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Continuous Monitoring of Anaesthetics Concentration to Control Anaesthesia Delivery

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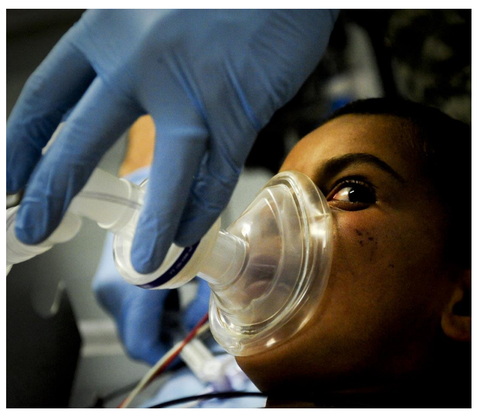
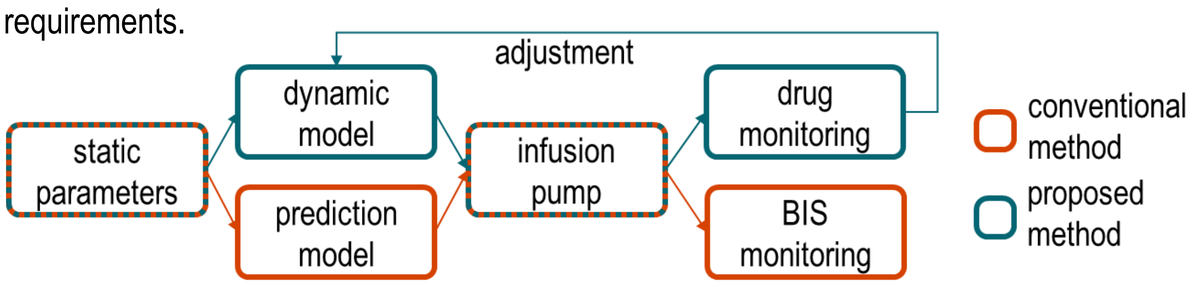
Research context and motivation

- Every year, **30,000 people** undergo anaesthesia and **remain awake**, **feeling pain**, many more are put into uselessly deep or prolonged chemical coma.
- Proper anaesthesia requires the achievement of a certain concentration of drugs. Today, prediction errors in control models reaches **25%** due to the patients diversity.
- The **continuous monitoring of anaesthetic** would contribute to better individualization of patients management.

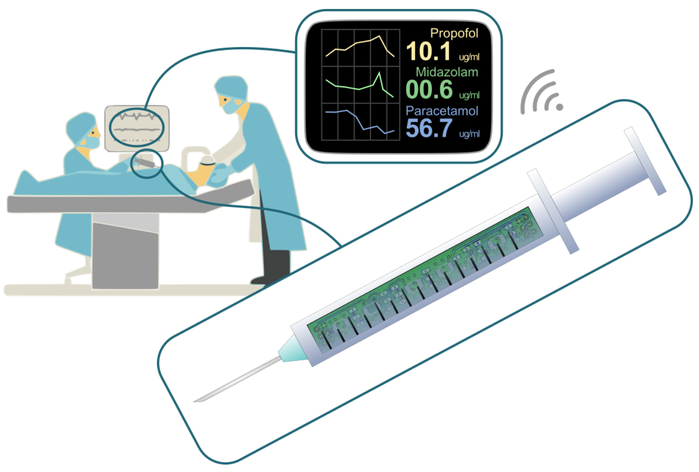


Addressed research questions/problems

- Conventional system to monitor the Depth of Ananesthesia (DOA), such as Bi-Spectral Index (BIS), show some limitations due to high inter-patient variability and the usage of predictive models.
- The **Therapeutic Drug Monitoring (TDM)** can measure the actual drug concentration in the patient, allowing a dynamic adjustment of the anaesthetic infusion to meet personal requirements.



- Nowadays, **no commercially-available** system is able to exploit a real-time point-of-care anaesthetic monitoring, due to the lack of technologies capable to read anaesthetics and possible to be integrated into a simple object.
- Electrochemical investigation can be adopted to measure the therapeutic compounds (**Propofol, Midazolam, and Paracetamol**), in particular, Cyclic Voltammetry (**CV**) and Differential Pulse Voltammetry (**DPV**) are highly attractive due to fast measurements, multi sensing, and high sensitivity.
- We propose a **portable intelligent syringe** to monitor the delivery of anaesthetic compounds during surgery.
  - **Needle:** bio-sensor (electrochemical cell)
  - **Chamber:** electronic sensor interface (quasi-digital, bio-inspired driver and read-out)
  - **Plunger:** intelligent wireless interface (custom digital architecture)



- The system requires to be **portable**, **low cost**, **small**, and **low power**, the sampling must be **autonomous**, **intelligent**, and **on-line**.

