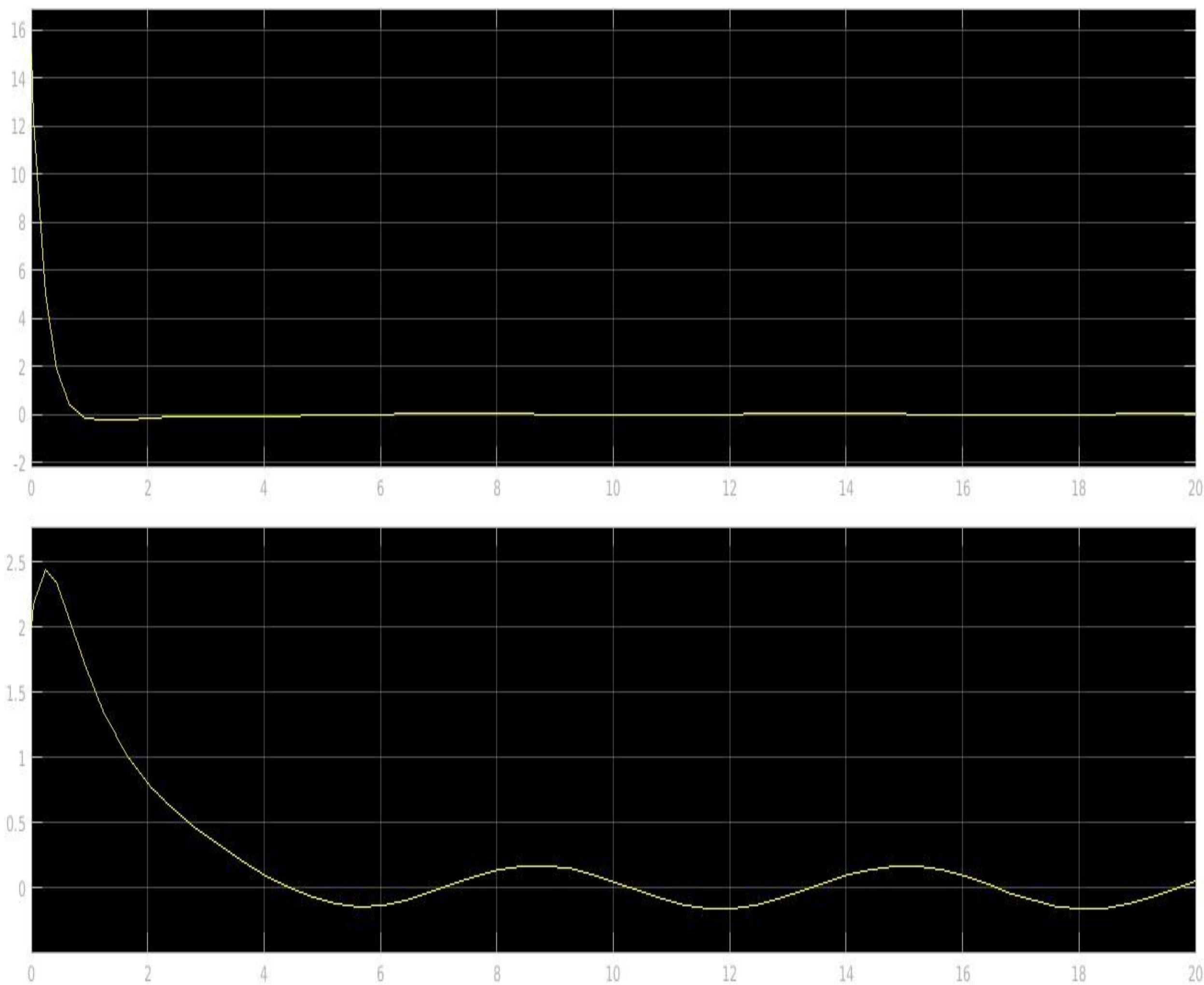
The plots of Charge in capacitor is :



1.d:

The plots from the simulink models are:

[Current in loop1
Charge in capacitor]



Solution 2:

