



EDEE Doctoral Programs in Electrical Engineering

EE-600: Usability Engineering

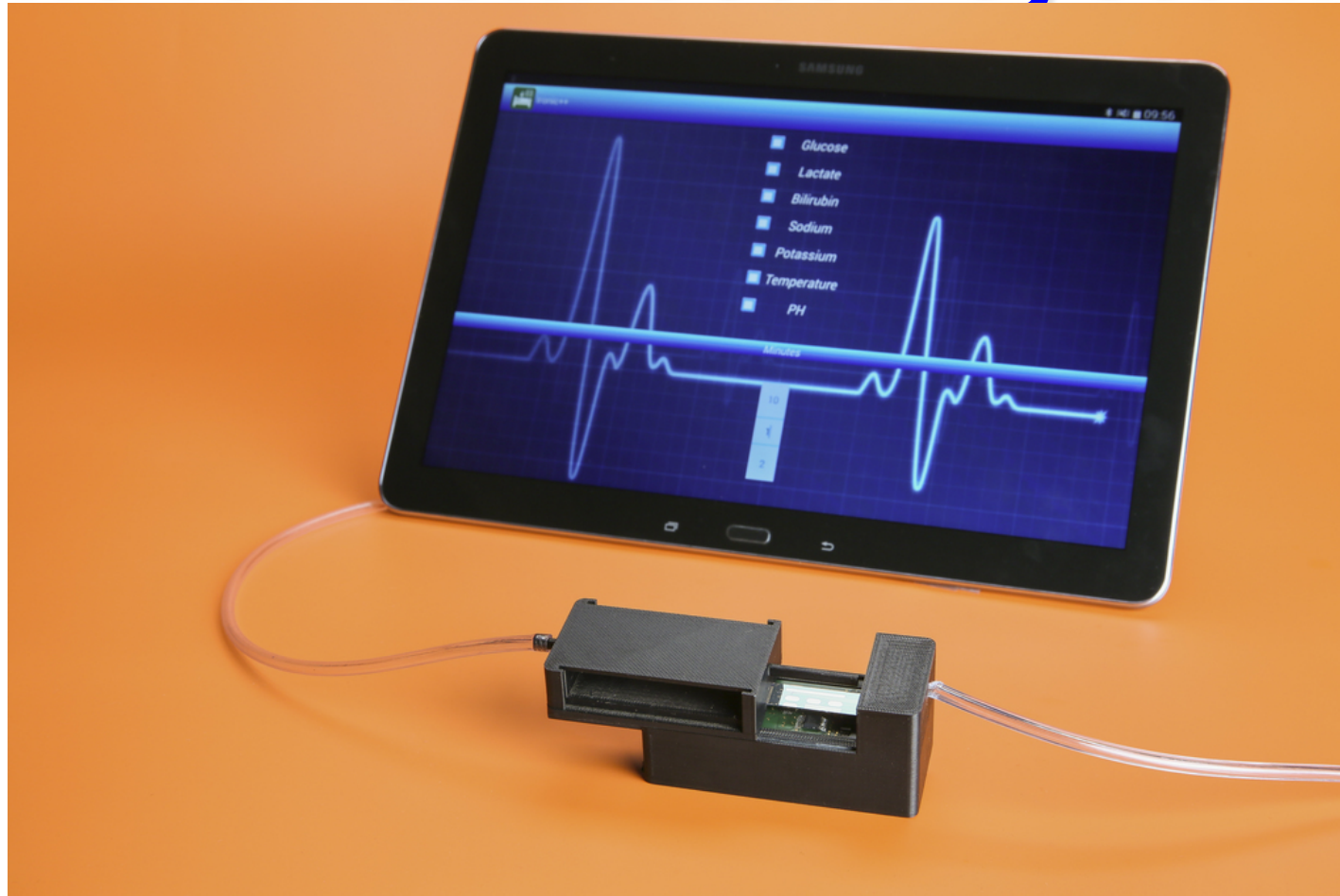
Lecture #11

Full System for

Personalized Anaesthesiology

In Precision Medicine (2nd part)

The full connected system

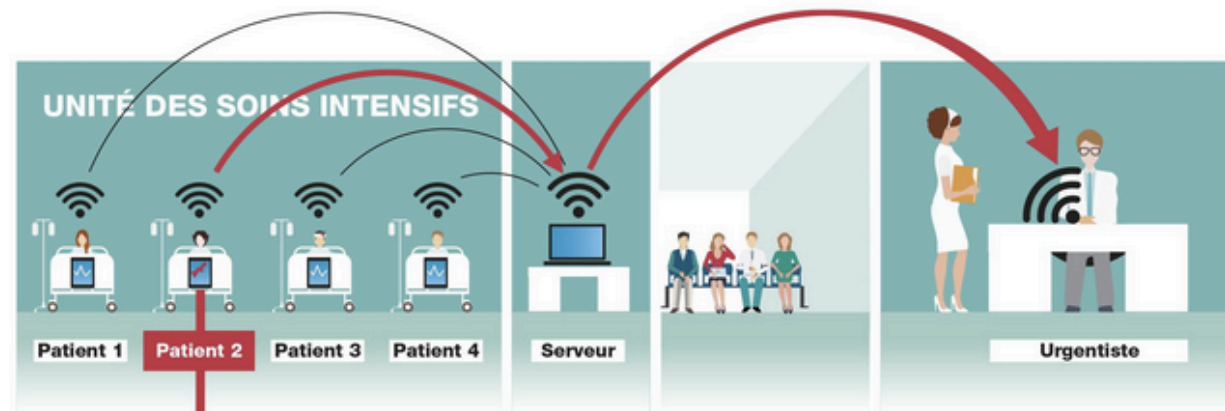


The whole system with the Android™ interface that allows connectivity too

Remote Patients' monitoring from Smartwatches

Des smartwatch pour alerter les médecins aux soins intensifs

Les patients admis en soins intensifs doivent être sous surveillance constante. Un dispositif de biocapteurs collecte en temps réel les données vitales du malade. Si une anomalie est détectée, une alerte prévient le médecin de garde.



La smartwatch de l'urgentiste est connectée via le wifi au serveur central de l'unité des soins intensifs. Il renseigne en continu le médecin sur l'état de santé de ses patients et l'alerte en cas de problèmes.



(c) S.Carrara

EPFL Infographic: Pascal Codrery

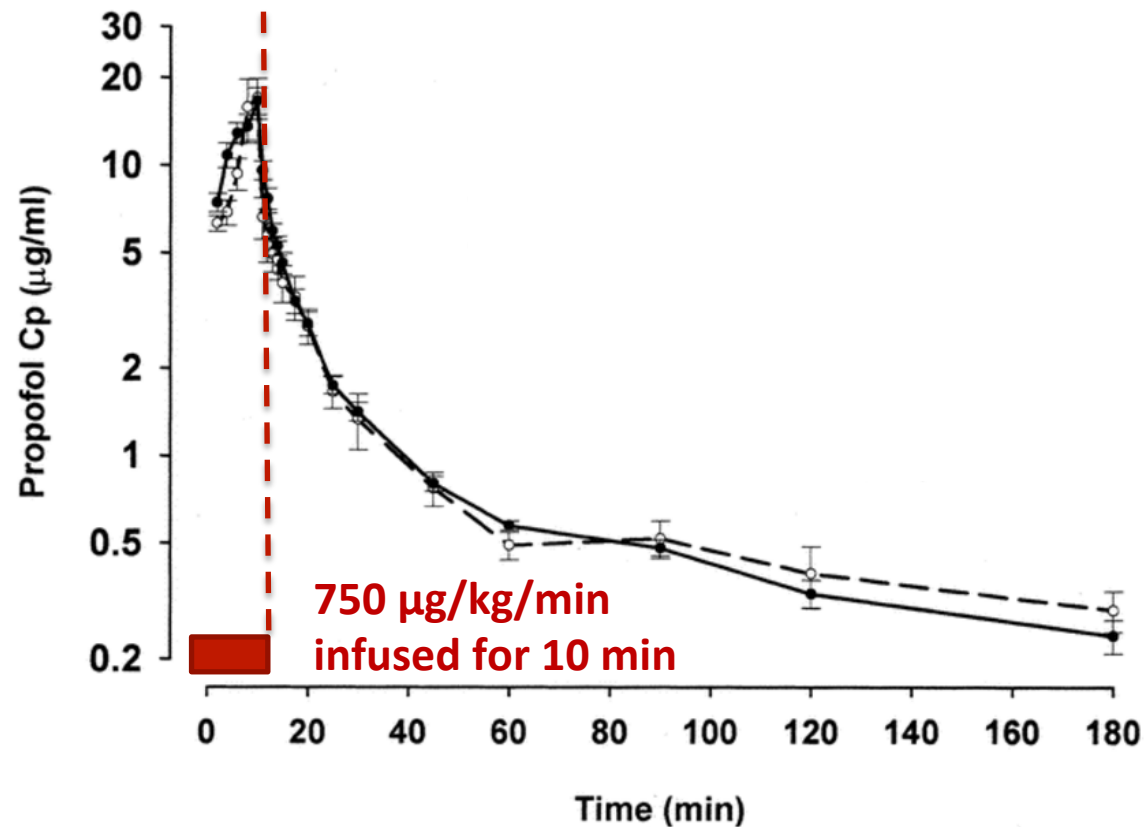
One Interface for Remote Monitoring of Patients in Intensive Care Units



