Project #8 – Robust parameter identification – Hierarchical identification

Your task is to hierarchically identify a 4-parameter model of lung mechanics.
Though being a body compartment with complex physiological behavior, basic properties of a mechanically ventilated human lung can be represented by simple mathematical models. They usually use electrical analogues to simulate the human lung. Thus, resistors are used to represent lung resistance and capacitors are used to depict lung compliance. The least complex combination comprises one resistor and one capacitor. Fig. 1 shows the electrical analogue of the human lung during inspiration according to the first order model (FOM).

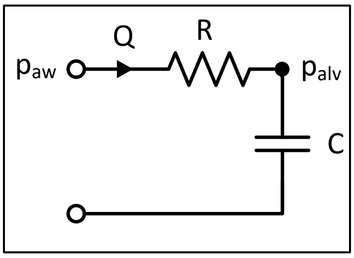


Fig. 1: Electrical analogue of the first order model (FOM). P_{aw} is the airway pressure, Q is the air flow in the lungs, P_{alv} is alveolar air pressure.

A more detailed model includes two resistances and two compliances. It is able to simulate the viscoelastic relaxation effects in the inspiratory hold phase. Fig. 2 shows the electrical analogue of the viscoelastic model (VEM) during inspiration.

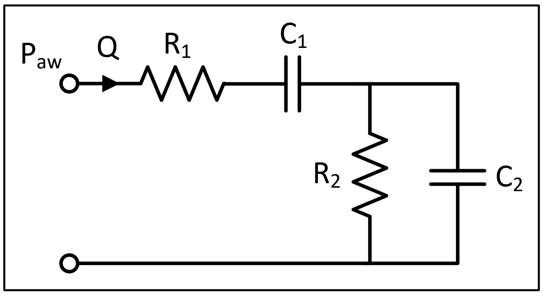


Fig. 2: Electrical analogue of the viscoelastic model (VEM). P_{aw} is the airway pressure, Q is the air flow in the lungs.

Even though the viscoelastic model comprises only four parameters that need to be identified, the robust identification of those parameters (i.e. the dependable identification of physiologically plausible values without knowing good initial guesses) is still problematic. One approach to solve that problem is to initially identify a simpler model with less parameters that is related to the VEM. The identified parameter values can then be used as good initial guesses when identifying the VEM. Schranz *et al.* have published such a method where the FOM is identified first and then the VEM using the result of the initial identification [1].

Task 1

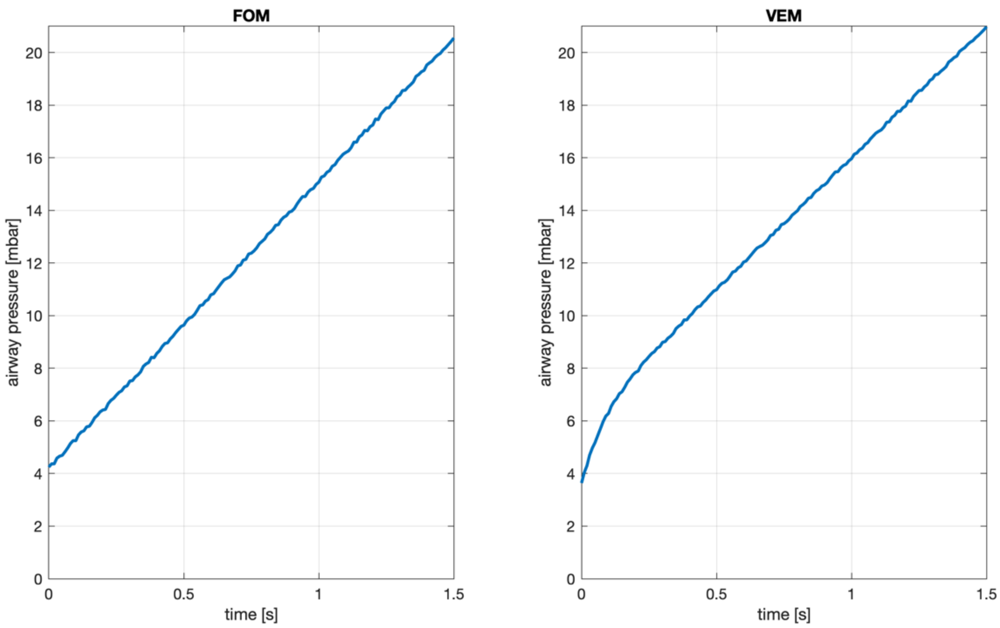
Both models are provided as function files. *FOM* represents the first order model, *VEM* represents the viscoelastic model. The signatures of those functions are:

```
[Paw] = FOM(t,Q,R,C)
[Paw] = VEM(t,Q,R1,R2,C1,C2)
```

