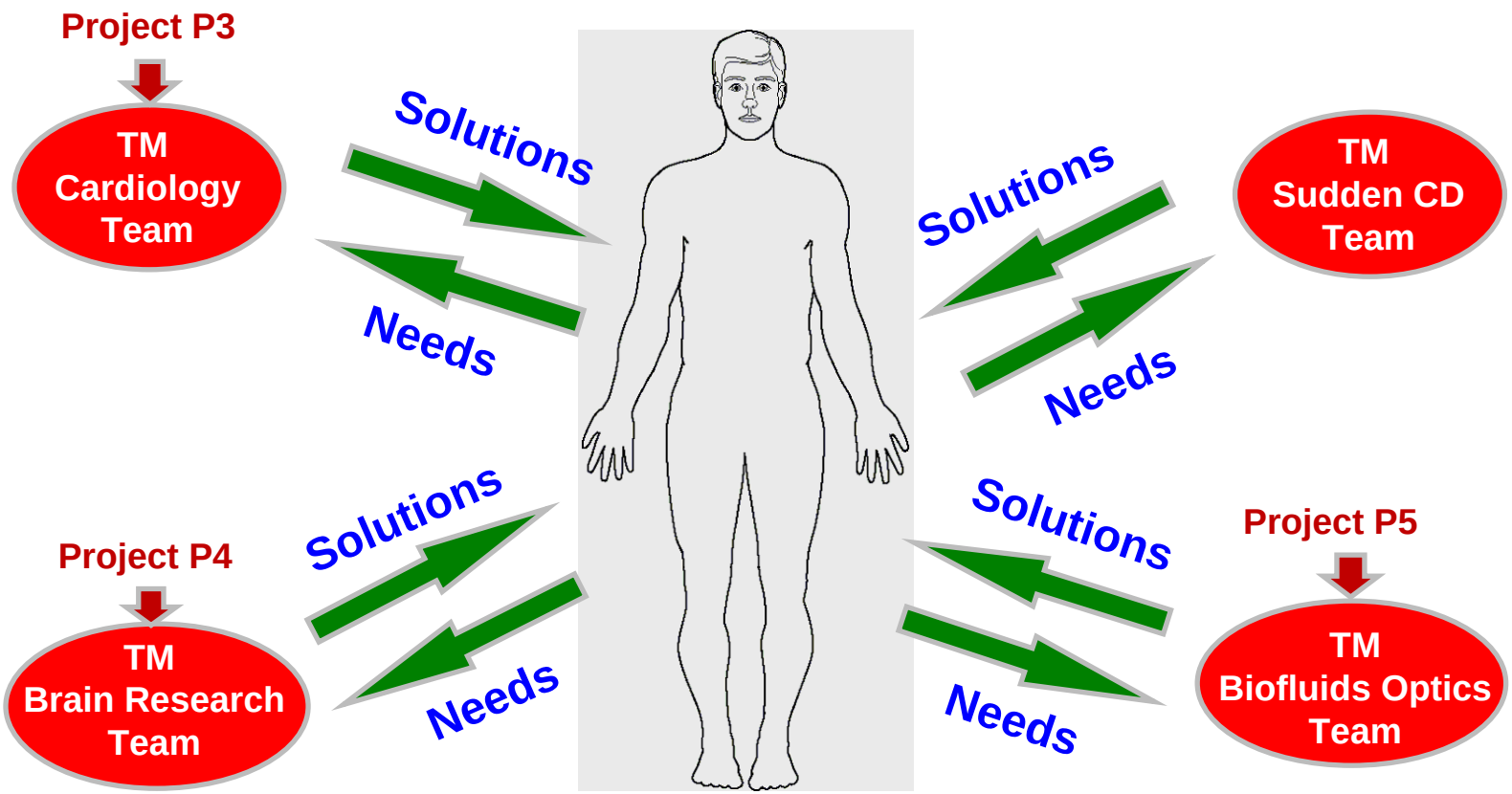
Cooperation in CEBE



CEBE | Centre for Integrated Electronic Systems and Biomedical Engineering

1918 TALLINNA TEHNIKAÜLIKOOL TALLINN UNIVERSITY OF TECHNOLOGY

Reliable and disturbance free monitoring of dialysis

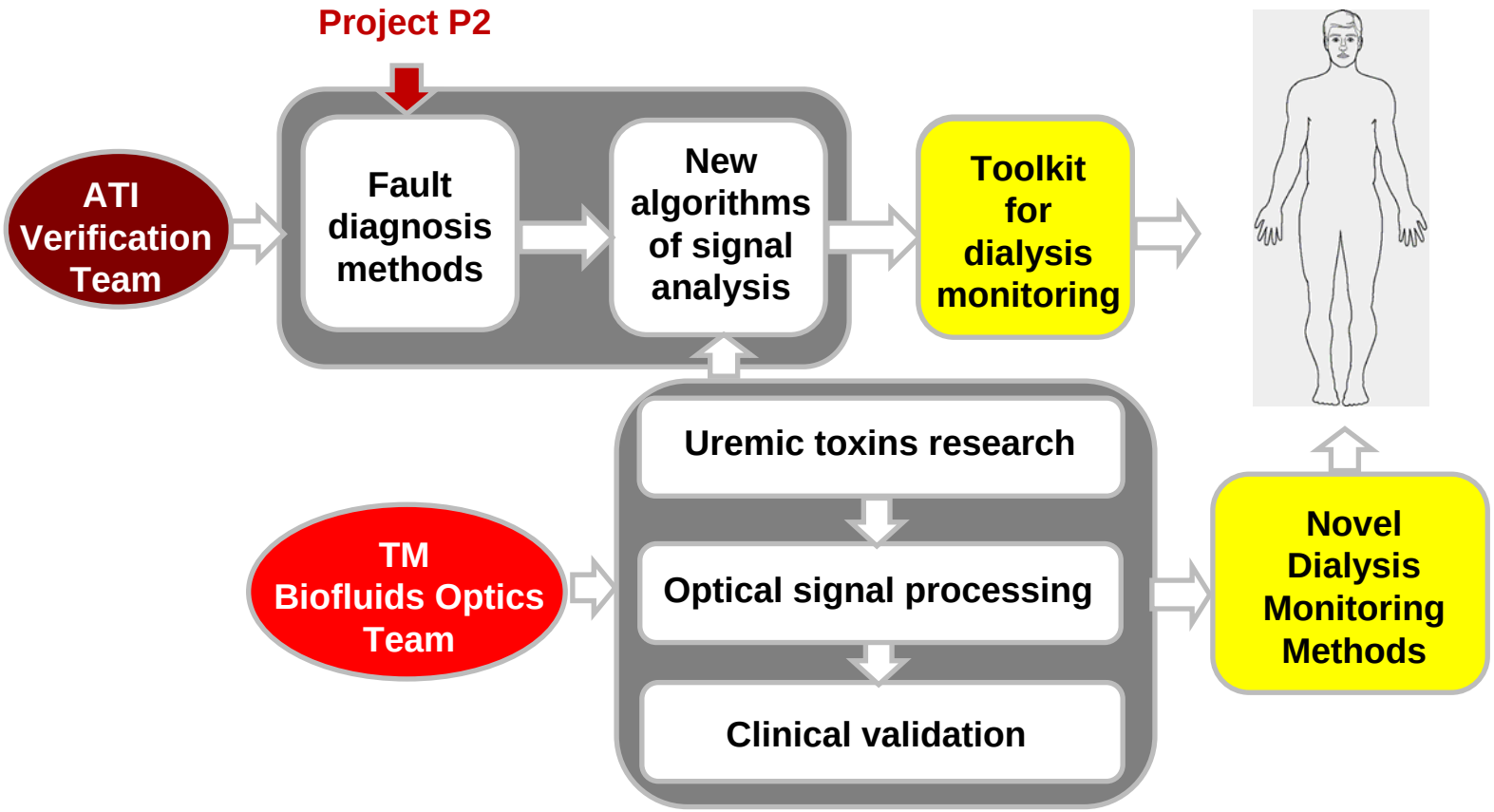
S. Kostin1, D. Karai2, A. Scherbakov2, R. Ubar1, I. Fridolin2

1 Department of Computer Engineering, Tallinn University of Technology, Ehitajate tee 5, 19086 Tallinn, Estonia
2 Department of Biomedical Engineering, Technomedicum, Tallinn University of Technology, Ehitajate tee 5, 19086 Tallinn, Estonia

Centre for Integrated Electronic Systems and Biomedical Engineering (CEBE)
Tallinn University of Technology