List of attended classes

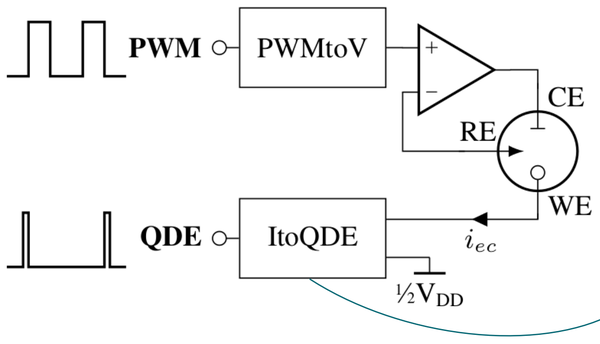
- 01SGURV - Intellectual property rights, technology transfer and hi-tech entrepreneurship (22/03/2018, 6 CFU)
- 01SHCRV - Unsupervised neural networks, didattica di eccellenza (09/04/2018, 6 CFU)
- 01LCPIU - Experimental modeling: costruzione di modelli da dati sperimentali (16/04/2018, 6 CFU)
- 01SFURV - Programmazione scientifica avanzata in Matlab (20/04/2018, 4 CFU)
- 01SIHRV - Bio-nano electronics and biomolecular computing (07/09/2018, 4 CFU)

External activities

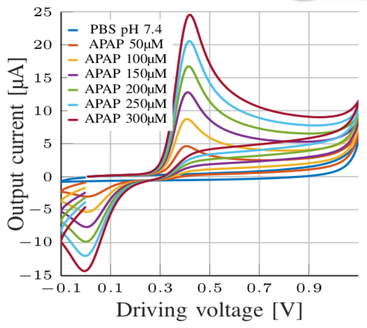
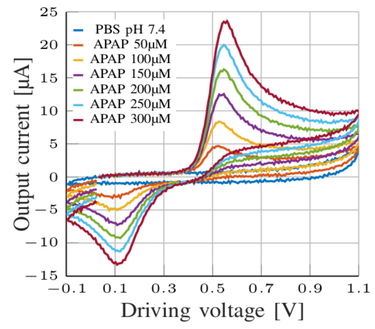
- Guest PhD student at Integrated System Laboratory (LSI), École Polytechnique Fédérale de Lausanne (EPFL) (June 2018 - up to present)
- Innovation for Change program (SEI and CERN, 27/06/2018, 2 CFU)
- Electrochemical nano-bio-sensing and bio/CMOS interfaces (EPFL, 22/06/2018, 1 CFU)

Novel contributions

- I propose a fully **quasi-digital, bio-inspired** interface to drive and measure an electrochemical cell:
  - **PWM to voltage** driving;
  - **current to Quasi Digital** stream of Event read-out.



- Features of the proposed approach:
  - **no ADC or DAC** required, **no filter** required;
  - **simple information management**, processing, and transmission;
  - **noise reduction** and accuracy increase;
  - **complexity reduction** and better integration.
- The system can achieve **comparable results w.r.t a lab instrument**, being small and portable with **one order of magnitude** of cost reduction;

Lab instrument	Our board
	
	
Sensitivity: 57.6±5.9 nA/µM LOD: 5.43±0.57 µM	Sensitivity: 54.1±7.1 nA/µM LOD: 1.43±0.18 µM

Adopted methodologies

- Design and implementation of a quasi-digital bio-interface developed on a **custom PCB**.
- Design and implementation of a **custom digital architecture** deployed on an **FPGA** board to control the system.
- Lab calibration of **paracetamol (APAP)** in comparison to a lab instrument to validate the system.

Future works

- Final optimization of the analog board, **2 channel** to measure **3 drugs**.
- Test on **propofol** and **midazolam**, with previous result comparison.
- Addition of a wireless interface, **Wi-Fi** to allow IoT integration.
- Development of an automatic, programmable digital interface for **intelligent detection**.
- Design and test of a **syringe-integrated** bio-sensor for **in-blood** measurement.

Acknowledgment

This work is supported by Politecnico di Torino and Compagnia di San Paolo under the initiative *Joint research projects with top universities* in co-operation with École Polytechnique Fédérale de Lausanne (EPFL), under the co-supervision of Prof. Sandro Carrara.

Compagnia di San Paolo
EPFL
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Submitted and published works

- S. Aiassa, F. Stradolini, A. Tuoheti, S. Carrara, and D. Demarchi, *Quasi-Digital Biosensor-Interface for a Portable Syringe to Monitor Anaesthetic Delivery*, 2019 IEEE Int. Symp. on Circuits and Systems (ISCAS), Sapporo, Submitted.
- S. Aiassa, P. Motto Ros, G. Masera, and M. Martina, *A Low Power Architecture for AER Event-Processing Microcontroller*, 2017 IEEE Biomedical Circuits and Systems Conf. (BioCAS), Turin, 2017.

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