Simulate both models with the following model parameters:

R = 0.007 [mbar*s/mL]
C = 55 [mL/mbar]
R_1 = 0.006 [mbar*s/mL]
R_2 = 0.004 [mbar*s/mL]
C_1 = 60 [mL/mbar]
C_2 = 20 [mL/mbar]

Load inputs t and Q from the file *Inputs_ task1.mat*.Your results should look like this:



Task 2

Write a function that identifies the FOM using matrix inversion. Your function should have three inputs for the measured signals: time t, air flow $\dot{V}$ and airway pressure p_{aw}. First, derive the volume V from the flow signal by integrating over time:

$$V_0 = 0$$
$$V_t = V_{t-1} + \Delta t \cdot \dot{V}_t$$

Then, use matrix inversion to calculate the parameters:

$$A \cdot \begin{bmatrix} C^* \\ D^* \end{bmatrix} = b \rightarrow \begin{bmatrix} C^* \\ D^* \end{bmatrix} = A \backslash b$$

$$A = [\vec{\dot{V}} \quad \vec{V}]$$

$$b = \overrightarrow{p_{aw}}$$

The two model parameters in the FOM are resistance R and compliance C. They can be derived from C^* and D^*:

$$R = C^*$$

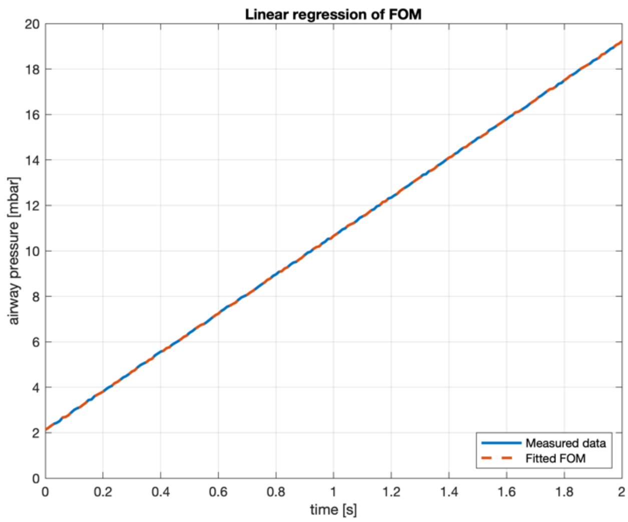
$$C = 1/D^*$$

Test your function with the signals in *Inputs_task2.mat*. Your results should be:

R = 0.004 [mbar*s/mL]

C = 62.0003 [mL/mbar]

Plot the measured airway pressure against the simulated airway pressure of the identified FOM. The result should be this:



Task 3

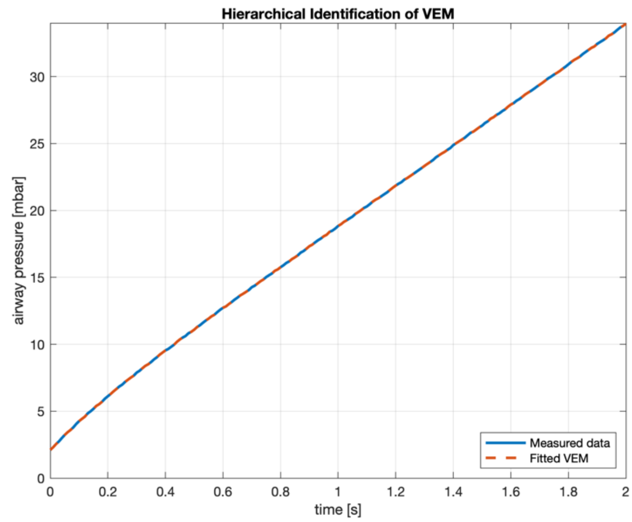
Write a function that identifies the VEM. In that function you should first identify the FOM using the function from task 2. Then, use the following rules to calculate good initial guesses for the identification of the VEM:

$$R_1 = 0.5 \cdot R$$
$$R_2 = R - R_1$$
$$C_2 = \frac{\tau}{R_2}$$
$$C_1 = (C^{-1} - C_2^{-1})^{-1}$$

Finally, fit the VEM using `fminsearch` (Remember: You first need an objective function, i.e. a function that calculates the Summed Squared Error between the measured p_{aw} and the simulated p_{aw} from the VEM). Test your function with the data in *Inputs_task3.mat*. Your results should be:

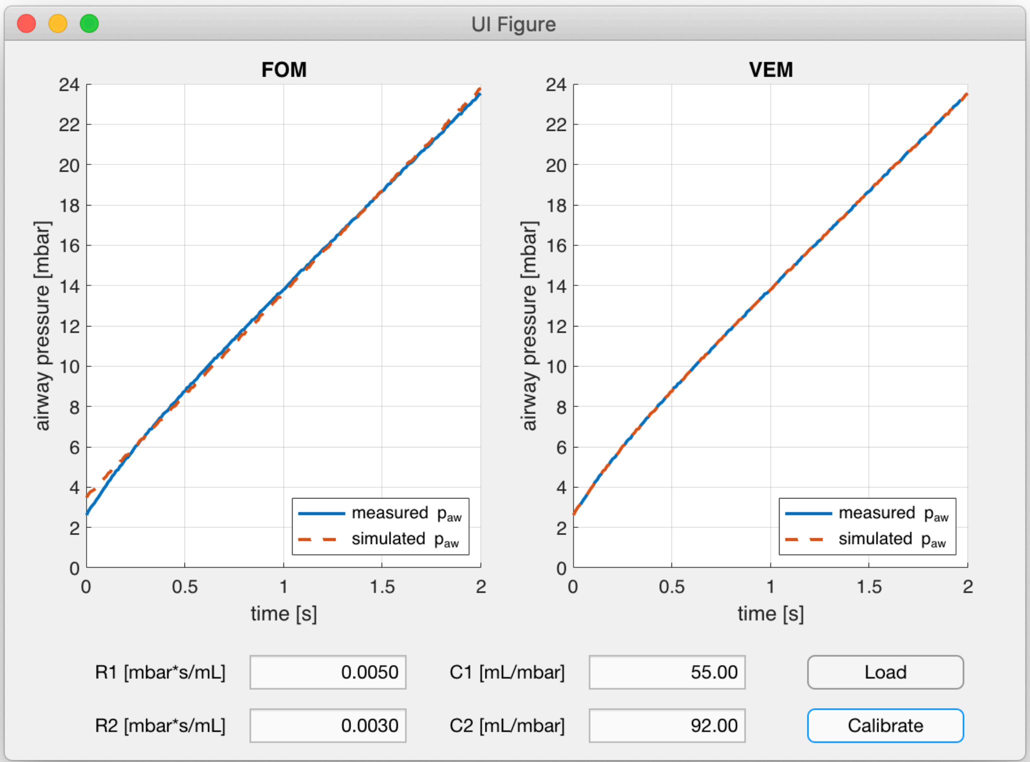
R_1 = 0.004 [mbar*s/mL]
R_2 = 0.003 [mbar*s/mL]
C_1 = 35 [mL/mbar]
C_2 = 69.9998 [mL/mbar]

Plot the measured airway pressure against the simulated airway pressure of the identified VEM. The result should be this:



Task 4

Create a GUI where the user can load data and fit the VEM hierarchically. The GUI should show the resulting VEM parameters along with two graphs showing the fit results of the FOM and the VEM. Test your GUI with the provided patient files. Check the files first in MATLAB to see how they are constructed. *GUI_ example* contains the GUI below, which you can use to test. Just call it from the MATLAB command window.



To open a file with a file dialog, use:

```
[fileName,pathName] = uigetfile('.mat','Select Patient file');
filePath = fullfile(pathName,fileName);
load(filePath);
```

Try to avoid errors that can be made by the user (start simulation before importing patient file, entering wrong numbers,...) by e.g. disabling buttons or checking entered values.

[1] Schranz C, Knöbel C, Kretschmer J, Zhao Z, Möller K (2011) Hierarchical parameter identification in models of respiratory mechanics. IEEE Trans Biomed Eng 58:3234-3241