Image / Bam Labs

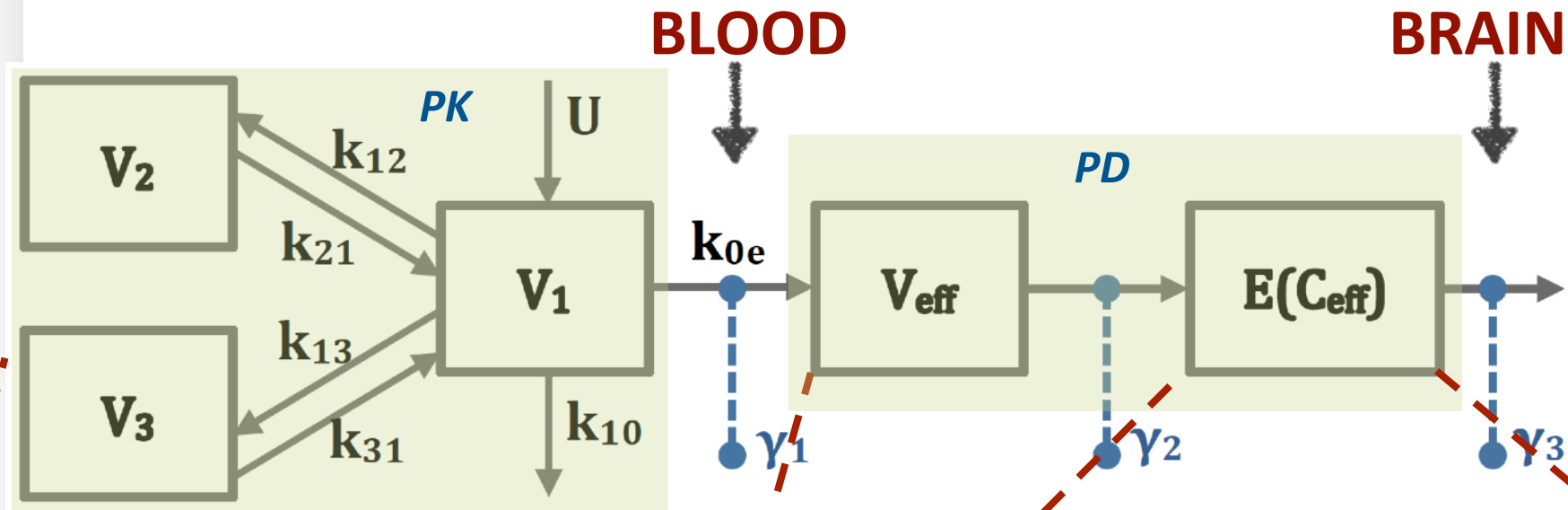
The whole system with the Android™ interface that allows connectivity too

Propofol : *Multiexponential Pharmacokinetics*



Johnson KB & al. Influence of Hemorrhagic Shock Followed by Crystalloid Resuscitation on Propofol. Anesthesiology 2004;101:647-59

Propofol PK-PD model



$$\frac{dC_1}{dt} = C_2 k_{21} + C_3 k_{31} - C_1 (k_{10} + k_{12} + k_{13}) + U$$

$$\frac{dC_2}{dt} = C_1 k_{12} - C_2 k_{21}$$

$$\frac{dC_3}{dt} = C_1 k_{13} - C_3 k_{31}$$

$$\frac{dC_{eff}}{dt} = (C_1 - C_{eff}) k_{0e}$$

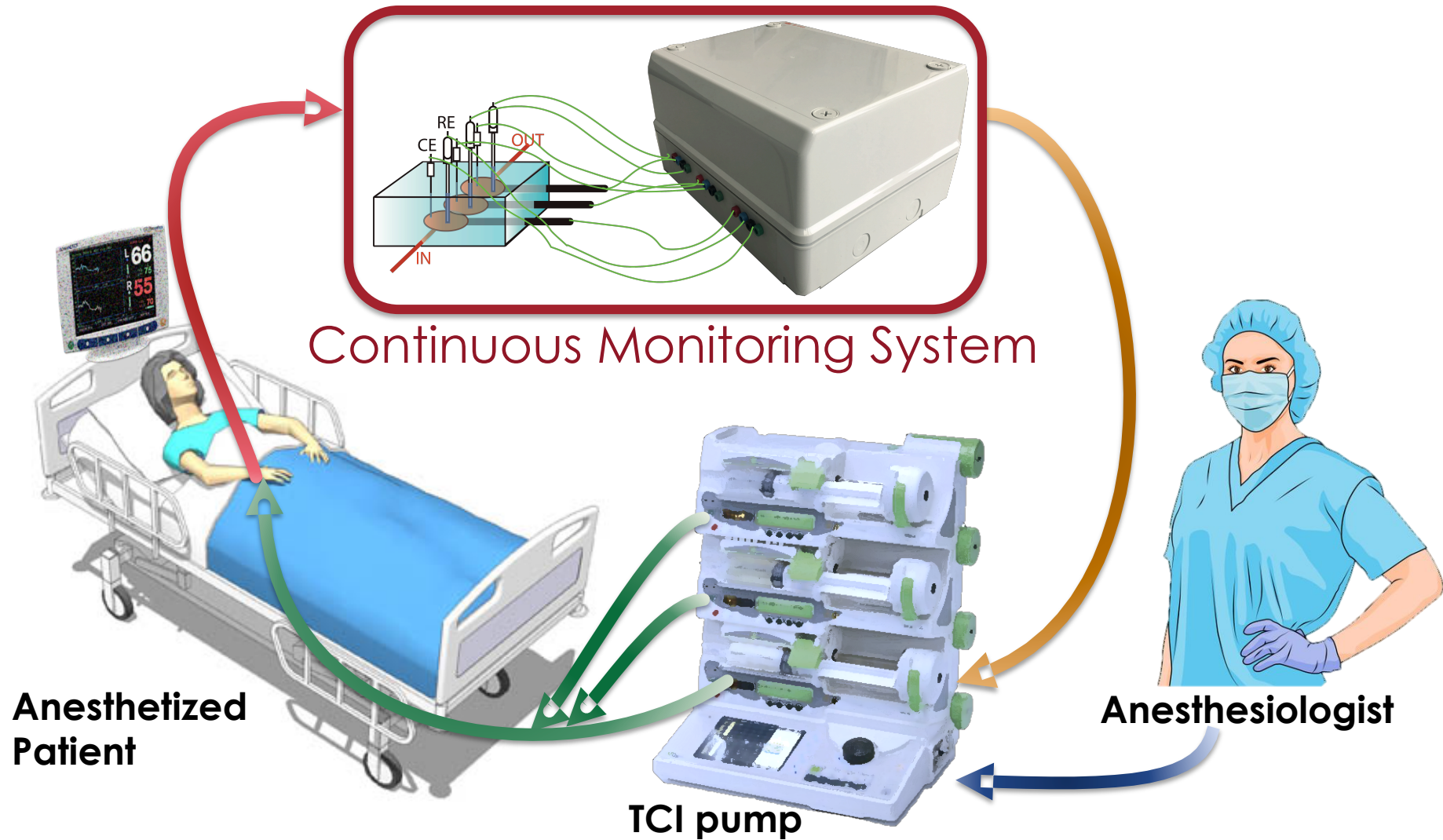
$$E(C_{eff}) = E_0 + (1 - E_0) \frac{C_{eff}^\gamma}{C_{eff,50}^\gamma + C_{eff}^\gamma}$$

