Project #1 – Identifying the Riley model of human gas exchange

Your task is to identify a model of human gas exchange and to present the results in a GUI. The gas exchange model that is used is a simple mathematical model to predict reactions in gas exchanges to changes in minute volume (MV) and inspired oxygen (FiO_2) [1]. It describes lung gas exchange as a system of three compartments with different distributions of blood and air:

- The dead space compartment, which receives a fraction of the inspired air, but is not perfused, i.e. it defines the part of the inspired air that does not participate in gas exchange.
- The shunt compartment, which receives a fraction of blood, but is not ventilated, i.e. it defines the part of venous blood that is not oxygenated.
- The lung compartment, which is both ventilated and perfused, i.e. it defines the parts of inspired air and venous blood that participate in gas exchange.

Figure 1 shows a schematic overview of Riley's model. Here, P is partial pressure, C is gas concentration, $\dot{V}$ is air flow, Q is cardiac output, fs denotes shunt fraction, fA denotes size of dead space. Indices are I – Inspiratory, A – Alveolar, v – venous, e – end-capillary, v – venous, a – arterial.

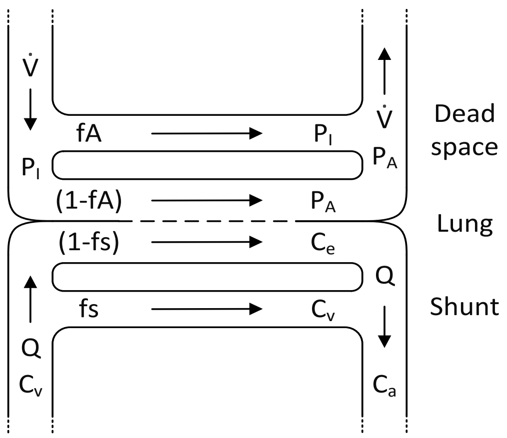

Fig. 1: Schematic overview of Riley's model

The model is provided in the function `Rileymodel` which has the following signature:

```
[PaO2, PaCO2] = Rileymodel(dVCO2,MV,RQ,fA,fs,FiO2,Q,Temp,pH,Hb)
```

Inputs are:

$dVCO_2$ – metabolic carbon dioxide production [l/min]
MV – minute ventilation [l/min]
RQ – respiratory quotient [%/100]
fA – fraction of dead space [%/100]

- *fs* – fraction of shunted blood [%/100]
- FiO_2 – oxygen supply [%/100]
- *Q* – cardiac output [l/min]
- *Temp* – body temperature [°C]
- *pH* – blood pH [-]
- *Hb* – heamoglobin concentration [g/l]

Outputs are:

- PaO_2 – arterial partial pressure of oxygen
- $PaCO_2$ – arterial partial pressure carbon dioxide

Task 1

Run the model with the following inputs:

Parameter	Value
$dVCO_2$	0.24
MV	6
RQ	0.8
FiO_2	0.5
fA	0.4

Parameter	Value
fs	0.1
Q	5.5
T	37
pH	7.35
Hb	145

Your result should be $PaO_2 \approx 151.96$ mmHg, $PaCO_2 \approx 48.42$ mmHg.

Task 2

Run parameter identification to identify the values of *fA* and *fs* that are necessary to reproduce previously recorded PaO_2 and $PACO_2$.
Use the following objective function to calculate the SSE:

$$W_{O2,CO2} = \sum \sqrt{\left(PaO_{2,recorded} - PaO_{2,simulated}\right)^2} + 2 \cdot \sqrt{\left(PaCO_{2,recorded} - PaCO_{2,simulated}\right)^2}$$

Use the following data:

Parameter	Value
$dVCO_2$	0.24
MV	6
RQ	0.75
FiO_2	0.5
Q	6.2

Parameter	Value
Recorded PaO_2	100
Recorded $PaCO_2$	46
T	37.5
pH	7.35
Hb	145

Your result should be $fs \approx 0.18$, $fA \approx 0.36$.

Task 3

Create a GUI that allows the user to import patient data and to calibrate the model (i.e. calculate *fs* and *fA*) and to predict PaO_2 and $PaCO_2$ using user inputs from the GUI. Your GUI should also include a graph to display recorded PaO_2, $PaCO_2$ versus PaO_2, $PaCO_2$ of the calibrated model and a graph to display predicted PaO_2 and $PaCO_2$. Figures 2 and 3 show an example of such a GUI comprising text fields to display the imported patient data, the calibration results and the predicted PaO_2 and $PaCO_2$ as well as buttons to load, calibrate and predict. *GUI_example* contains the below GUI, which you can use to test. Just call it from the MATLAB command window.

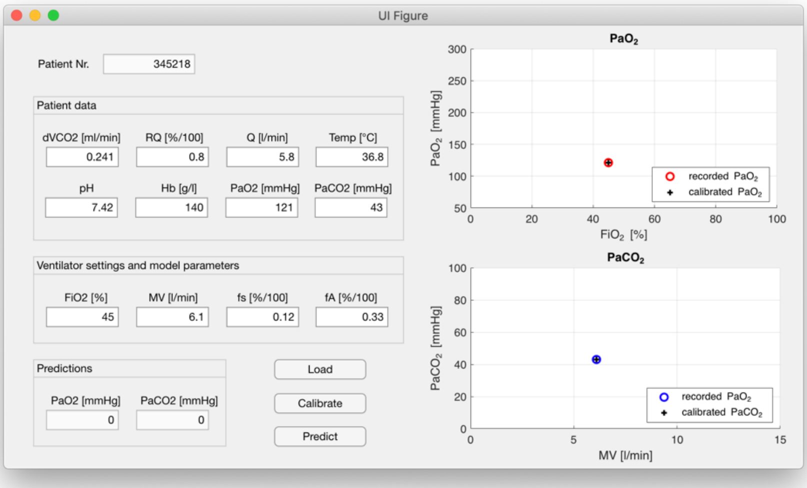

Fig. 2: GUI with calibration results

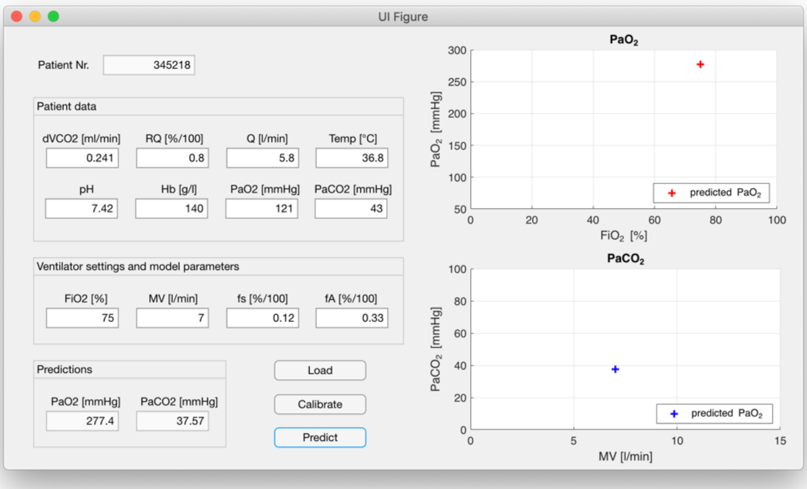

Fig. 3: GUI prediction results

Test your GUI with the provided data files (**pay attention to the units that are used in the data files and convert them where necessary**). You can use the following code example that allows you to use GUI based file selection for the patient data import.

```
[fileName,pathName] = uigetfile('.xlsx','Select Patient file');
filePath = fullfile(pathName,fileName);
Data = xlsread(filePath,...
```

Try to avoid errors that can be made by the user (start calibration before importing patient data, predict PaO_2 and $PaCO_2$ before model calibration ...) by e.g. disabling buttons during computation or checking entered values.

[1] R. L. Riley, "Development of the three-compartment model for dealing with uneven distribution," in *Pulmonary Gas Exchange*. vol. 1, J. B. West, Ed., New York: Academic Press, 1980.