# Repetitive control to improve pressure tracking performance in mechanical ventilation of sedated patients

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## Mechanical ventilation

Mechanical ventilation is used in Intensive Care Units (ICUs) to save lives of patients unable to breathe on their own. Mechanical ventilation supports patients by ensuring adequate oxygenation and carbon dioxide elimination. Mechanical ventilators attached to the patient, as depicted schematically in Figure 1, are used to ensure airflow in and out of the lungs. For a fully sedated patient this is achieved by generating a pressure profile as shown in Figure 2. This results in the desired flow of air in and out of the lungs.

## Control problem

This paper considers Pressure Controlled Mandatory Ventilation (PCMV) of fully sedated patients. The goal in PCMV is to track a given airway pressure reference repeatedly. This reference is exactly periodic with a known period length which is preset by the clinician. Besides this reference pressure, no patient breathing effort is considered.

Controller design for mechanical ventilation is challenging because of the large plant variations. One control system should accurately track the desired target pressure for a large variety of patients (ranging from neonates to adults), hoses, and filters. Therefore, the aim is to exploit the repetitive nature of the target signal to achieve accurate performance for this variety of plants. This is achieved in the following section by using Repetitive Control (RC) [1].

## Repetitive controller design

Next, a single repetitive controller that achieves accurate pressure tracking for a wide variety of patients is designed. A detailed explanation of this design process can be found in [2] and [3]. To design the RC filters, a Frequency Response Function (FRF) of the complementary sensitivity is identified for different patients. The mean of these FRFs is used to design the learning filter. Next, a robustness filter is designed such that the SISO RC stability criterion is guaranteed for every individual patient. In the next section, the improvement in performance compared to traditional PID control is shown by means of an experimental case study.

## Experimental results

In Figure 2, the results of an experimental case study are shown. In this case study an adult patient with a typical target pressure is considered. The patient is emulated using a mechanical lung simulator and the Demcon Macawi ventilation module is used. Figure 2 clearly shows that the rise-time of the PID controller is rather slow and it shows significant overshoot. The converged repetitive controller shows almost perfect tracking. In terms of the error 2-norm, the tracking error is reduced by a factor 10. Other patient types show similar results.

Concluding, it is shown that repetitive control can significantly improve pressure tracking performance in ventilation of fully sedated patients.

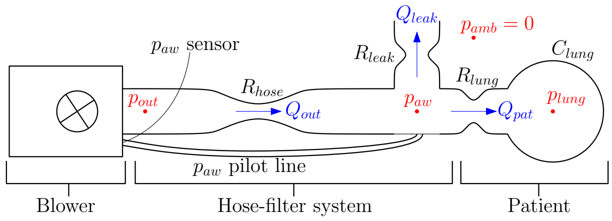


**Figure 1:** Schematic representation of the blower-hose-patient system, with the corresponding resistances, lung compliance, pressures, and flows.

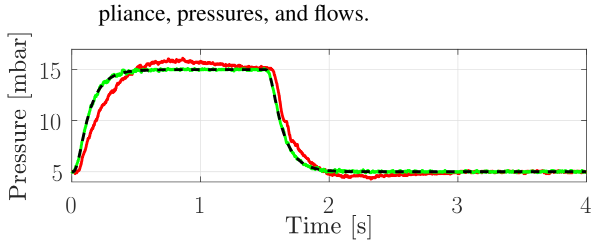


**Figure 2:** Results of an experimental case study, showing the target pressure (- - -), the airway pressure with a PID controller (—), and the airway pressure with the converged RC controller (—).

## References

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