Courtesy, Alena Simalatsar

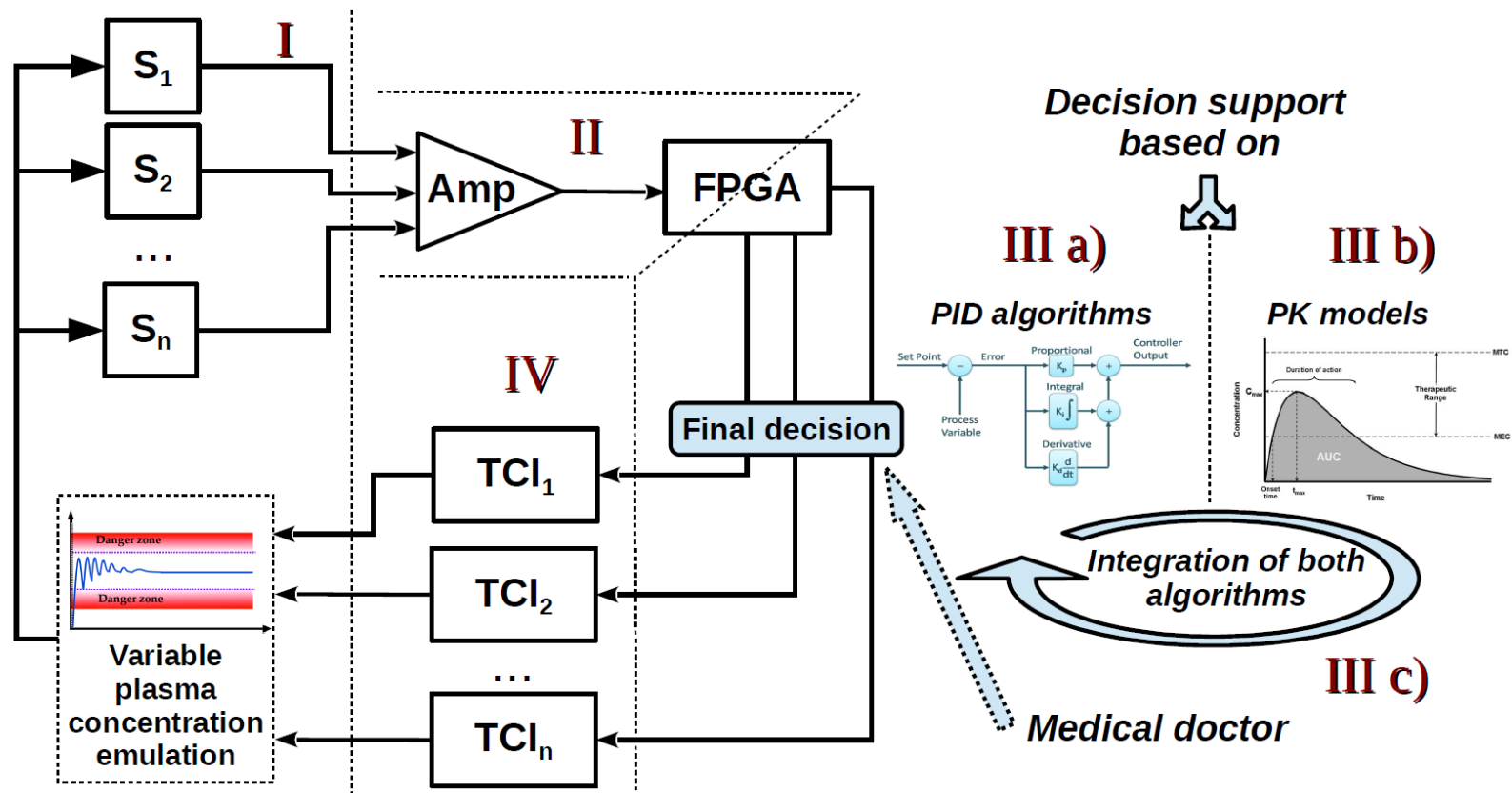
Prediction



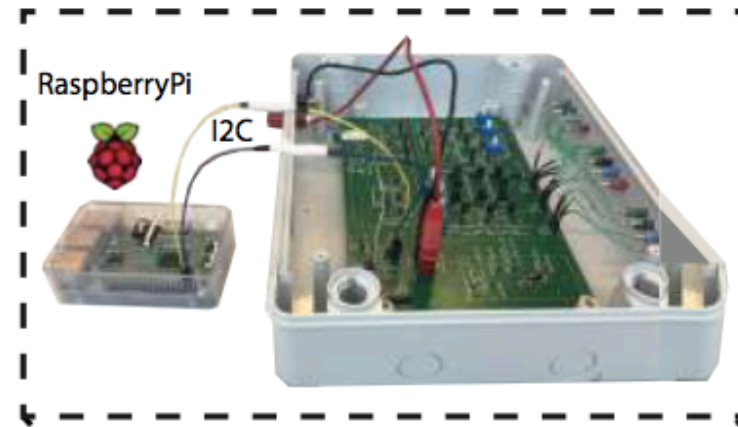
Monitoring during Anesthesia



The new technology: Monitoring integrated in the Pump

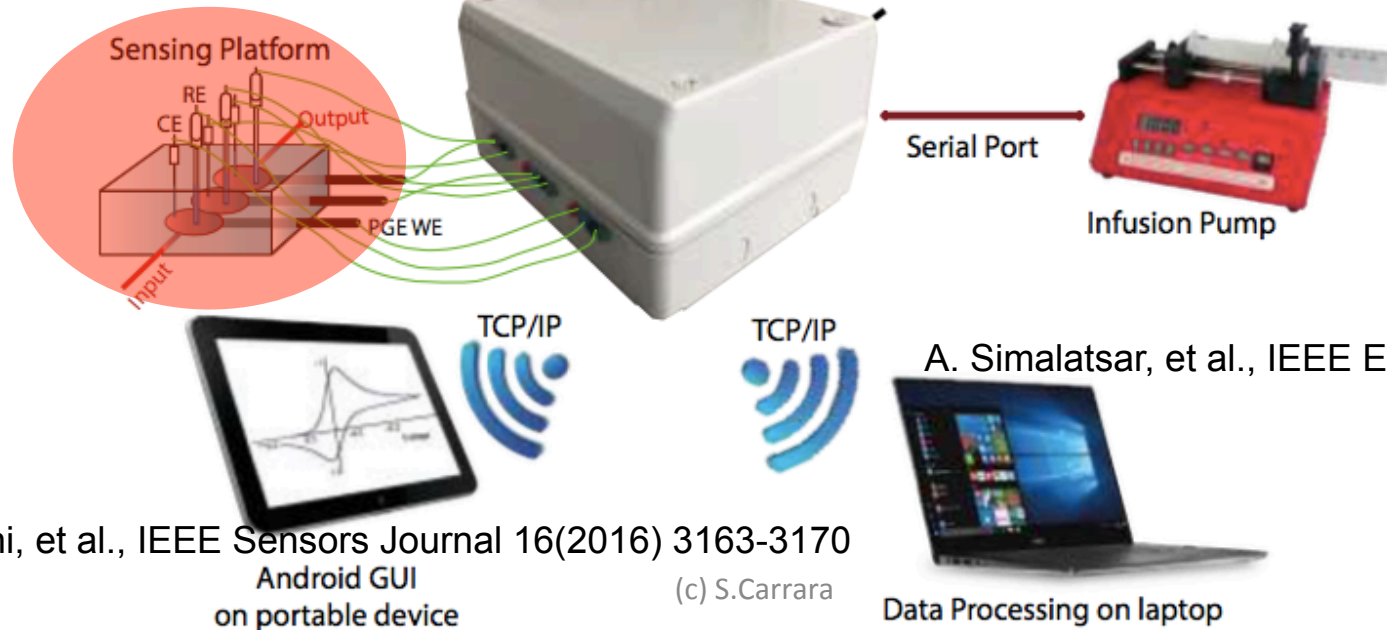


Monitoring and Injection in Surgery



F. Stradolini, et al., IEEE NGCAS 2017

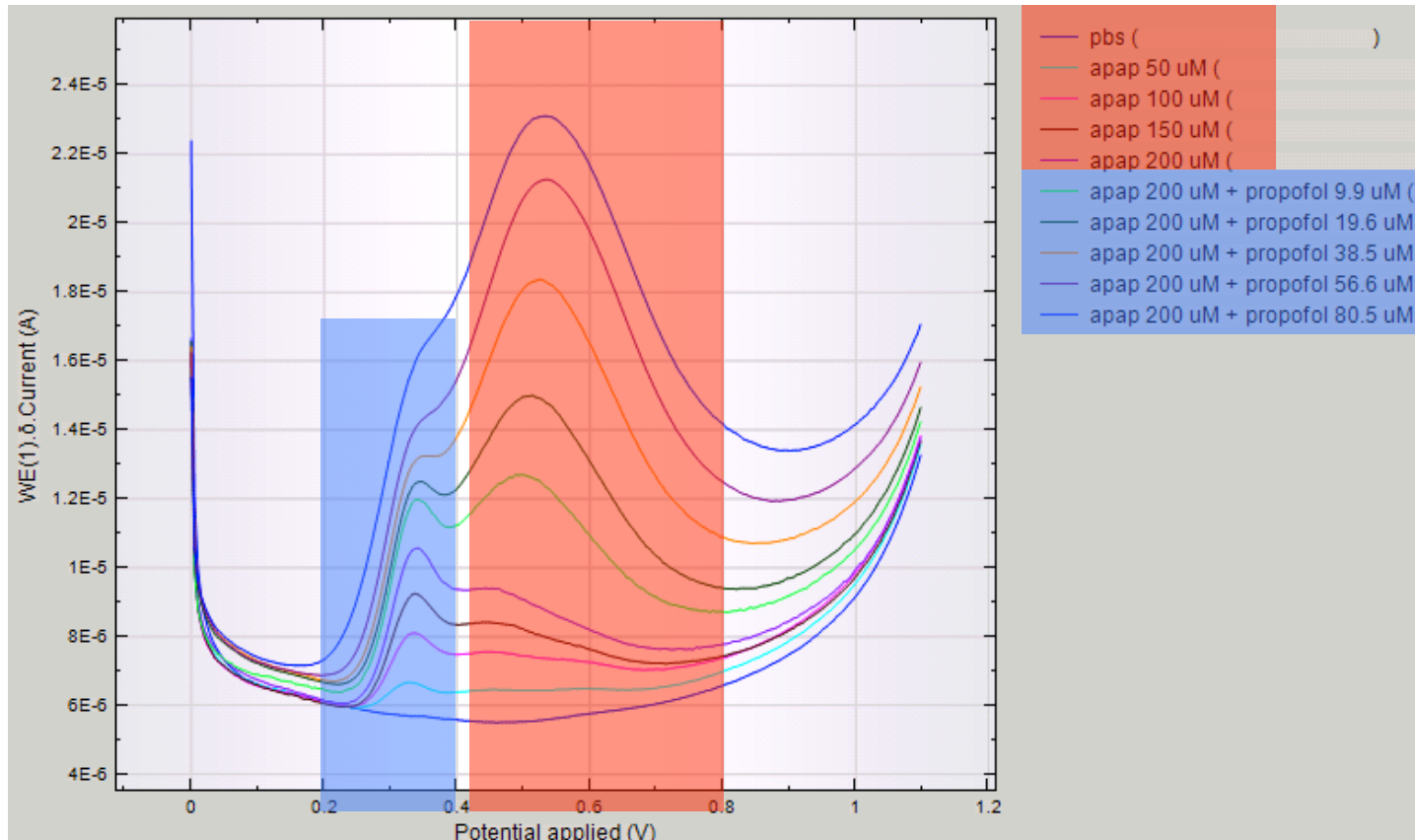
F. Stradolini, et al., IEEE ISCAS 2016



A. Simalatsar, et al., IEEE EMBC 2016

F. Stradolini, et al., IEEE Sensors Journal 16(2016) 3163-3170

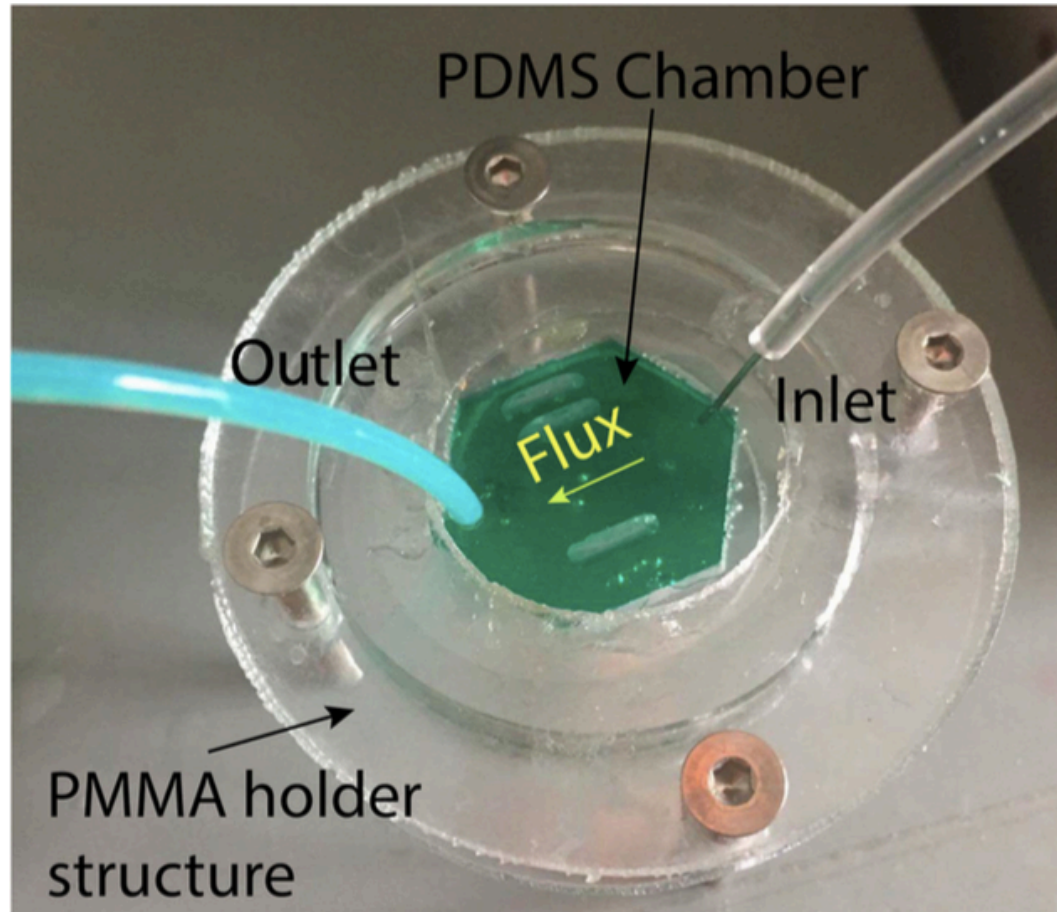
Multiplex of Anaesthetics



Cyclic Voltammograms measured for propofol and paracetamol (APAP) with Pencil Graphite Electrodes

Monitoring of Anaesthetics

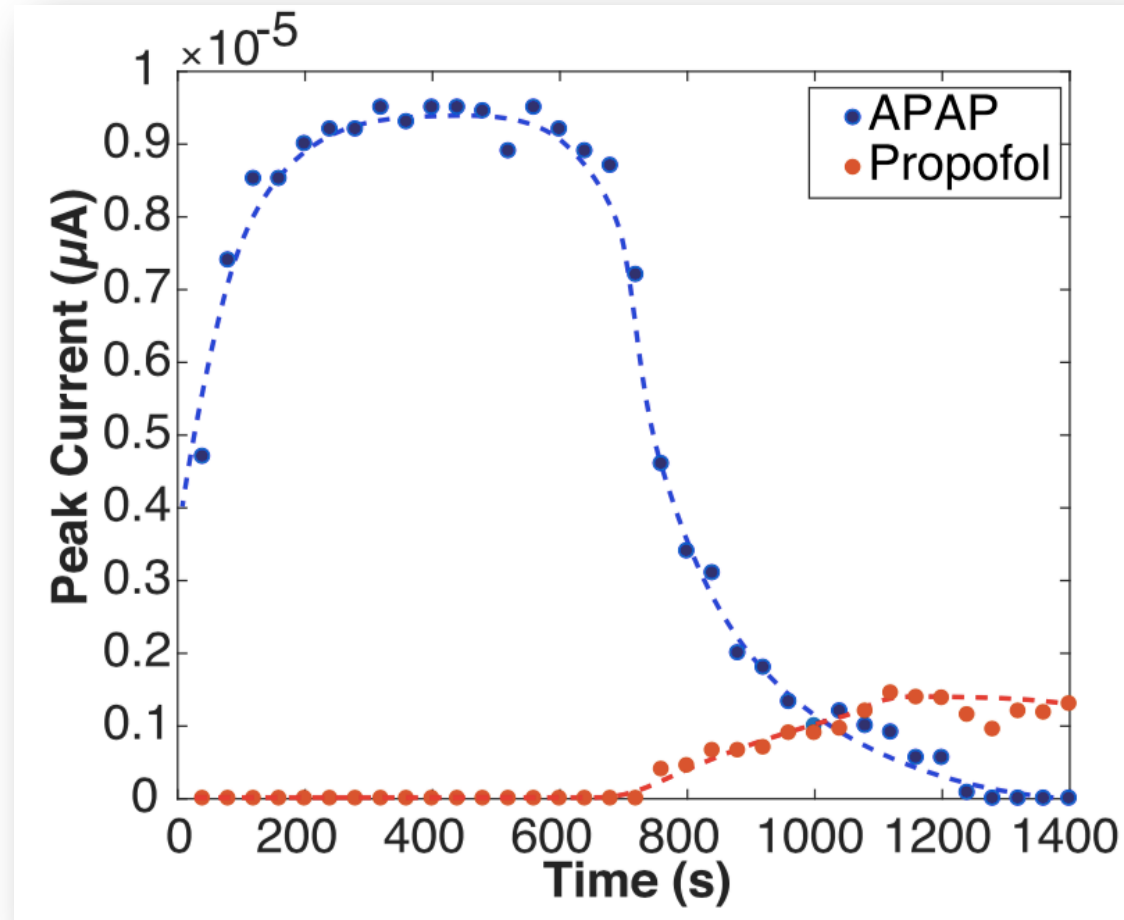
F. Stradolini, et al., IEEE Transactions of Biomedical Circuits and Systems 12 (2018) 1056-1964



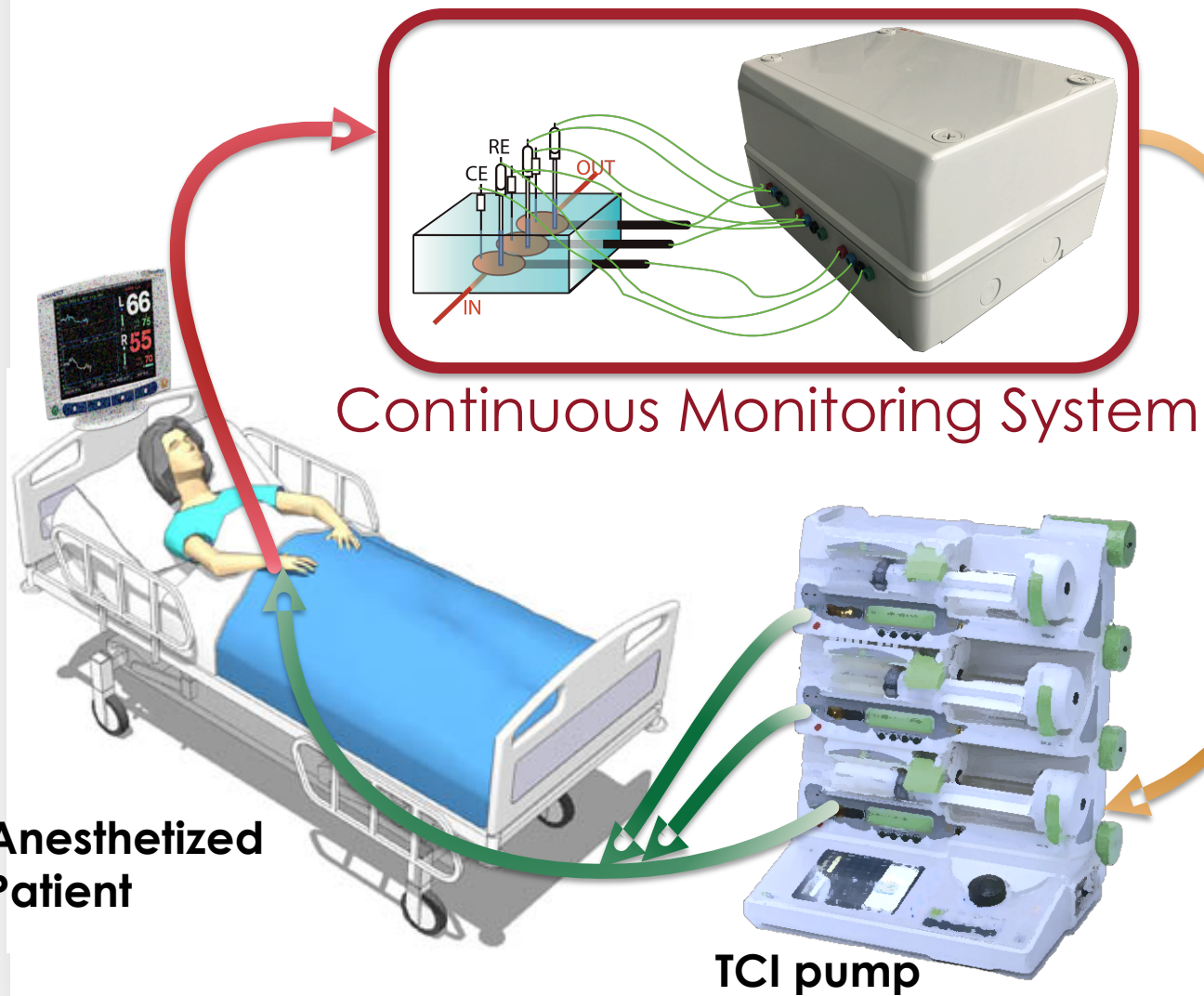
Too much blood for any single measure

Monitoring of Anaesthetics

F. Stradolini, et al., IEEE Transactions of Biomedical Circuits and Systems 12 (2018) 1056-1064



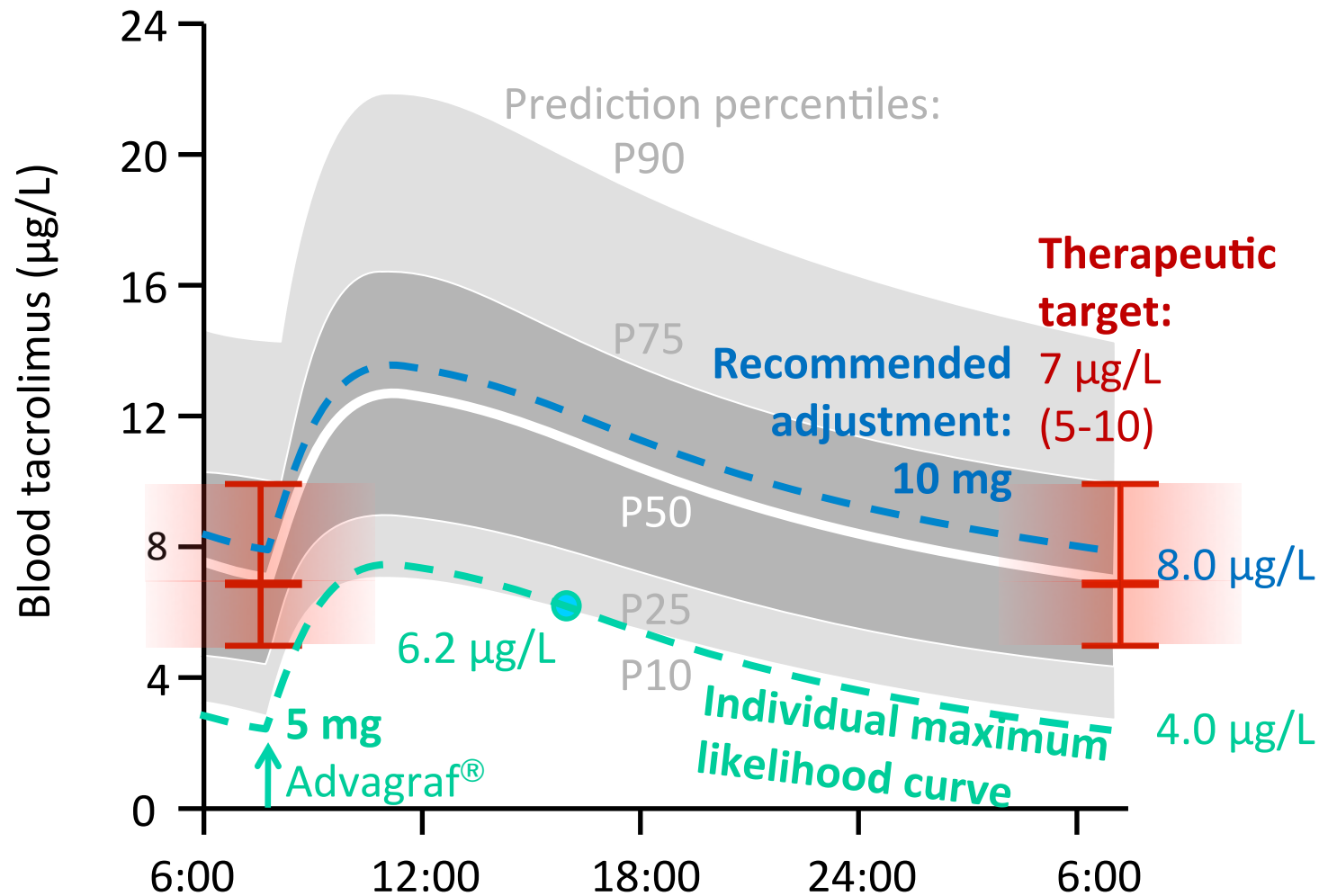
Sensing the Propofol and Paracetamol ALMOST continuously

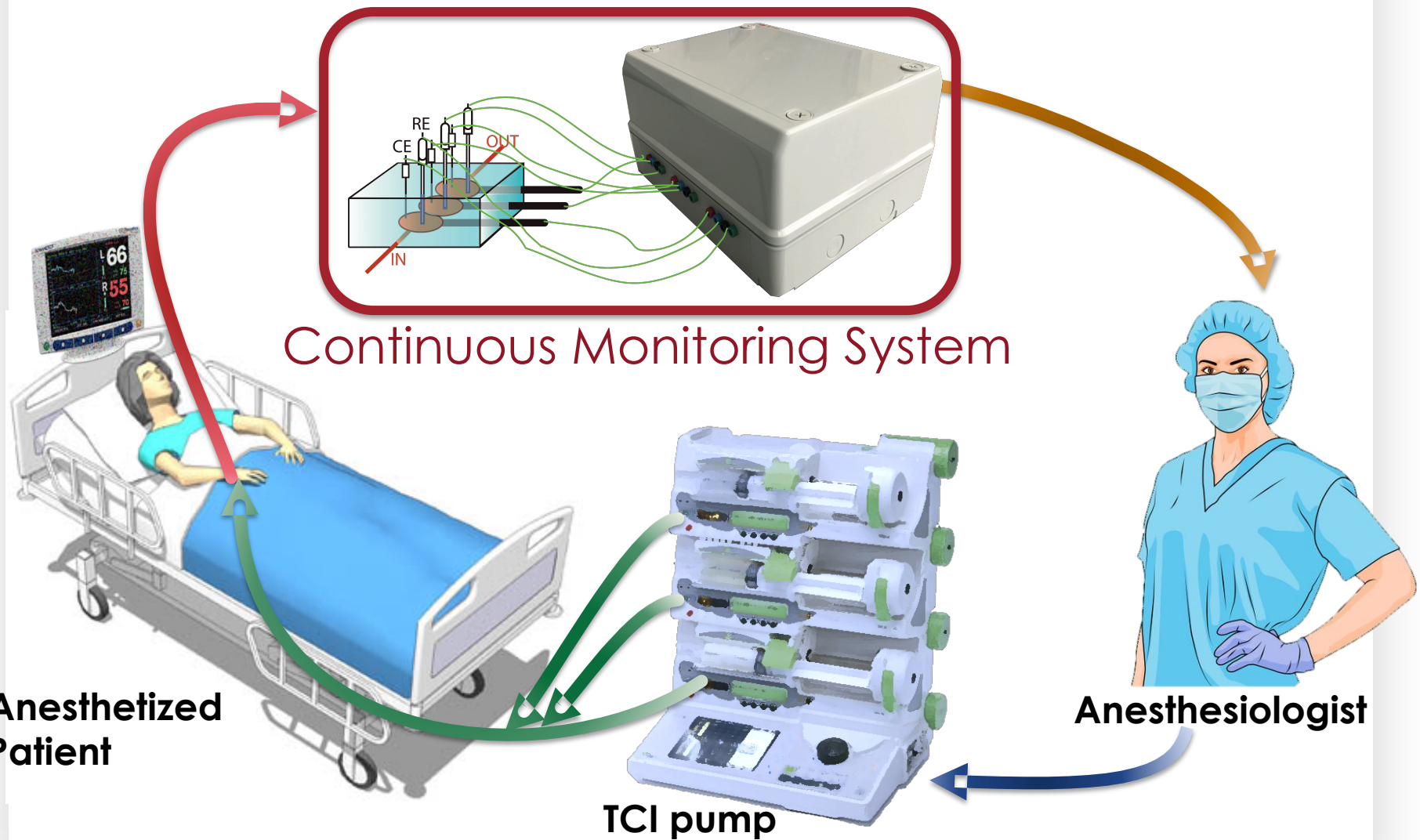


Not
Possible
The
Closed
Loop!