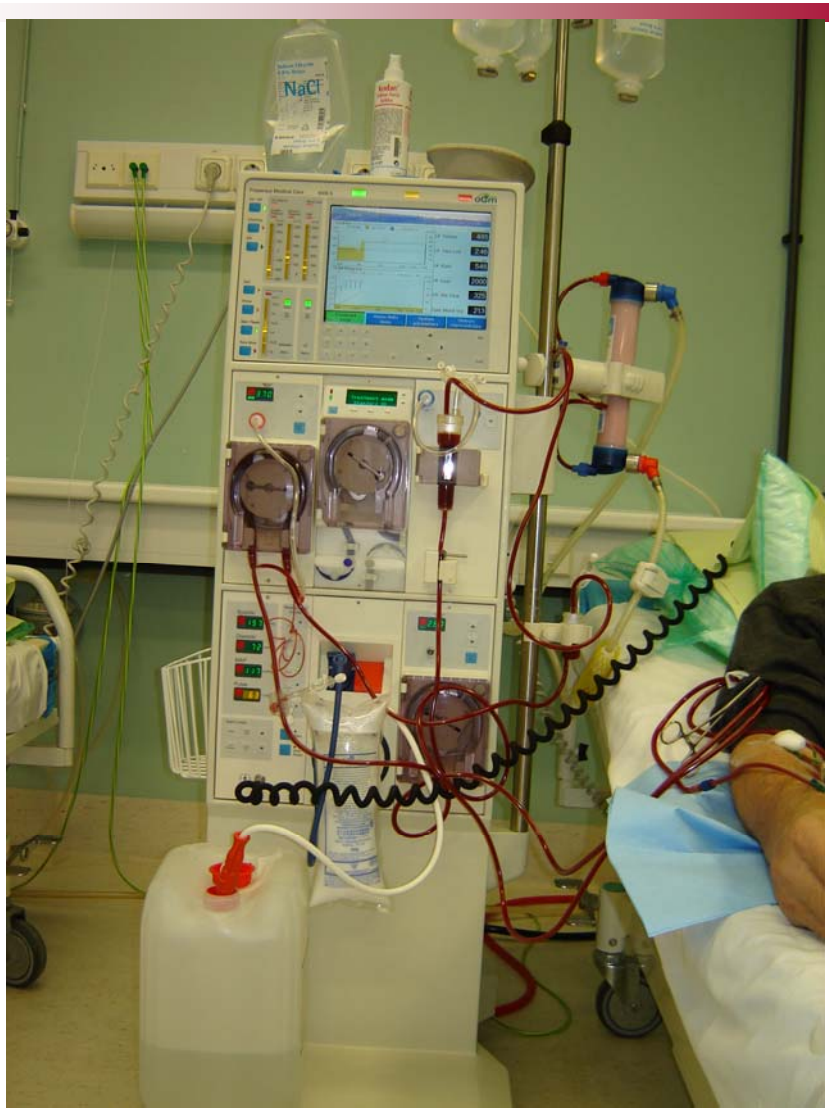
www.cebe.ttu.ee

Cooperation Project P5



Dialysis dose

- ✓ Many studies have shown a relationship between dialysis dose, measured as *Kt/V* and morbidity and mortality among haemodialysis patients.



Dialysis dose

HD dose should be expressed in terms of equilibrated Kt/V (eKt/V) with the rate equation based on the regional blood flow two-pool urea kinetic model (evidence level: B).

European Best Practice Guidelines Expert Group on Haemodialysis. Nephrol Dial Transplant 2002: 17(Suppl 7): S16–S31

4. Minimum adequate dialysis
Guideline 4.1
In anuric patients, treated by three times per week dialysis, the prescribed target eKt/V should be at least 1.2. …

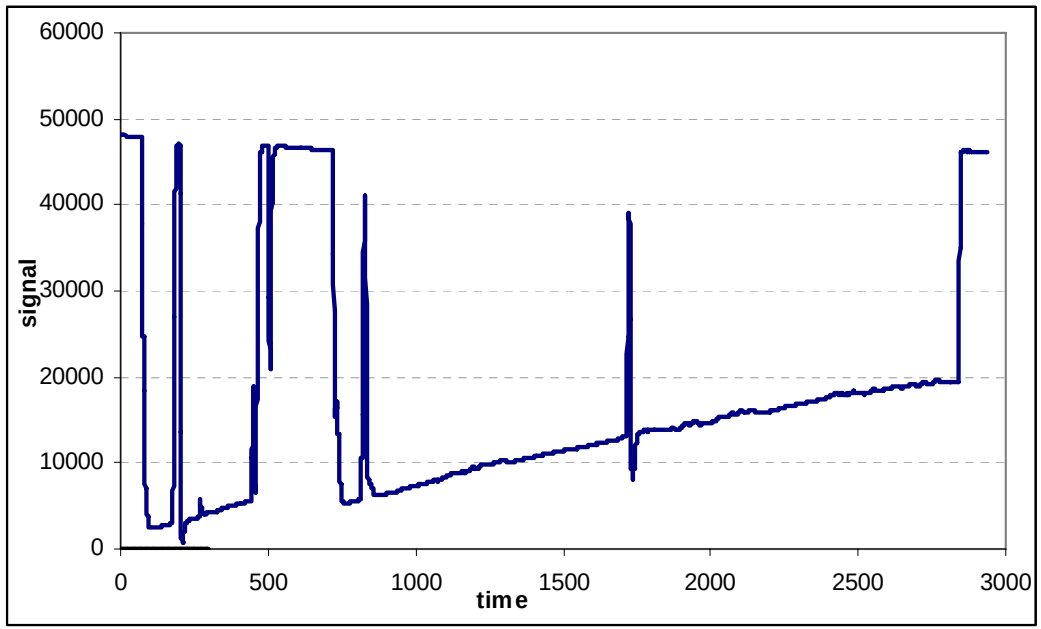
Tattersall, J., A. Martin-Malo, et al. (2007). "EBPG guideline on dialysis strategies." Nephrology Dialysis Transplantation 22: 5-21.

