My ICU Twin - A patient specific Cardio/Respiratory model based on ODEs

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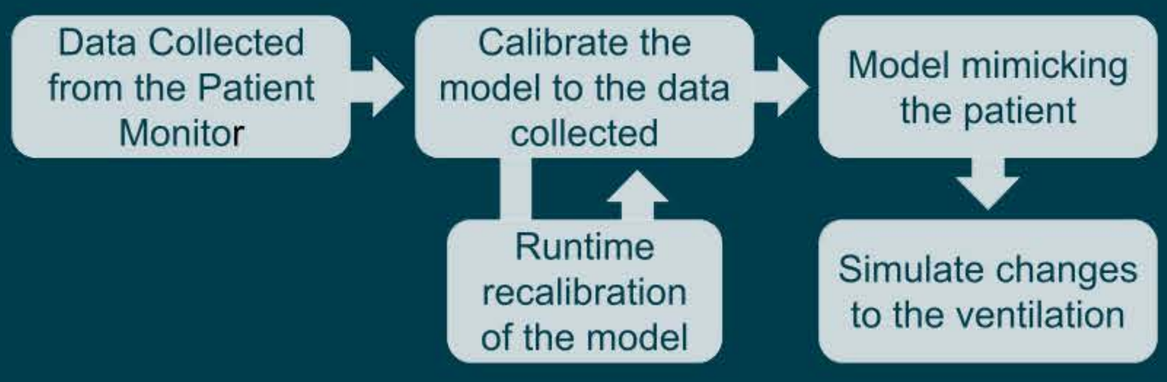
Context

- Patients in the ICU are inherently unstable and need constant attention from the healthcare providers (HP).
  - Condition examples: COVID, ARDS, Sepsis
- Managing these patients usually involves the optimisation of ventilatory and cardiovascular parameters
- It's not always obvious which parameters to adjust and for what value.
- Testing the effects of these changes is often difficult
- It is therefore important to develop new methodologies that would allow HP to test the effects of new therapies in a safe, quick and reliable way before they are applied to the patient.

Objectives

- Develop a software that can be used at the bedside capable of being calibrated to the patient and where new treatments can be simulated prior to being applied.
- The software will ingest the data being generated on the bedside monitors in real time and will:
  - Calibrate the model to the live data
  - Recalibrate during runtime
  - Estimate in real time parameters that can only be accessed using blood tests (PAO2, PCO2, pH)
- At any point, the model can be isolated from the live data and simulate the reaction of the model to changes

