Postdoctoral position - 12 to 24 months

Project AirPad: Airways monitoring and Patient/ventilator Dyssynchronies

L2S – Laboratoire des signaux et systèmes
Université Paris-Saclay – CentraleSupélec - CNRS

Context

This post-doctorate aims to develop new control techniques, applied to invasive artificial ventilation, as part of a proof-of-concept project funded by Satt Paris-Saclay and related to a pending patent application. The aim is to partially automate the settings of the PSV (pressure support ventilation) mode. Although this mode also exists in non-invasive ventilation, the project is primarily focused on intensive care patients, for whom the development of this technology is more affordable due to the relative tightness of the airways circuit ensured by intubation.

The problem addressed is the automatic tuning of the expiratory trigger parameter. This parameter determines the instant at which the ventilator's exhalation phase is triggered; it enables the synchrony between the end of the patient's effort and the end of insufflation (triggered by the ventilator control) to be adjusted. Today, the expiratory trigger is manually adjusted by the clinician. To be optimal, this adjustment requires considerable expertise and regular reassessment (difficult to reconcile with clinical activity). This manual adjustment of the cycling setpoint leads to the frequent occurrence of patient-ventilator asynchronies, such as prolonged insufflations and ineffective efforts. The automatic adjustment of cycling and improved synchrony provided by our technology therefore have a dual benefit: facilitating the clinician's work, by saving time, while reducing the risk of setting errors and their deleterious effects on the patient.

Our automatic tuning algorithm is based on the study of the system's limit cycles. From a mathematical point of view, to determine the limit cycles corresponding to a certain ventilator setting, one can compute the Poincaré first-return map of the system. However, such an approach is unrealistic in terms of computation time, since for each setting it would be necessary to calculate the first-return map, find its equilibrium point, determine the corresponding limit cycle, evaluate the synchrony of this limit cycle and search for the optimum tuning out of all possible values of the expiratory trigger. We have therefore developed a strategy in which the Poincaré map is replaced by a synchronization map, whose fixed points are calculated to determine the optimal setting. With our technology, the hours-long computation time associated to Poincaré's approach is reduced to fractions of a second.

To be exploited clinically, our technology must be tested on the L2S laboratory's ventilation test bench and in the form of a mobile app usable by clinicians in the context of a clinical trial. Robust estimation of the expiratory time constant (ETC) is another open problem to be solved. These two themes will be the main lines of research addressed during this post-doctorate.

Objectives

One of the objectives of this postdoctoral position is to improve the technological readiness level (TRL) of our work, to make it usable in a clinical context. To achieve this, several topics need to be addressed.

On the one hand, we will study the patient-ventilator synchronization algorithms on an experimental setup. A first aspect to consider will be the improvement of flow regulation in the valves of our prototype ventilator, to achieve a similar performance to that of commercial ventilators. This work will be based mainly on non-linear control techniques. We will also consider adapting the synchronization algorithm to run on the prototype ventilator's embedded architecture. An implementation on a mobile device (cell phone) is also envisaged, as part of a preparatory stage for a clinical trial. This part of the post-doctoral project requires good programming skills.

On the other hand, we will study the problem of estimating the parameters associated with the patient's respiratory mechanics (airway resistance and elastance). Solving this open problem has several clinical applications: assessing the muscular effort developed by the patient and estimating the time constant (ETC) associated with the dynamics of his/her airways. This work will exploit estimation techniques derived from automatic control and signal processing.

The post-doctorate objectives include the following:

- Improving the flow regulation of the prototype ventilator (non-linear control).
- Adaptation of the patient-ventilator synchronization algorithm to an embedded architecture.
- Development of this algorithm on a mobile device (cell phone or tablet).
- Development of new techniques for estimating the expiratory time constant (ETC).
- Publication of articles in international peer-reviewed journals.

Available resources:

- Matlab/Simulink software and associated toolboxes.
- MakAir OpenSource toolchain (on STM32).
- L2S artificial ventilation experimental setup.

Profile / Professional and personal skills

- Thesis in control theory, biomedical engineering or applied mathematics.
- Proficiency in Matlab/Simulink programming.
- First programming experience in C/C++ (Arduino) would be appreciated.
- Experience in biomedical research would also be an asset.
- Fluency in English (required for understanding scientific literature).

Additional information

- **Geographical location**: L2S, in Paris-Saclay's University, located at Gif-sur-Yvette France.
- Occasional travels to AP-HP (Paris region, France).
- **Remuneration**: According to profile and experience (CNRS scale).
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