Bayesian TDM interpretation

Example: Tacrolimus, extended release formulation (Advagraf®)





Smart Pen for Anesthesiology

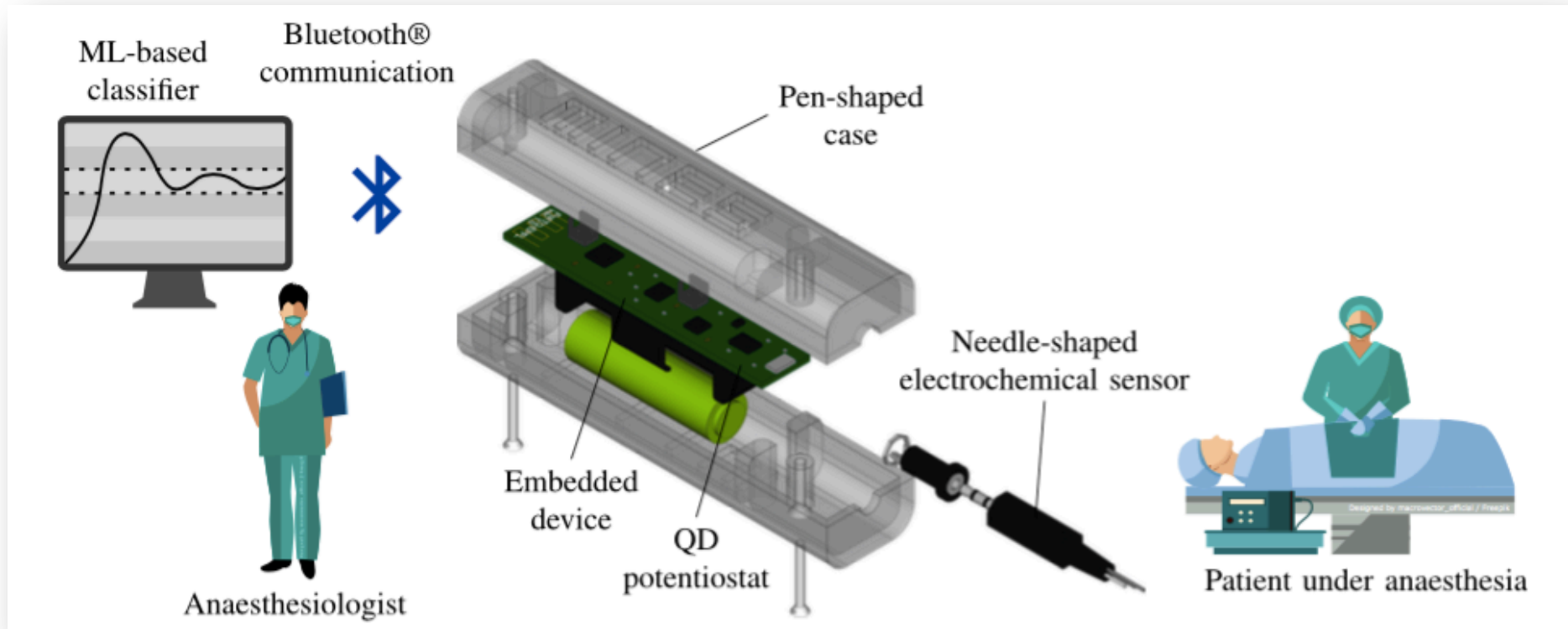


S. Aiassa, et al., IEEE Transactions of Biomedical Circuits and Systems, 15(2021) 294 - 302

Smart Portable Pen for Continuous Monitoring of Anaesthetics

(c) S.Carrara

Smart Pen for Anesthesiology

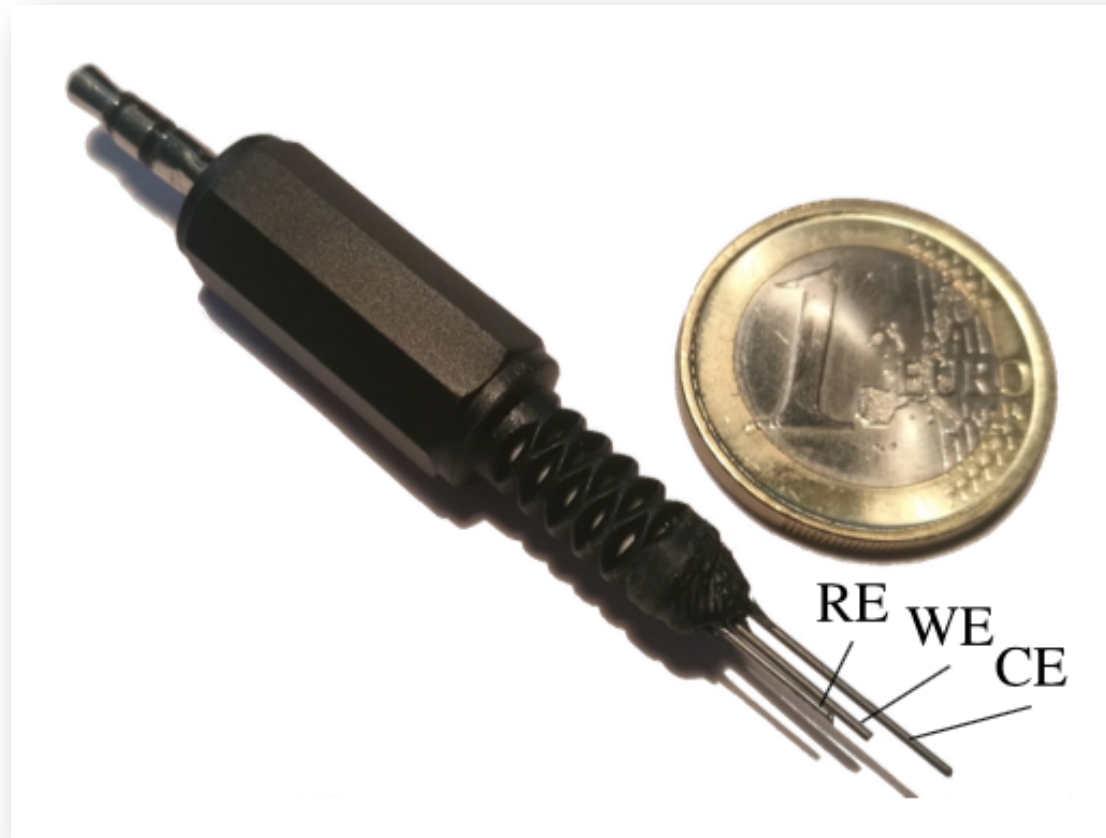


S. Aiassa, et al., IEEE Transactions of Biomedical Circuits and Systems, 15(2021) 294 - 302

The anaesthesiologist follows up the infusion of anesthetics in the patient body through the portable pen

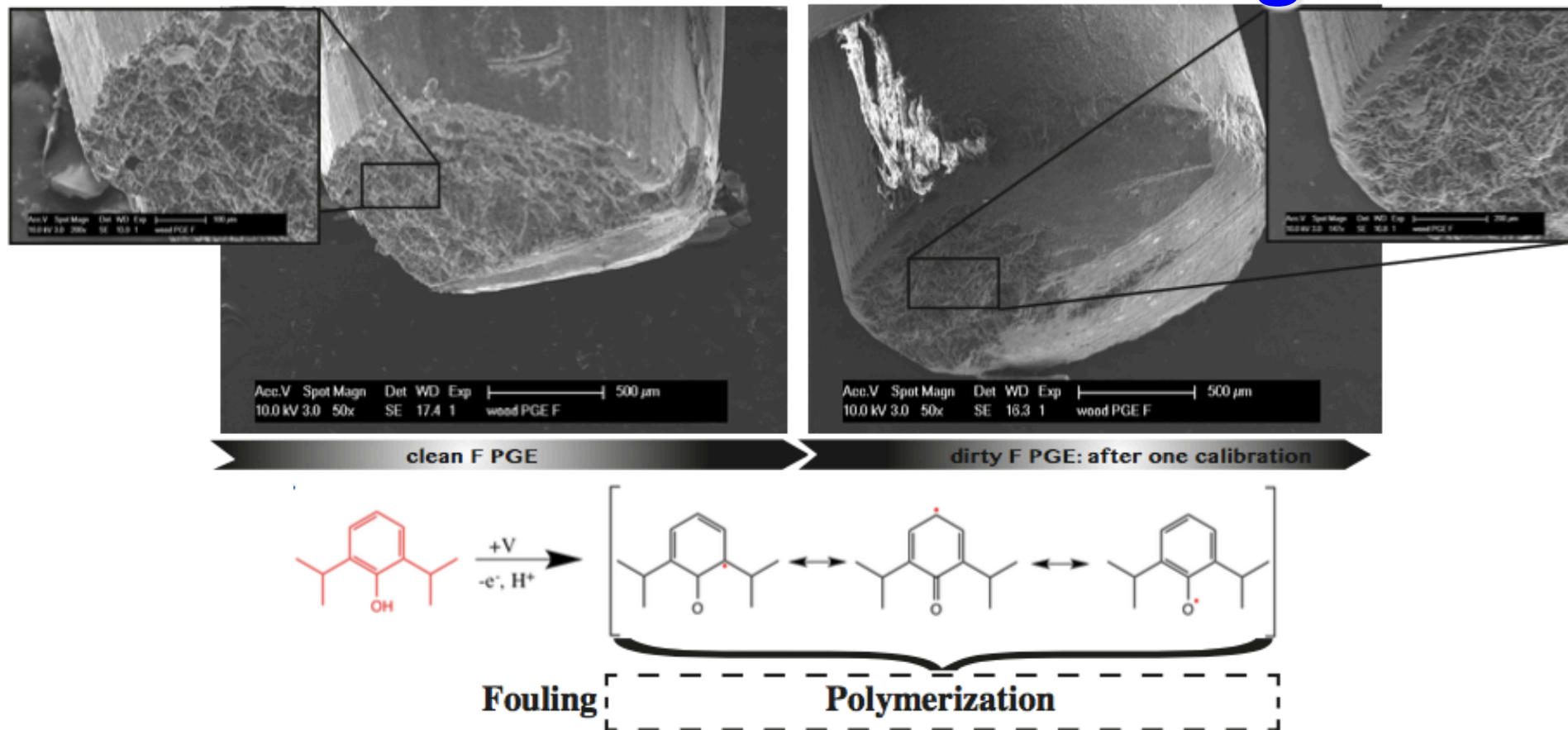
A new kind of electrodes

S. Aiassa, et al., IEEE Transactions of Biomedical Circuits and Systems, 15(2021) 294 - 302



Disposable pencil graphite needle-shaped sensor
for detection of propofol in human serum

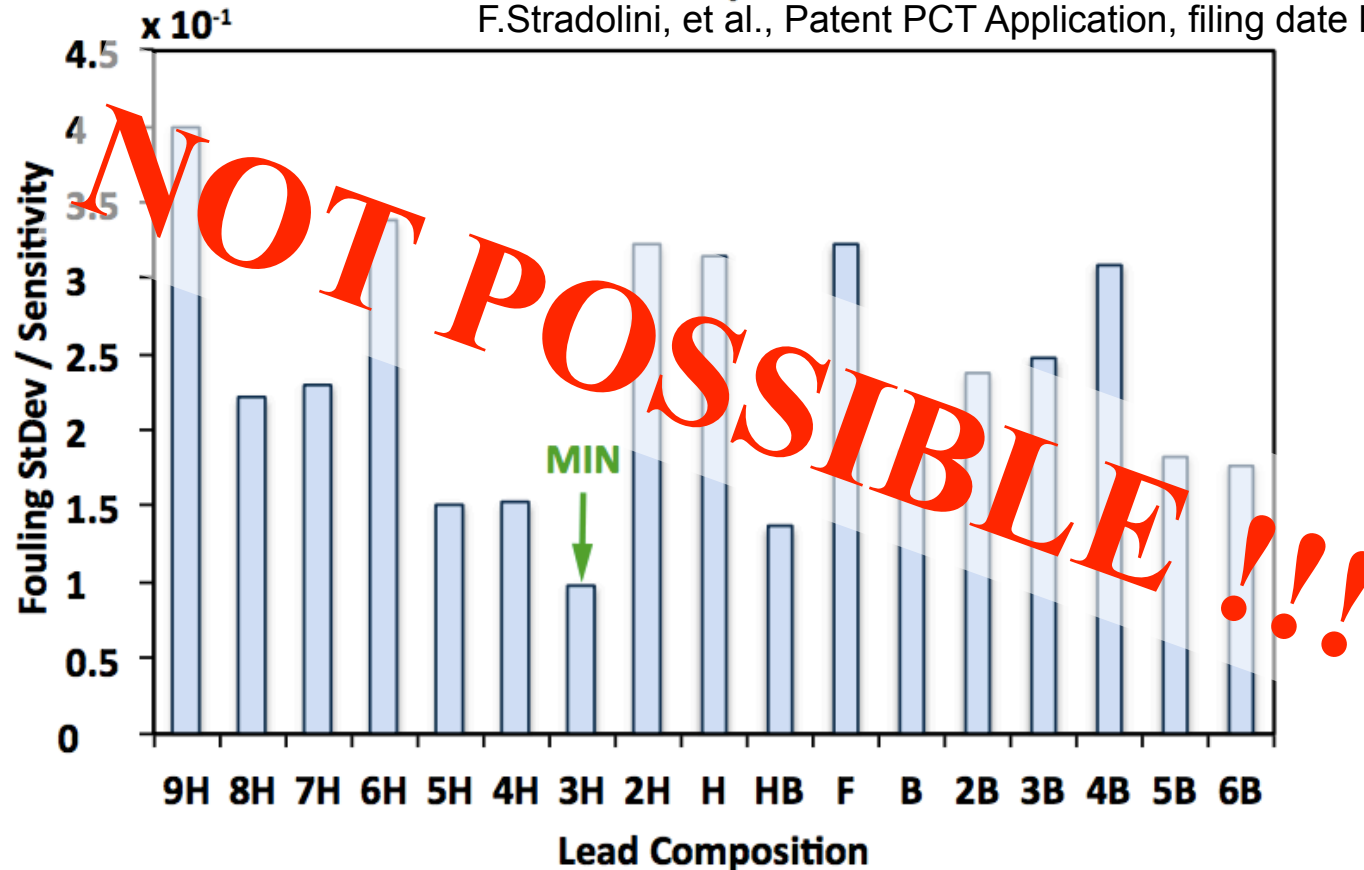
Back to issues with Fouling !!!



Sensitivity is going down due to issues related to Fouling of Propofol onto the graphite electrode: SEM images and suggested mechanism of propofol electro-oxidation reaction

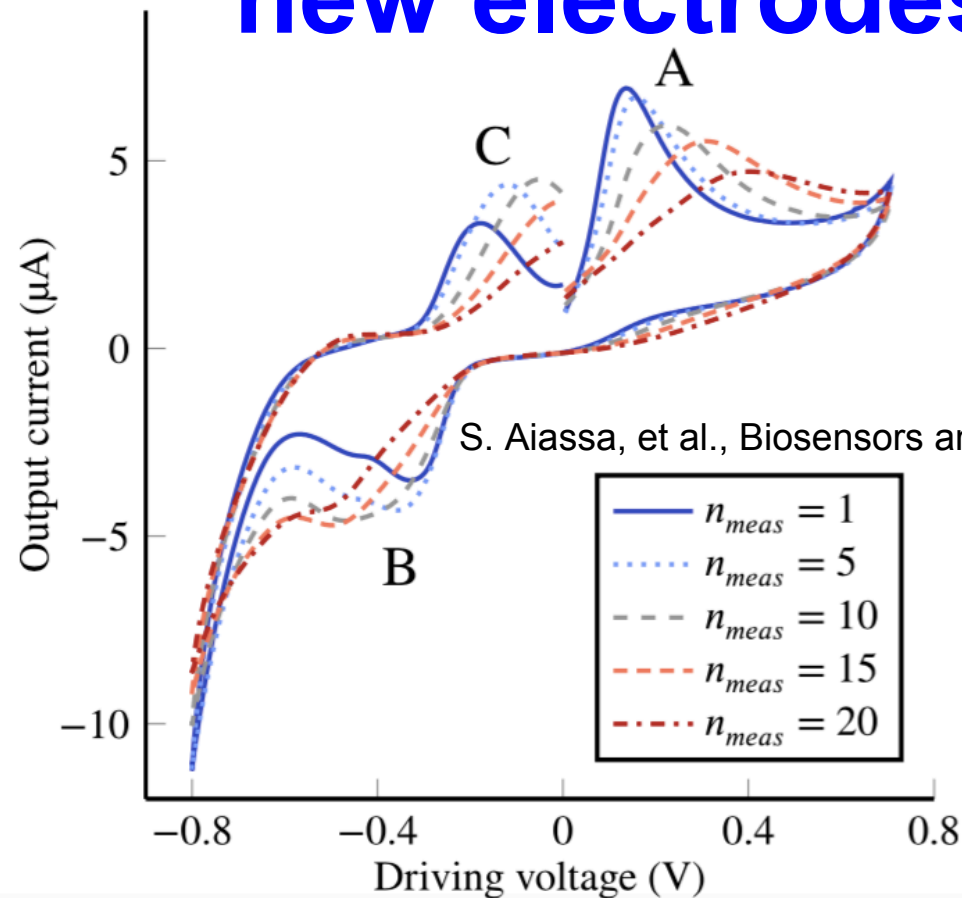
Solving by special carbon paste

F.Stradolini, et al., Patent PCT Application, filing date May 30, 2017



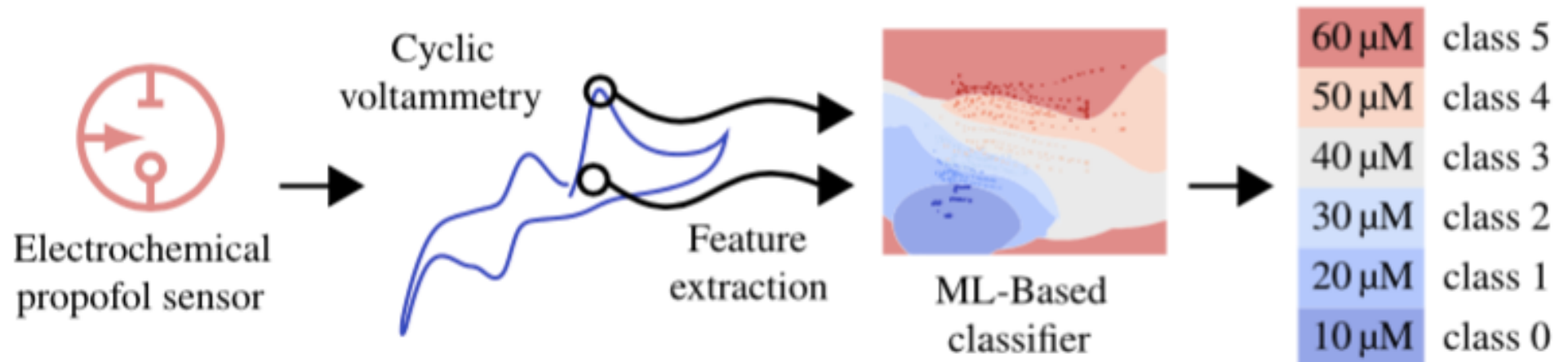
Variability in S for subsequent propofol calibrations on the same electrode
respect to the average S of the electrode itself
(Fouling StDev/Sensitivity)

The Fouling issue with the new electrodes



Voltammogram from propofol detection with lower peak current after each new measurement