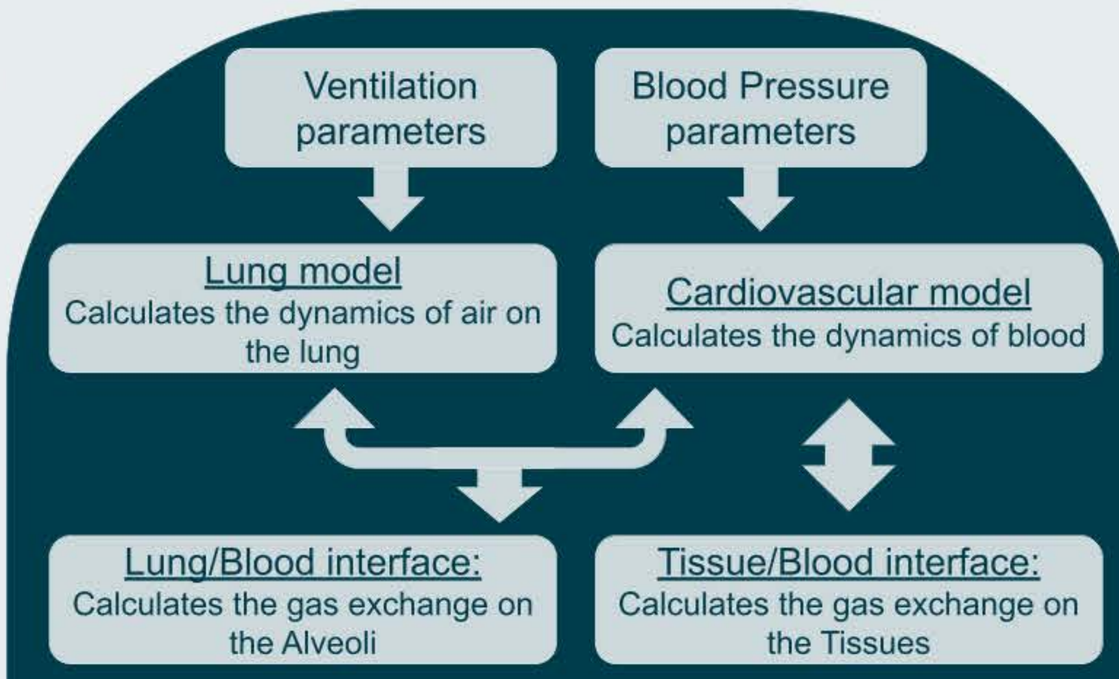


Methods

The model is based on ODEs and is composed of 4 modules:

- Lung model calculates the gas dynamics
- ★ Cardiovascular model calculates the blood dynamics
- ★ Lung/Blood interface performs the gas exchange on the alveoli
- ★ Tissue/Blood interface performs the gas exchange on the tissues

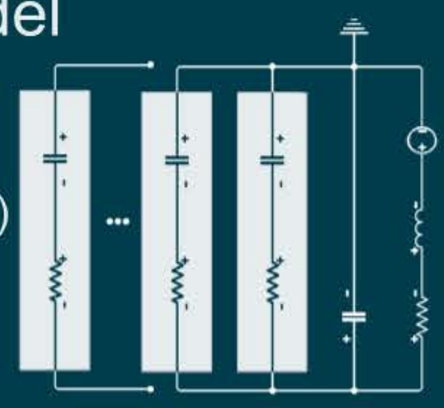
*Modules with ★ are still in development



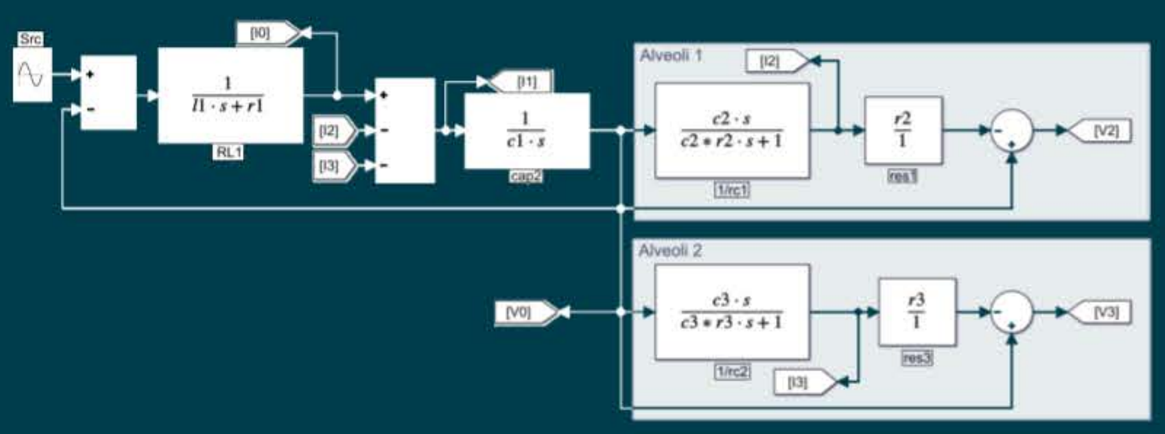
Lung model

The lung model is an electrical circuit composed of:

- Power source (Ventilatory curve)
- RLC section representing the trachea
- 100 RC sections representing the alveoli



The model yields the pressures, flows and volumes on each section of the lung



Future work and Main challenges

- Cardiovascular module
- Model mechanisms to stimulate the sympathetic nervous systems ability to keep homeostasis
- The Genetic algorithm will be the biggest challenge to overcome in this project. This is because the evolution process is very computationally expensive and often requires the use of a cluster. To overcome this we are considering:
  - Building a continuously growing database of patient adjusted models to use for the first stages of the evolution
  - Decoupling the bedside tool from the evolution process, delegating this task to a external cluster. This will also help on the scalability of the tool as one cluster could serve an entire hospital
    - Use a island model genetic algorithm that can maintain genetic diversity on the populations

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References: