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ADVANCES IN DRUG DOSING PREDICTIVE CONTROL DURING ANESTHESIA

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Abstract

Since manual methods to deliver drugs during anesthesia require significant effort from the clinical standpoint, not guaranteeing an optimal performance, various drug delivery control methods have been proposed and tested. Performance in control strategies has been improved from PID to advanced techniques like predictive and adaptive control approaches. The latest results refer to an in-house adaptive MPC (Model Predictive Control) controller, based on a nonlinear patient model, using Propofol infusion and Bispectral Index (BIS) as manipulated and controlled variables, respectively. A set of 12 patients has been studied to show the improvements given by the adaptation over the non-adaptive MPC performance.

1 From manual to advanced control strategies

Anesthesia plays a crucial role in the operating theatre. Its effects on the patient are difficult to measure. The BIS, which is a variable derived from the EEG signal, has been found as most suitable for measuring depth of anesthesia [1]. When undergoing surgery, the desired BIS target is 50 and must remain between 40 and 60, given an adequate sedation by the anesthesiologist.

Normally, anesthesiologists control the drug dosing during anesthesia aided by monitors of hemodynamic signals. This (open-loop) technique reaches the target level of BIS fast, but it may result in minimal values (undershoot) which are not safe for the patient.

Target-controlled infusion (TCI) techniques have shown a significant reduction in the number of times the anesthesiologist intervenes. Patients show less movement to surgical stimuli, meaning that the sedation is deeper. During induction, less propofol is used, without leading to longer induction times [2]. Those techniques predict the drug concentration based on pharmacokinetic / pharmacodynamic models. Because of the patient variability, these open-loop strategies present inaccuracy in drug administration.

Closed-loop technology can mitigate this problem. Due to the fact that PID controllers can not anticipate to response of the patient and do not have any knowledge of the drug metabolism, stability problems are present. Therefore, model-based strategies using fuzzy, adaptive and predictive approaches have been developed [3].

2 Non-adaptive and adaptive MPC controller

Although non-adaptive MPC tackles well patient variability, adaptive prediction models are being used to reduce modeling errors. Our adaptive MPC strategy [4] has been tested in simulations with a set of 12 patients, proving a more accurate BIS level and a better control performance when dealing with both inter and intra-patient variability. These improvements are presented in the table below.

Performance indices	Non-adaptive predictive controller	Adaptive controller
Time to target	109.16±43.42	106.25±35.42
Minimum BIS	48.06±3.08	48.98±1.91
Settling time	122.91±41.85	106.25±55.42
Undershoot	0.0039%±0.01%	0%

Synergy and coupling between the hypnotic and analgesic components can be tackled by means of a multivariable approach. Our next challenge is the application of the algorithms developed hitherto, with a MIMO controller.

References

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