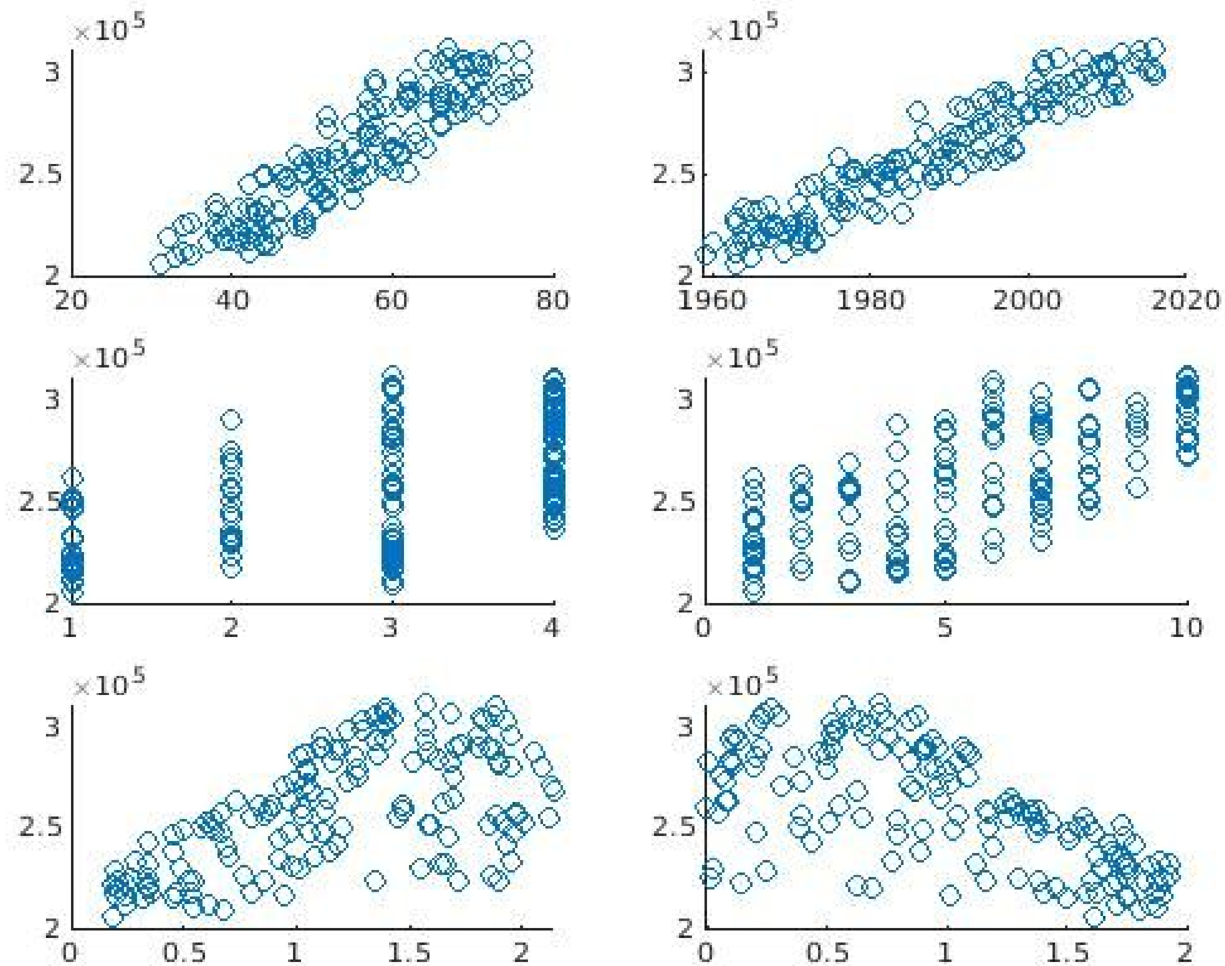
The given data in xlsx format was read and the data was separated with X and Y data. Also the dataset was separated into training and validation sets.

data_training_size   = uint8(0.75*data_m);
data_validation_size = data_m - data_training_size;

Where data_m is the total size of the data from the code(please refer code for this information).

When the input parameters was plotted with the output parameter “price” , it was observed that all the parameters are linearly related to the output. Please find the plot of all input parameters with output. The scatter plots in a single figure is shown the linear relationship

[“area vs price”   “year vs price”
“No_of_rooms vs price”   “Floor vs price”
“X_coordinates vs price”   “y_coordinates vs price”]



The data was split into two categories. 75% of data was used for estimation, 25% was used for validation.

```
[data_m data_n] = size(data);
data_training_size   = uint8(0.75*data_m);
data_validation_size = data_m - data_training_size;
data_training = zeros(data_training_size,data_n);
data_validation = zeros(data_validation_size , data_n);
i=1;
j=1;
k=1;
while i < data_m
        if i <= data_m
        data_training(k,:) = data(i,:);
        end
        if i+1 <= data_m
        data_training(k+1,:) = data(i+1,:);
        end
        if i+2 <= data_m
        data_training(k+2,:) = data(i+2,:);
        end
        if i+3 <= data_m
        data_validation(j,:) = data(i+3,:);
        end
        j=j+1;
        i=i+4;
        k=k+3;
end
```

The code shown above is used to separate the dataset into two categories.
Since there is a linear relationship between input parameters and output, closed form solution is used to obtain the model parameters.

```
theta = inv(transpose(X)*X)*transpose(X)*Y;
```

And output was computed using this “theta” parameter.

```
Y = X*theta;
```

The test cases were tested and calculated price for each test cases is updated in the table below:

Case	area	year	rooms	floor	x	y	price
1	45	1978	1	1	0.2	0.3	236384
2	56	2000	2	2	0.6	1.6	275016
3	72	2016	3	6	1.4	0.65	302684

Vaidation Procdures:

The validation dataset was separated from the estimation dataset and the validation parameters which includes SSE, R2 were computed for both datasets.
This code is used to compute the SSE for the estimation data

```
SE = (Y-Y_est).^2;
SSE= sum(SE);
```

Along with the R2 calculation for the estimation dataset

```
Ymean = mean(Y);
SST = sum((Y-Ymean).^2);
R2 = 1-(SSE/SST);
```

Similarly they were computed for validation dataset as well

```
Y_val_est = X_val*theta;
SE = (Y_val-Y_val_est).^2;
SSE= sum(SE);
Ymean = mean(Y_val);
SST = sum((Y_val-Ymean).^2);
R2 = 1-(SSE/SST);
```

The final validation results are :

THE SSE of training data is 8663658341.896820
THE R^2 of training data is 0.931770
THE SSE of validation data is 3252950041.731249
THE R^2 of validation data is 0.922257

