Efficient algorithm for pulmonary nonlinear model online estimation of patients under assisted ventilation

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Abstract: An efficient algorithm to estimate a respiratory system nonlinear model of sedated patients under assisted ventilation is presented. The considered model comprises an airways resistance and a volume-dependant compliance and, for each respiratory cycle, the proposed algorithm provides online the model parameters guaranteeing a minimum accuracy, above a user-defined threshold. Relying on standard nonlinear identification techniques, it exhibits computational burden reduction features, which contribute to its suitability for its online application.

Key-Words: Nonlinear Identification, Mechanical Ventilation, Nonlinear Respiratory Modelling.

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1 Introduction

Continuous respiratory monitoring is an important tool for clinical supervision in the case of patients under assisted ventilation, specially in the case when there is a pathology involving the lungs, airways or some other part of the respiratory system. It is based on a model of the respiratory system and it relies on measuring some biological signals of the patient.

Respiratory system models are an important tool to simulate and assess effects which are hard to evaluate *in vivo*, to contribute to functional diagnosis and, particularly, to determine the best treatment for patients in intensive care, attaining weaning more quickly and safely [1] [2] [3] [4] [5]. The most widespread model of the respiratory system among clinicians is a single compartment lung model which comprises two lumped parameters: resistance and compliance [6]. The first one considers the effect of resistance to pass of the air flow, and the second one takes into account the elastic properties of the tissues and chest wall. Usually, their values are computed considering specific points of the pressure and airflow signals, measured by the respiratory machine at the patient's mouth, P_B and F, respectively [7].

Model-based methods may help clinicians with decisions regarding the most appropriate ventilation strategy to improve the patient's situation and/or to avoid or reduce potential posterior negative effects of mechanical ventilation (MV) [8] [9]. They include finding a lung protective compromise either while a respiratory pathology or while under general anaesthesia [10] [11] [12], detection of asynchronies between the patient and the mechanical ventilation (MV) [13] [14], or ensuring patient safety regarding high *plateau* pressure values [15]. These models have the potential to enable predictive, personalised, and potentially automated approaches to MV. However, most of the models used in these works are linear, since low computational cost is an important factor to obtain useful information of the patient in real time.

In this work, an algorithm and its user interface are developed, with the objective of providing online the quadratic nonlinear model of the patient's respiratory system with a preset accuracy. The algorithm routines resort to standard nonlinear identification techniques to estimate the model parameters of the patient, using the pressure and flow signals measured at their mouth.

To better deal with online time requirements, a fit check process is run to avoid a new full model estimation at every respiratory cycle. Using the input pressure signal of the current respiratory cycle and the last estimated model, the process computes its output's fit to the real data and compares it to a specified threshold. If the fit is greater than the threshold, a new estimation of the model is omitted, considering that the last one truly represents the patient, i.e. the previous model is kept as valid. The fit check is the mechanism that aims at decreasing the amount of models estimates of the patient, consequently reducing the computational time and burden with respect to the case of continuous estimation. The threshold that defines the minimum acceptable fit can be adjusted online by the clinician, depending on the accuracy required for each particular patient, condition or case under study.

Some results are presented, obtained when using

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Conflicts of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.