Aims of P5

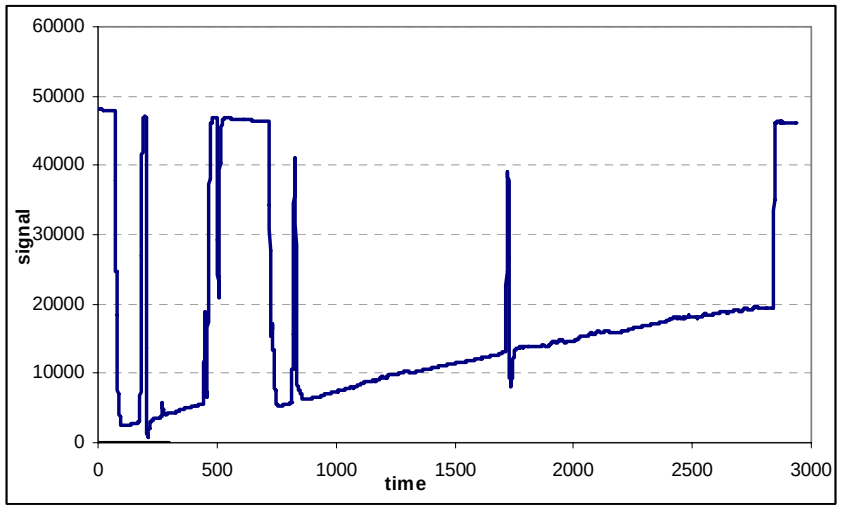
- ✓ **Specific target** is to work out signal processing algorithms for highly reliable and disturbance free dialysis dose estimation during the dialysis therapy by the optical monitoring technique.
- ✓ **The final aim** will be deliver **a practical toolkit for the clinicians** helping obtain adequate dialysis targets meeting the individual needs of each patient and leading to “personalized healthcare” within haemodialysis.

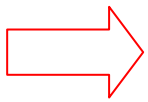
Sources of disturbances during dialysis

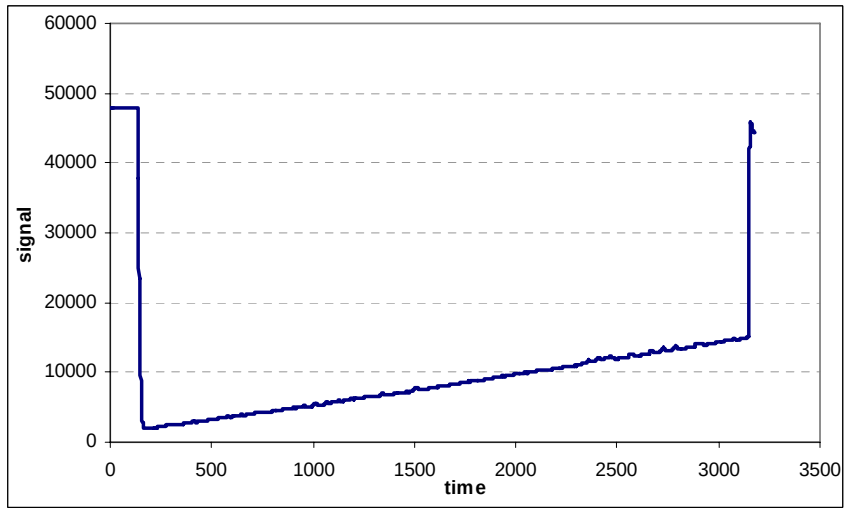
- ✓ Blood pressure changes
- ✓ Needle displacement
- ✓ Concentrate depletion
- ✓ Machine self-tests
- ✓ Air bubbles