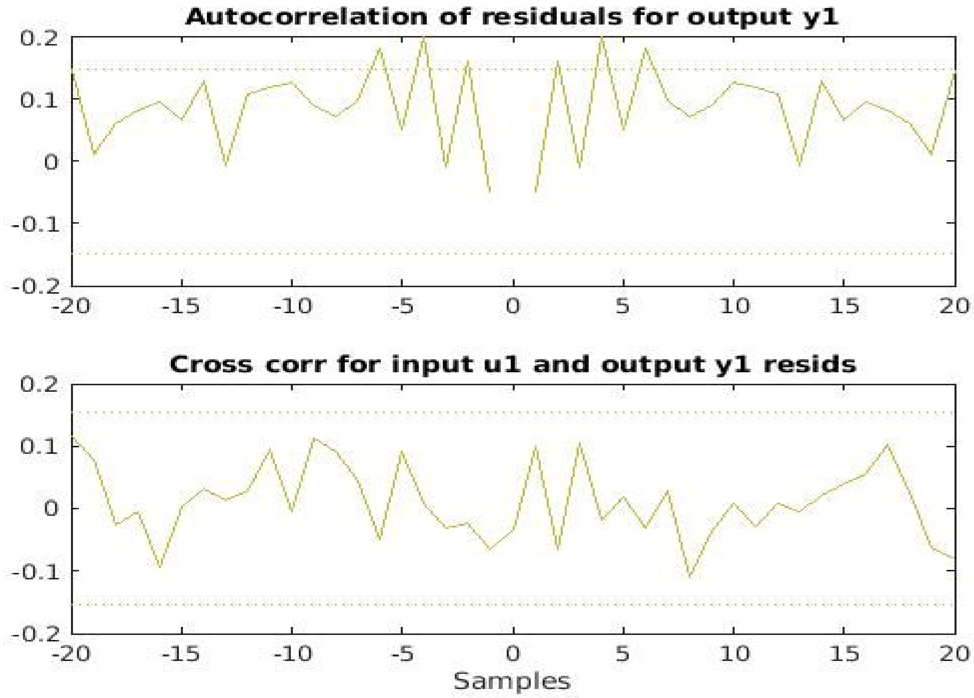
Note: The full code is available in “estimate_price.m” which is submitted in the form, as mentioned in the question paper. Please refer to the full code for computations.

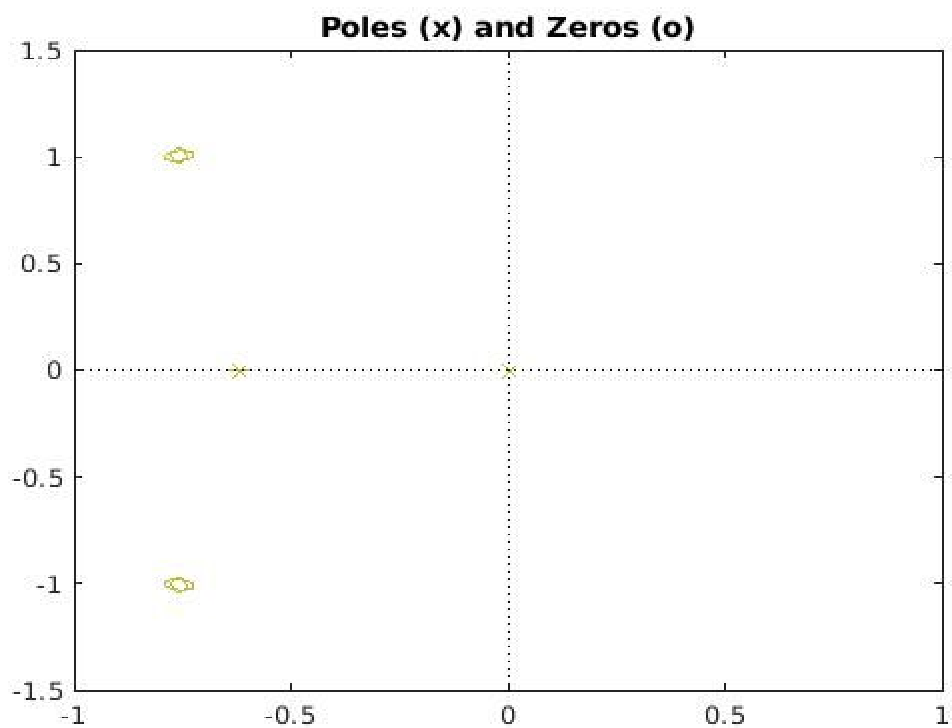
Solution 3:

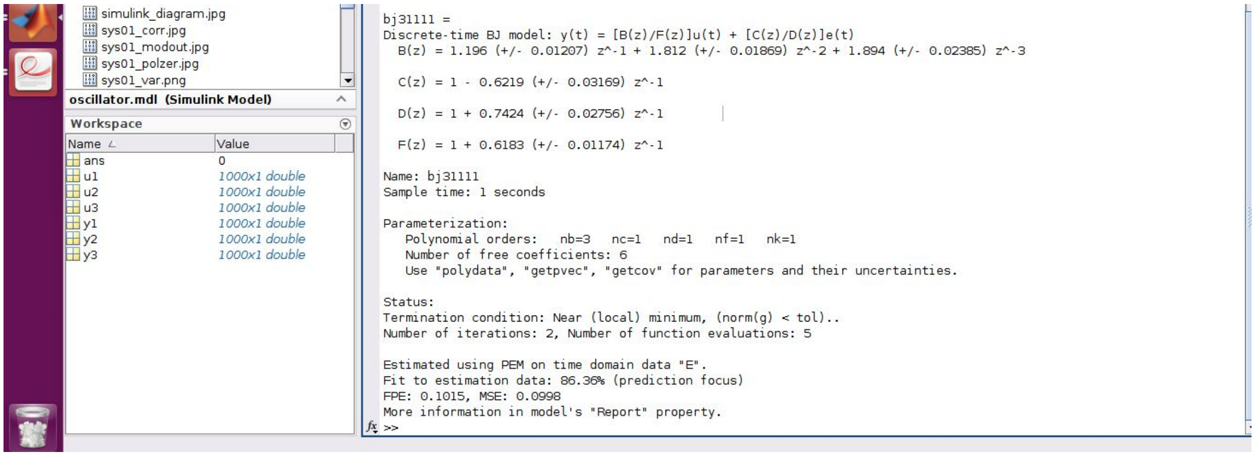
3.a :

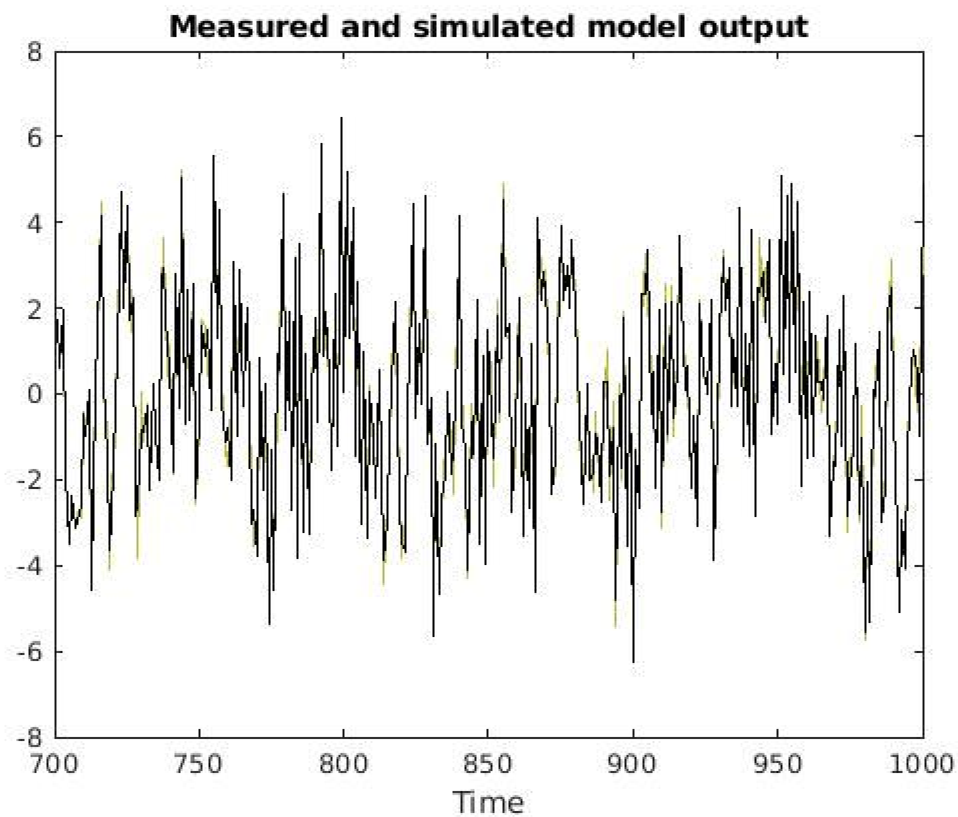
1. The selected model is **BJ31111.**

2. The system information which includes system identification screenshot, pole-zero plot, residual analysis, variance analysis and model output is shown below:


Autocorrelation of residuals for output y1
0.2
0.1
0
-0.1
-0.2
-20
-15
-10
-5
0
5
10
15
20
Cross corr for input u1 and output y1 resids
0.2
0.1
0
-0.1
-0.2
-20
-15
-10
-5
0
5
10
15
20
Samples


Poles (x) and Zeros (o)
1.5
1
0.5
0
-0.5
-1
-1.5
-1
-0.5
0
0.5
1

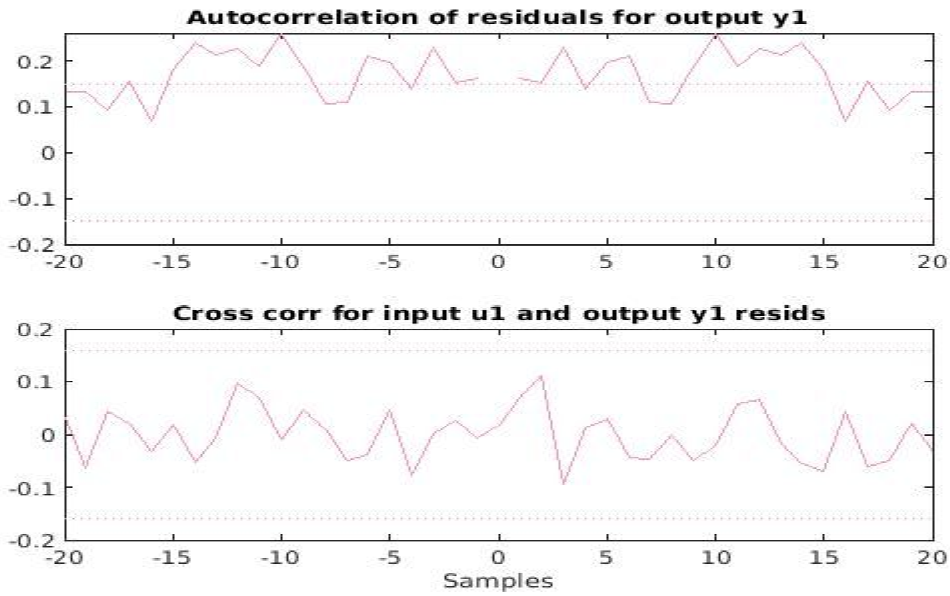


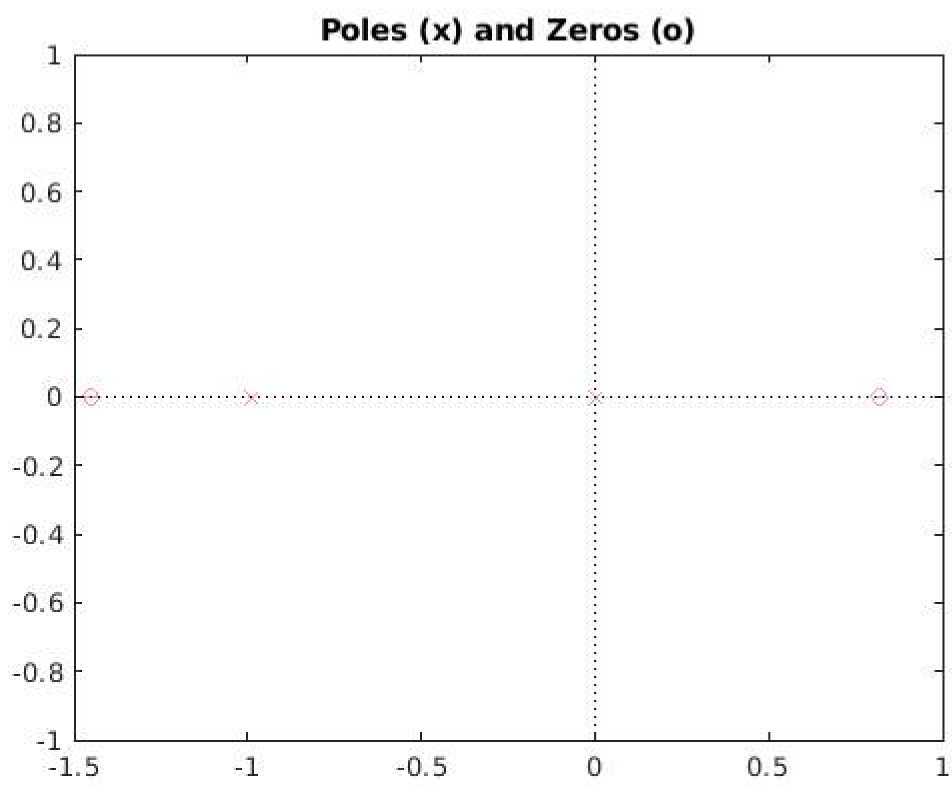


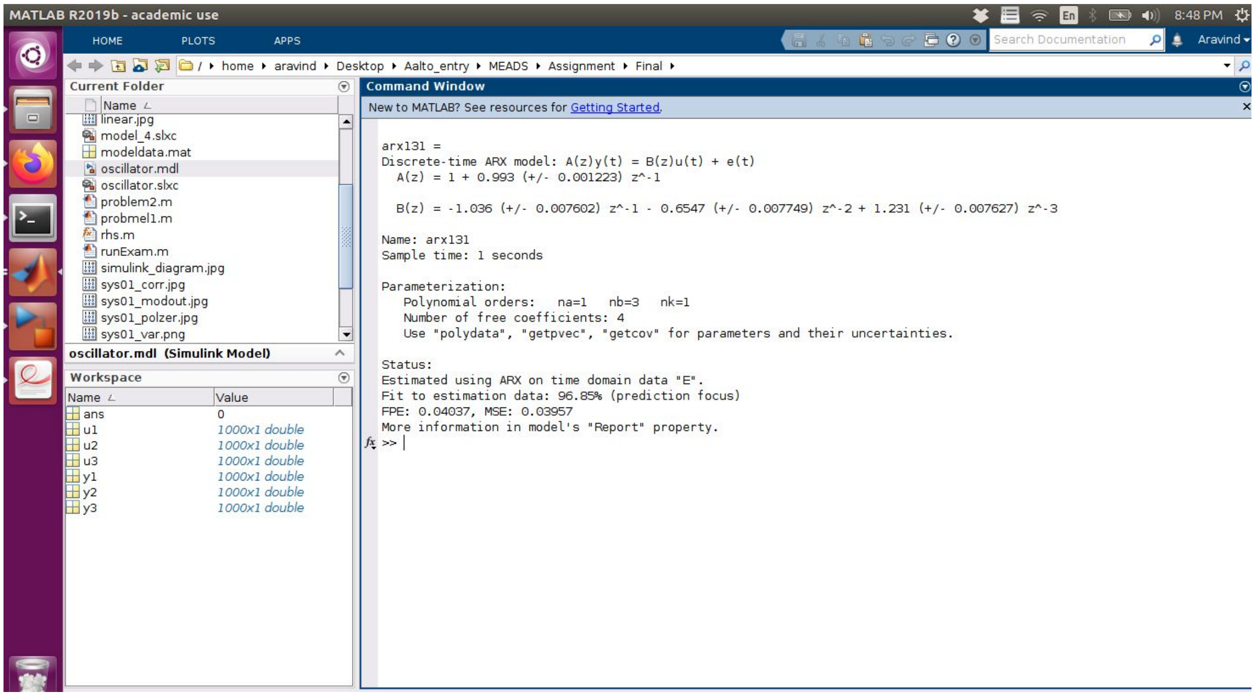
3. The alternative model of the system is ARMX 1311 as it was derived from BJ model assuing similarities in D and F.