Solving Fouling with new electrodes



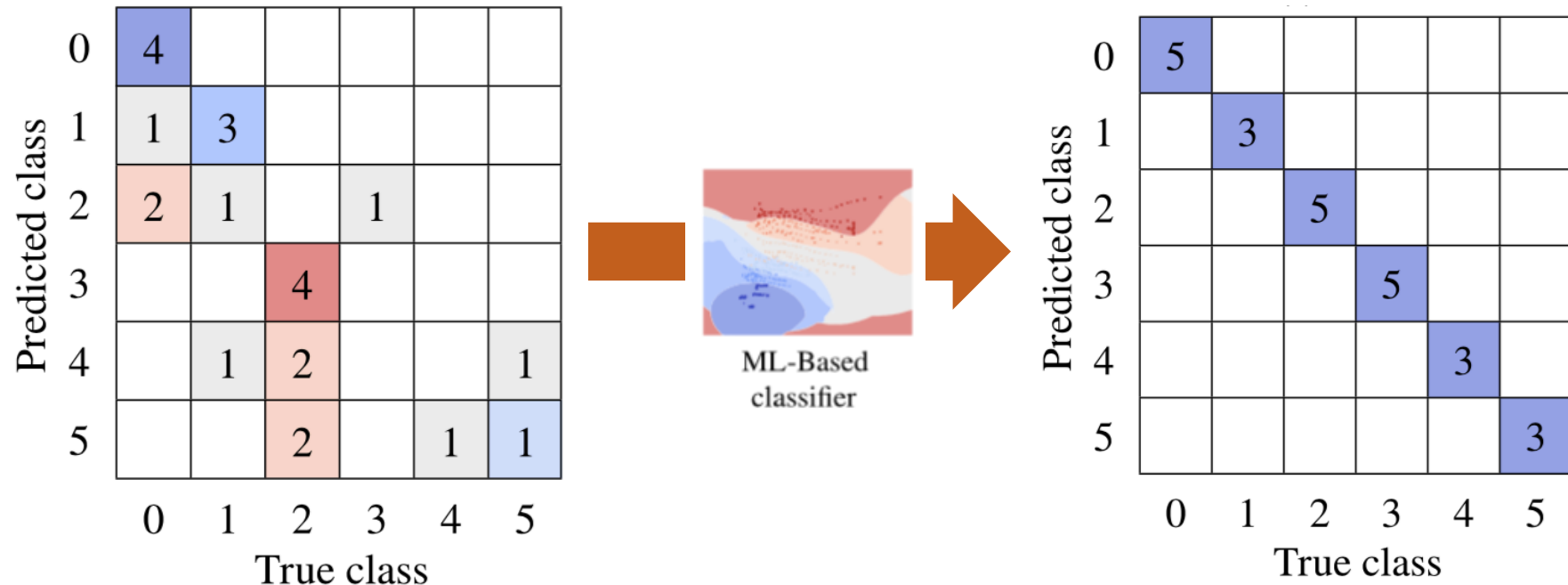
S. Aiassa, et al., Biosensors and Bioelectronics 171 (2021) 112666

Machine-learning based approach for
continuous monitoring of propofol

(c) S.Carrara

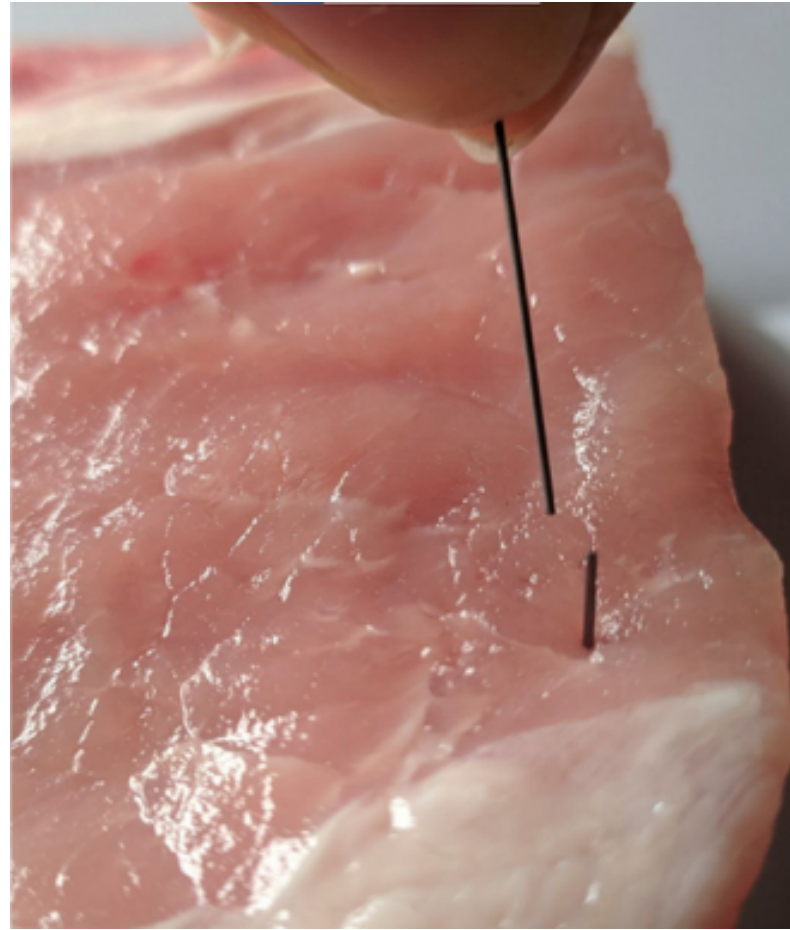
Solving Fouling with new electrodes

S. Aiassa, et al., Biosensors and Bioelectronics 171 (2021) 112666



Solution by Machine-learning on
continuous monitoring of propofol

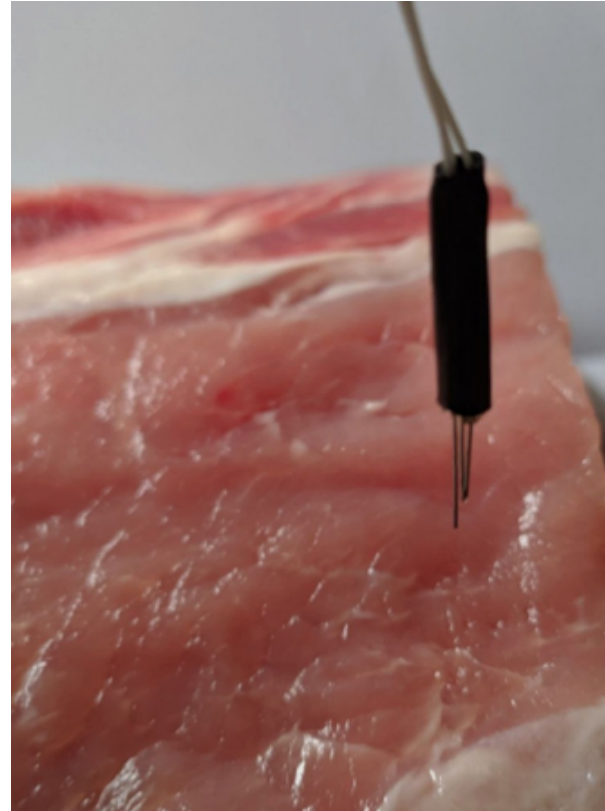
New issue on new kind of electrodes



Too weak for breaking skin and muscle
to reach veins and arteries

Again, another kind of electrodes

F. Barbeni et al., in preparation (2022)



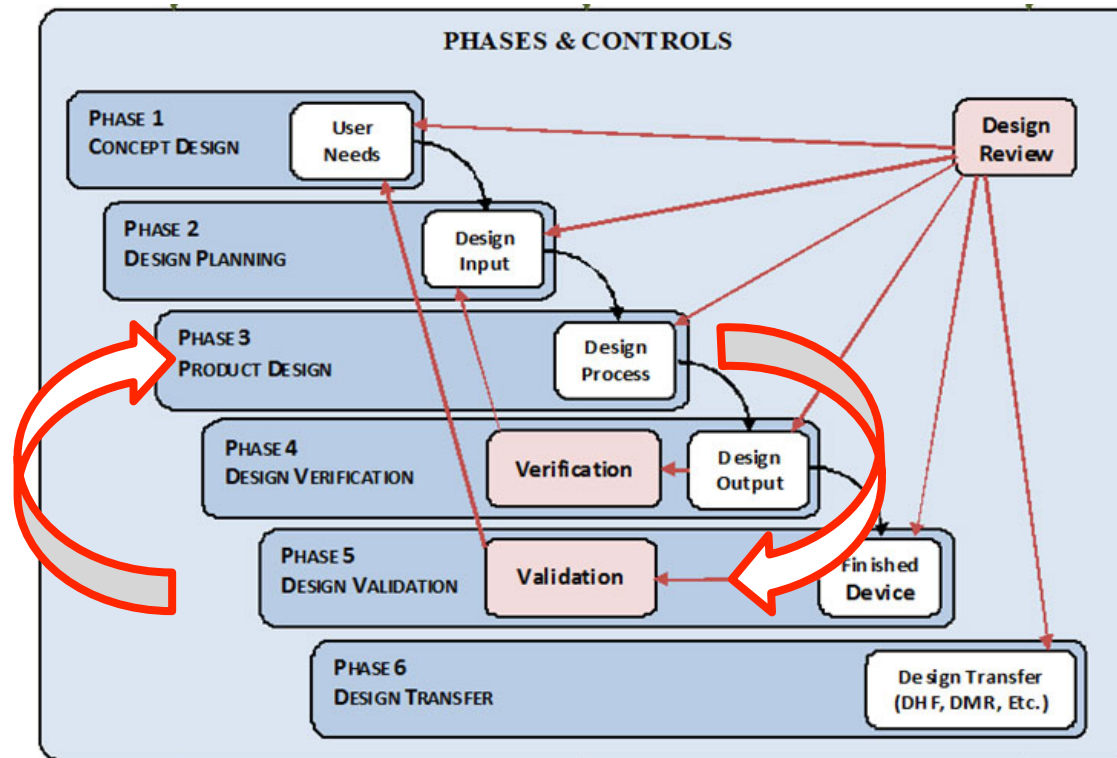
Enough strong for breaking skin and
muscle to reach veins and arteries

Thanks to all contributed....



(c) S.Carrara

...to the many moves on the V-cycle!



How many times we loop again in just phases 3, 4, and 5 !!!