Disturbance-free estimation of dialysis dose





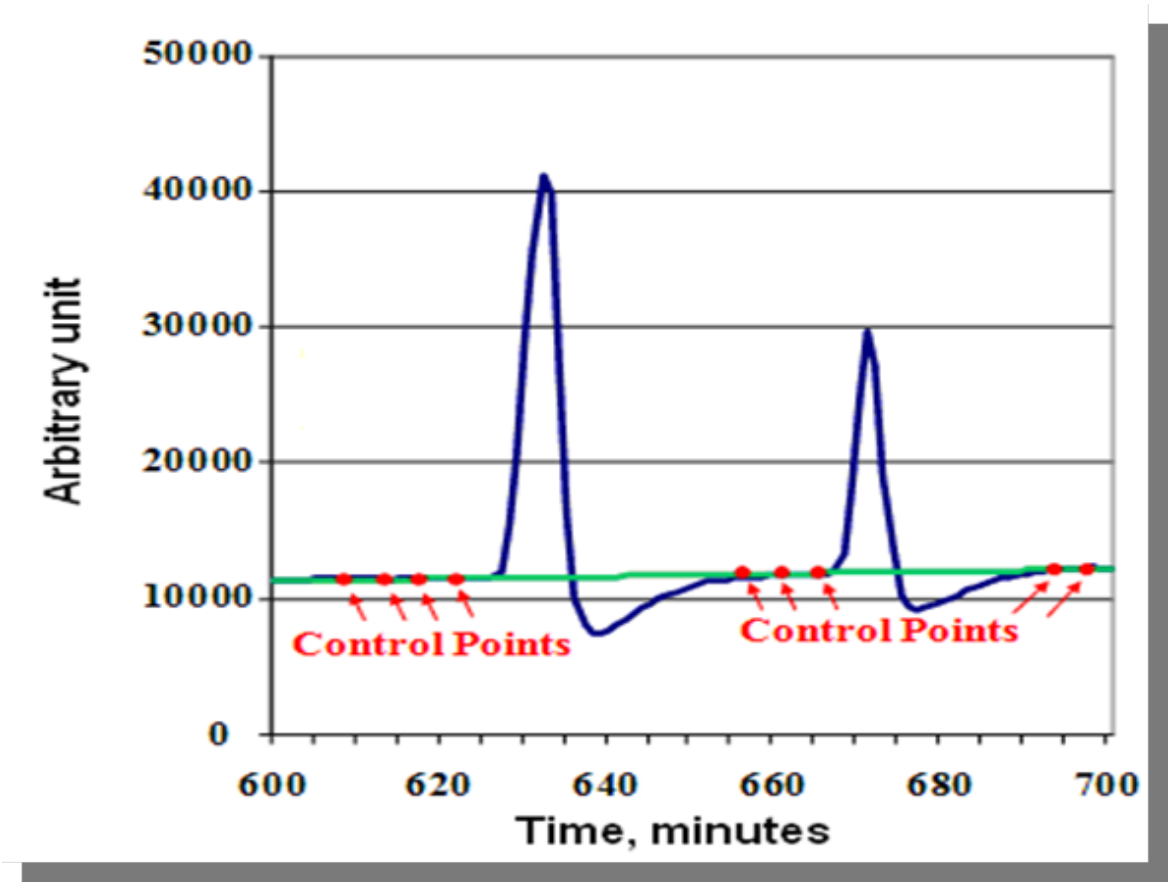


✓ Unstable dialysis

✓ “Pseudo Stable” dialysis

Smoothing alghorithms

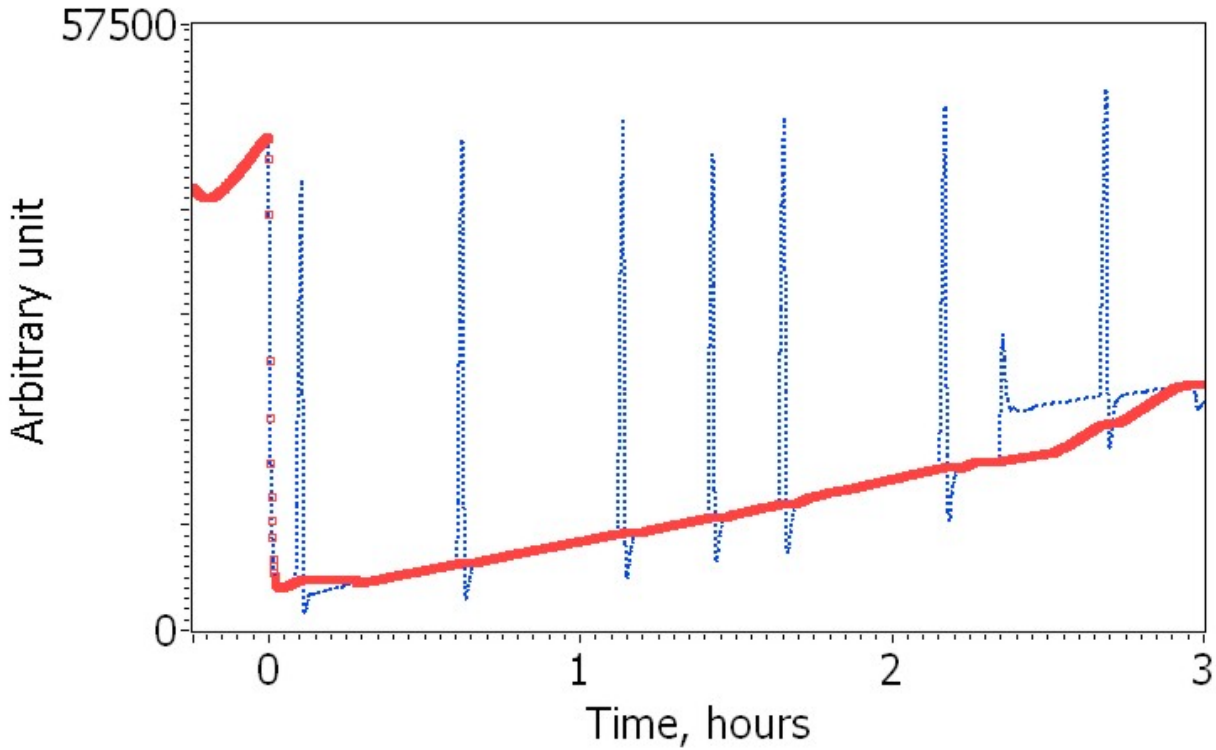
- ✓ Median filtering;
- ✓ AVRG
- ✓ SMART



Clinical evaluation: Patients

- ✓ The study included 20 treatments in total from 5 uremic patients, 3 male and 2 female performed in North-Estonian regional hospital. All patients were on chronic thrice-weekly haemodialysis therapy and standard procedure duration varied between 180 and 240 minutes. All patients were dialysed with polysulfone membrane dialysers (Fresenius Medical Care, Germany). Blood tests were performed in the hospital laboratory.
- ✓ All treatments were monitored by DiaSens which is a commercially available optical monitoring device that uses UV-radiation for constant monitoring of haemodialysis treatment and calculates *Kt/V* value.

New smoothing algorithms: an example



- ✓ The results of the given algorithms outperform previous ones in some aspects: no sudden impetuous rises and falls, the signal is more monotonous and smoother.

New smoothing algorithms: validation

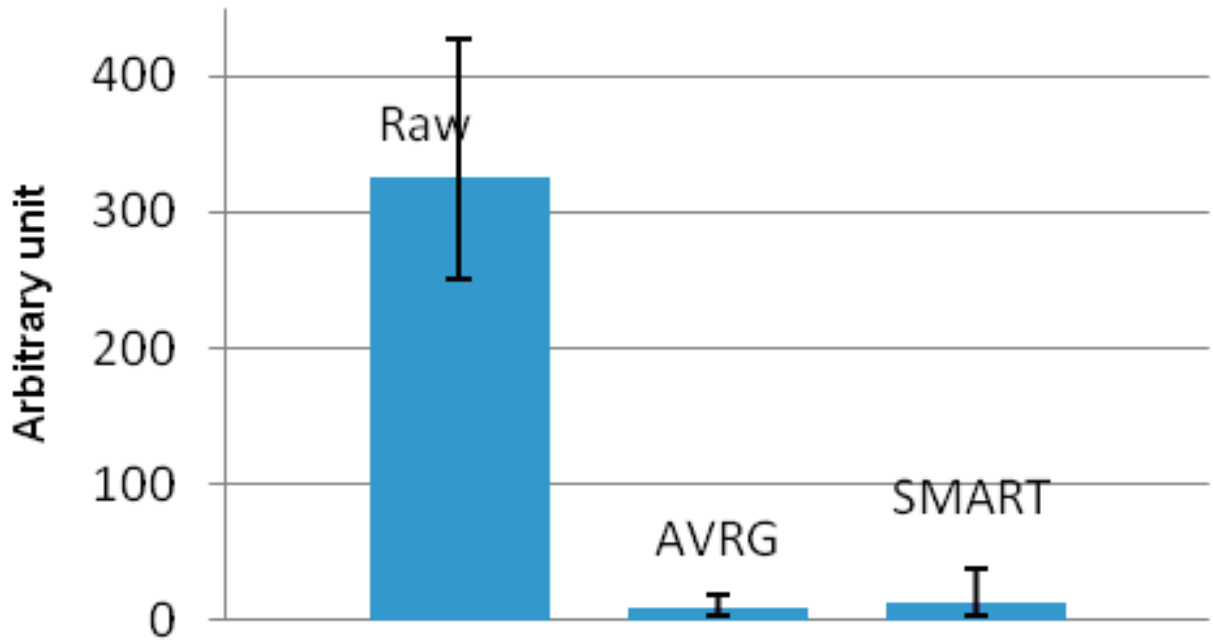
- ✓ In order to give quantitative estimation for all algorithms an instability coefficient was introduced.

$$InstabCoeff = \sum_{i=1}^{n} \frac{\left| Raw_{i+1} - Raw_i \right|}{n}$$

- ✓ In order to assure that signal processing does not have any adverse effect a comparison with *Kt/V* values obtained by laboratory measurements of urea concentration was performed using standard *RMSE* (Root Mean Square Error) coefficient:

$$RMSE = \frac{1}{n} \sum_{i=0}^{n-1} (x_i - y_i)^2$$

New smoothing algorithms: Instability coefficients

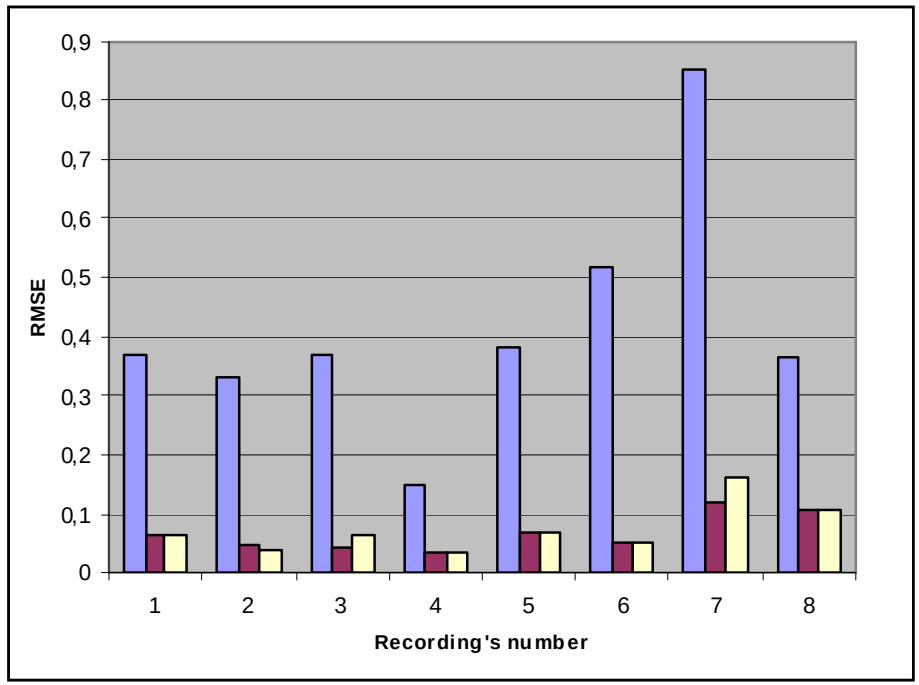


- ✓ The value of the instability coefficient for processed signal is almost 30 times lower than for raw data, which allows us to assert that generally both algorithms fulfil their primary task of removing disturbances.

Kt/V RMSE: blood samples compared by processed signals

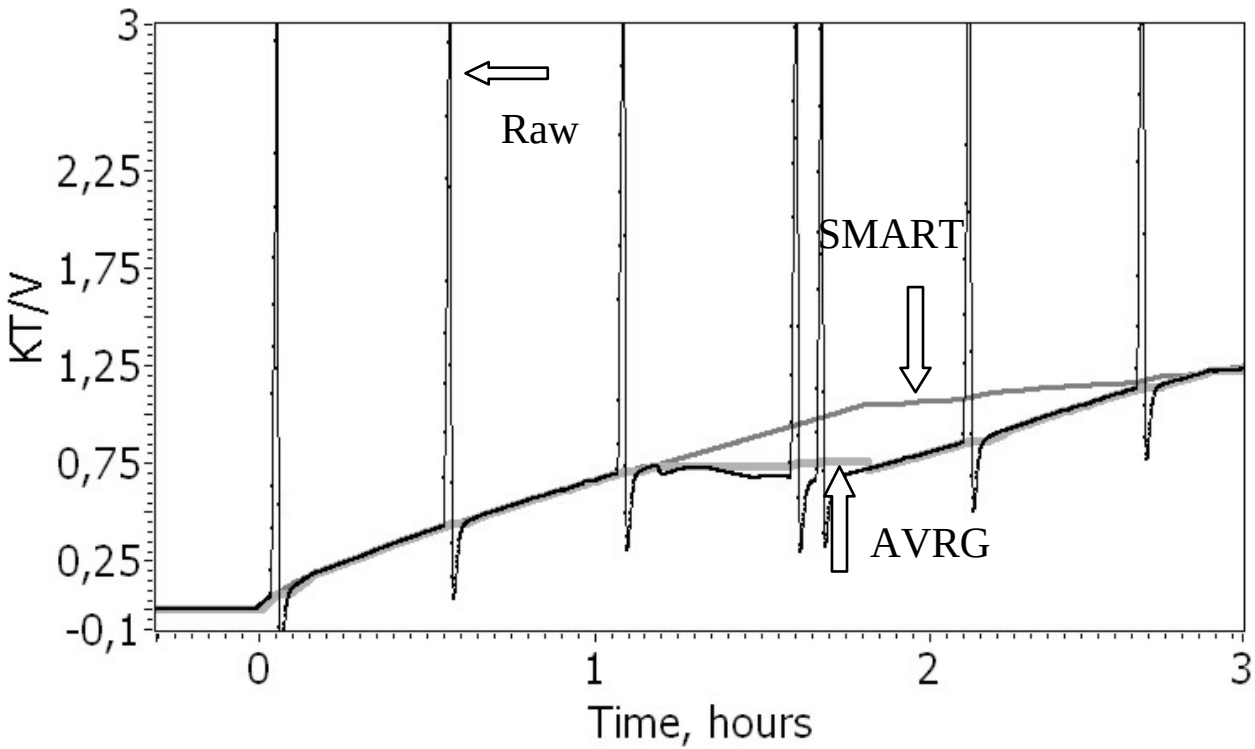
- ✓ **For all material**

Raw	AVRG	SMART
0,42 ± 0,20	0,07 ± 0,03	0,07 ± 0,04



- ✓ **For a single treatment**
  - **Blue**: *RMSE(*blood vs raw)
  - **Red**: *RMSE* (blood vs AVRG)
  - **Yellow**: *RMSE(*blood vs SMART)

On-line dialysis monitoring curves from Raw, AVRG and SMART algorithms



- ✓ An example for a single HD treatment

Conclusions

- ✓ Signal processing by both AVRG and SMART algorithms has a significant positive effect on data visualization for the doctors.
- ✓ Both algorithms show substantial improvement on both chart readability and measurement precision.
- ✓ Additional calculations introduced in AVRG add stability to measurement results.
- ✓ Comparison of modelled signals for different experiments indicates that in some cases AVRG outperforms SMART and vice versa, depending on raw signal behaviour.
- ✓ Given algorithms can be even improved when the causes and behaviour of raw signal disturbances will be more explored.

Conclusions II: a joint publication

- ✓ A. Talisainen, S. Kostin, D. Karai, I Fridolin, R. Ubar, “On-line Monitoring of Dialysis Adequacy Using Diasens Optical Sensor: Accurate Kt/V Estimation by Smoothing Algorithms“, 2010 12th Biennial Baltic Electronics Conference (BEC2010) in Tallinn, Estonia October 4-6, 2010. (Accepted)
- ✓ Synergy between the ATI Verification Team and TM Biofluids Optics Group starts to emerge within the CEBE sub-project P5.

Future

- ✓ Implement algorithms in “unvisible” way – aim is to present a simple parameter for clinicians (e.g. Pass/Fail)
- ✓ Associate the signal distorsions with the real clinical cause – **“treatment log”**;
- ✓ **A practical toolkit for the clinicians** leading to “personalized healthcare”

RESEARCH OBJECTIVES AND COOPERATION IN CEBE

APPLICATIONS

BIOSIGNALS
biosignal interpretation methods

BIOENGINEERING APPLICATIONS
health monitoring systems, body area sensor networks, implantable cardiac pacemakers, labs-on-chips

INDUSTRIAL APPLICATIONS
food processing, medical instrumentation, energy conversion, alternative energy

From quantity through collaboration to synergy

DATA ACQUISITION
bioimpedance, biosignals, brain electrical oscillations, biooptical methods

SIGNAL PROCESSING
algorithms

MISSION CRITICAL EMBEDDED SYSTEMS

TECHNOLOGY

SYSTEM DESIGN
synthesis, simulation, verification, emulation

HARDWARE
beyond silicon, nano-electronics, architectures, ASP, FPGA, ASIC, SoC, NoC

TEST RESEARCH
test synthesis and analysis, debug and fault diagnosis, dependability

RELIABILITY