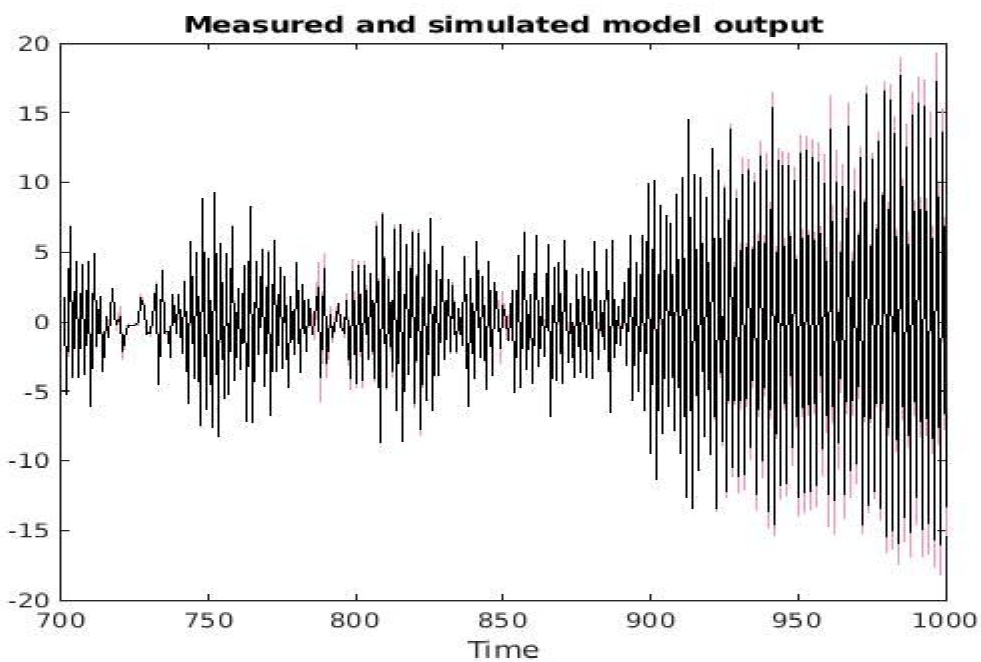
3.b

1. The system identified is **ARX 131**.
2. The system information which includes system identification screenshot, pole-zero plot, residual analysis, variance analysis and model output is shown below:


Autocorrelation of residuals for output y1
Cross corr for input u1 and output y1 resids
Samples


Poles (x) and Zeros (o)

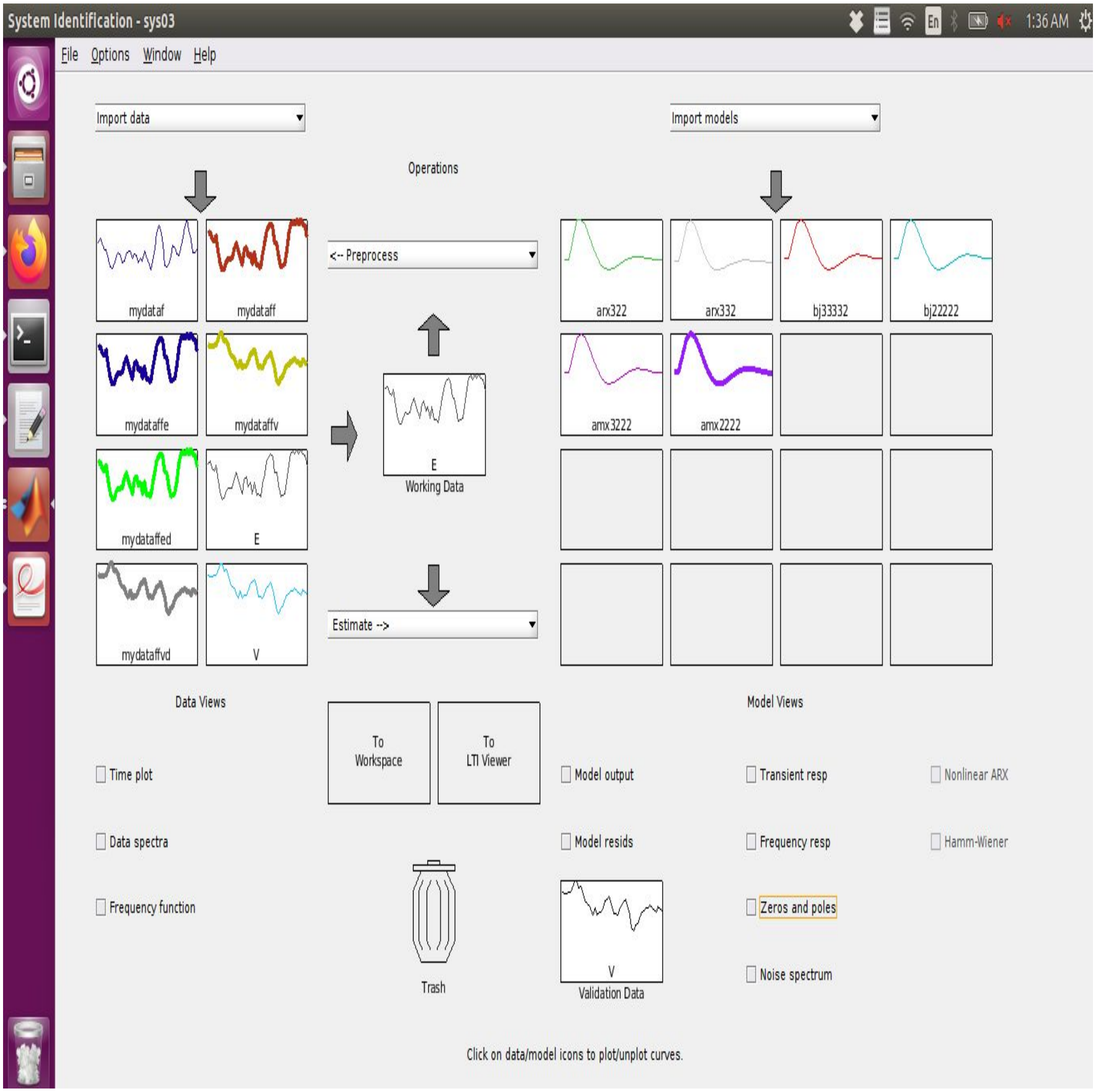


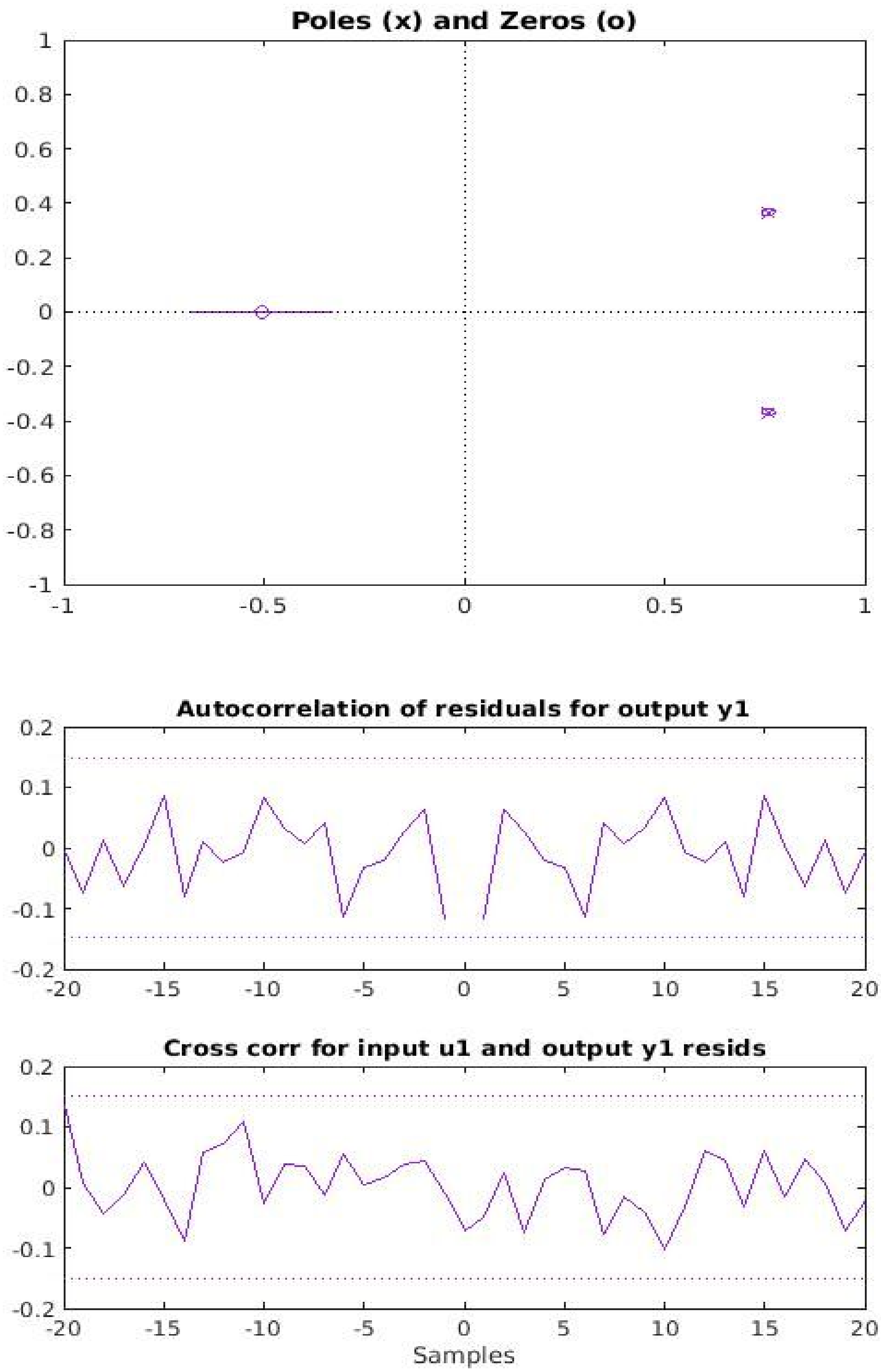


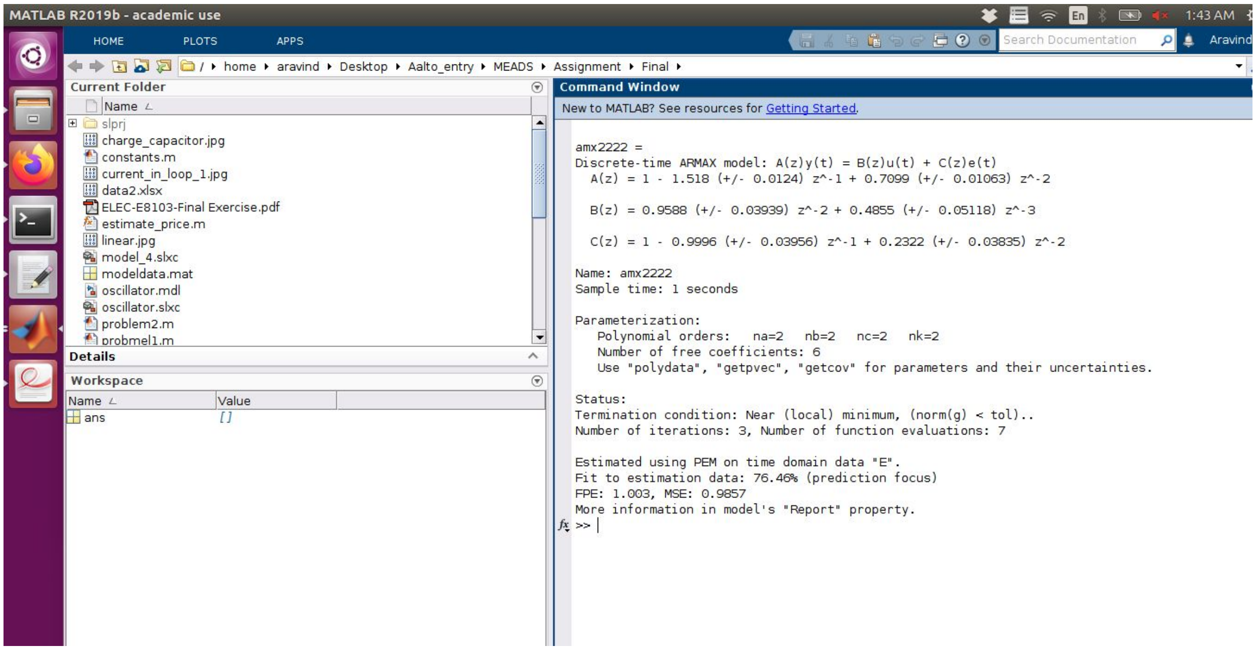
3. The alternative model for this system is BJ 31111. From which this model was reduced to from ARX model.

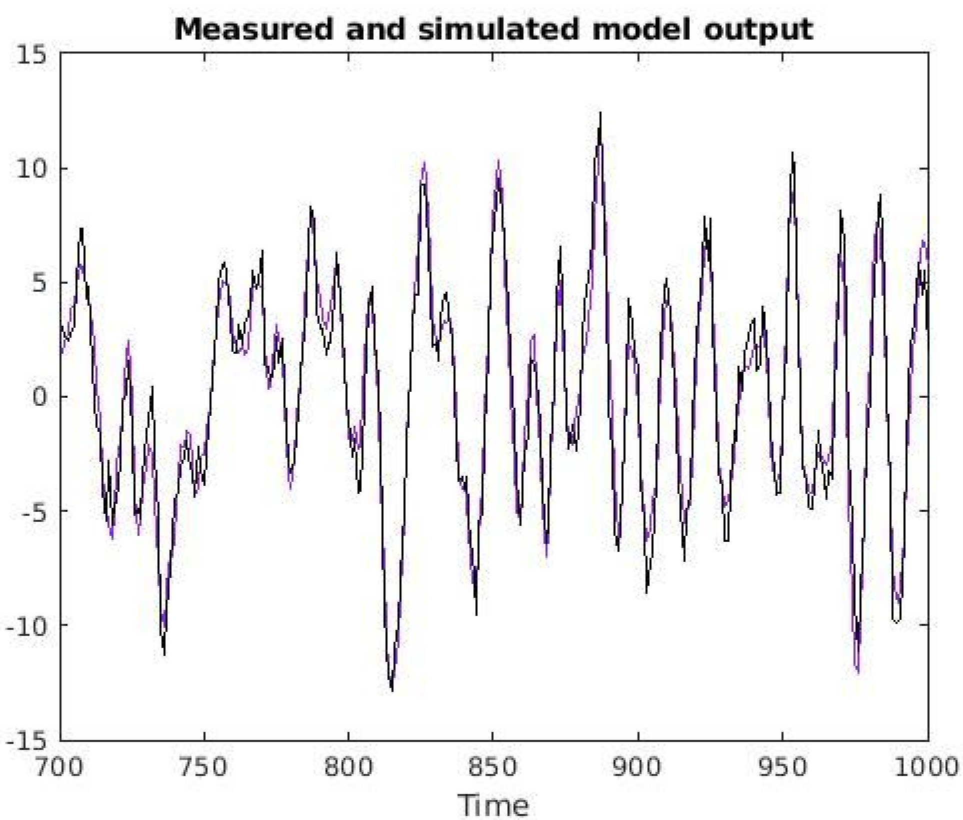
3.c:

1. The identified system is **ARMX2222**.
2. The system information which includes system identification screenshot, pole-zero plot, residual analysis, variance analysis and model output is shown below:




Poles (x) and Zeros (o)
Autocorrelation of residuals for output y1
Cross corr for input u1 and output y1 resids
Samples





3. The alternative model can be BJ2222 from which ARMX was derived. But the model might be complicated with more parameters.