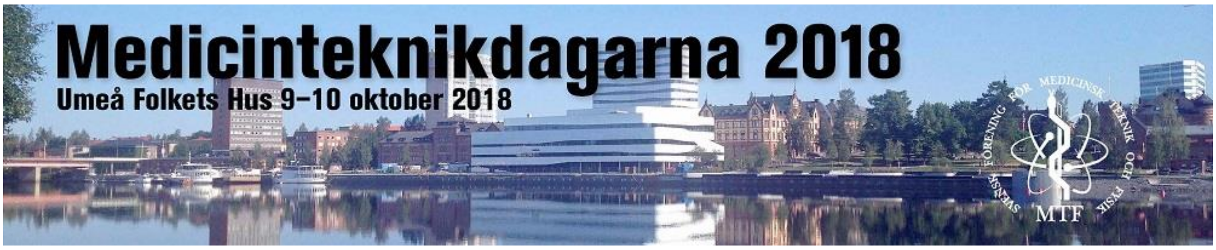

MEDICINSKA SENSORER – BIOOPTIK

Onsdag 10 oktober 14.40 – 16.10

Abstract: 67

Development of a hybrid laser Doppler flowmetry and diffuse correlation spectroscopy system

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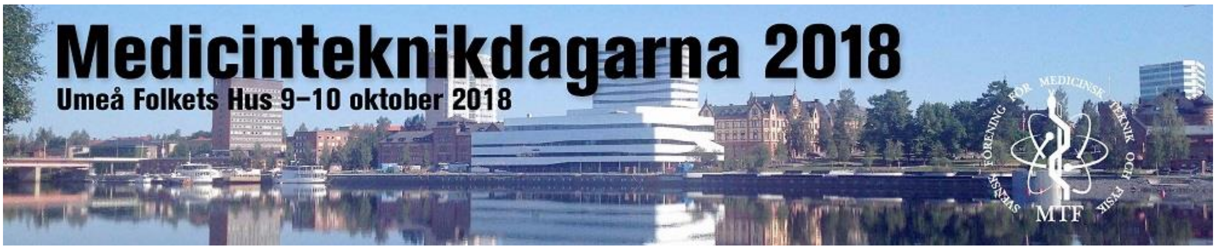
Background
Laser speckle techniques such as Laser Doppler Flowmetry (LDF) and Diffuse Correlation Spectroscopy (DCS) are useful for noninvasive monitoring changes in microvascular blood flow in tissue. LDF utilizes an array of simple photodetectors for measurements in superficial tissue, while DCS uses a single very sensitive photodetector, such as a Single Photon Avalanche Diode (SPAD), to be sensitive enough to measure deeper in the tissue. In this project, the multidetector approach of LDF and the sensitivity of DCS are combined by using a multipixel SPAD array in order to improve the signal quality.

Material and methods
The system has been tested on milk phantoms for different configurations, varying detector fiber diameter (200 and 600 µm), fiber-detector distance (2.5 – 36.5 mm), source-detector fiber separation (4.6 – 10.2 mm), contiguous measurement time for the autocorrelation (2-33 ms) and milk temperature (15.6 – 46.7 °C). The milk phantoms were illuminated by 780 nm light from a commercial LDF system and the detected light from 4 adjacent detectors of the SPAD array were used to calculate a difference autocorrelation, gd, based on the light intensity difference between two pixels at a time. Traditional DCS intensity autocorrelation, g2, based on each detector at a time was also calculated. Least squares fitting was then done to obtain Brownian diffusion coefficients (Db) from gd and g2.

Results
Similar values of Db were obtained for fitting to gd and g2 while varying the temperature of the phantoms. The hybrid approach (gd) improved the signal-to-noise ratio (SNR) at shorter source-detector separations of about 5 mm and benefitted from larger detector fiber diameter or shorter fiber-detector distance where there are more speckles on each detector. For traditional DCS (g2), optimal SNR was obtained for detector fiber diameter and distance corresponding to one speckle per detector. SNR improved by multiple speckles per detector for both approaches when increasing the source-detector separation to 10.2 mm. It was also found that having a longer contiguous measurement time for the autocorrelation was more important for the SNR than would be expected from signal averaging alone.

Conclusion
The hybrid LDF/DCS system is operational and beneficial, but would benefit from improvements regarding optimal settings and hardware.



Abstract: 129

Multispectral snapshot imaging of skin tissue for blood volume fraction and saturation estimation

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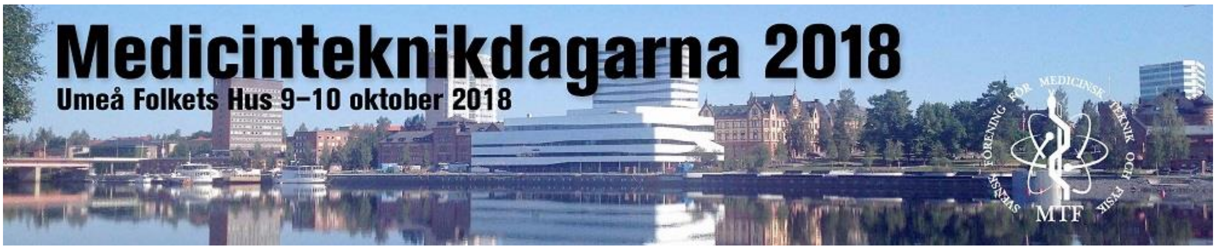
Background
Tissue saturation and blood volume fraction are important measures when evaluating the health state of skin microcirculation. The two properties are valuable indicators of tissue well-being, and imaging of those, spatially and temporally, can be used in diagnostic and therapeutic applications, especially i.e. wound healing and treatment follow-up.

Methods
We use a XIMEA xiSpec camera (MQ022HG-IM-SM4X4-VIS, XIMEA®, Germany) to optically capture diffusely backscattered light from skin tissue on forearm. The collected data is spectrally resolved in every pixel position in 16 wavelength bands in the range 470-630 nm, distributed in a mosaic pattern on the detector. The maximum temporal and spatial resolution is 170 multi spectral cubes per second using 512x272 pixels. 24 healthy subjects are admitted to a study with a protocol including baseline and arterial and venous occlusion. After five minutes of baseline, a cuff placed around the upper arm is inflated to 200 mmHg (arterial) and 60 mmHg (venous). The pressure is held constant for five minutes and then released immediately, whereafter data collection continues for another ten minutes. Collected spectra are compared to Monte Carlo simulation of photon propagation for a two layered tissue model where scattering and absorption properties are varied by values relevant for human skin tissue. A non-linear maximum-likelihood analysis of measured and simulated spectra finds the best fit and returns estimates of tissue saturation and blood volume fraction. A probe based reference method, EPOS (PF6000 Enhanced Perfusion and Oxygen Saturation monitor, Perimed AB, Sweden), is used to compare with the estimated values. The EPOS probe is placed on the skin in close vicinity of the xiSpec region of interest (ROI), and measurements are recorded simultaneously.

Results
During the two occlusions, markedly dynamic changes occur: a decrease in tissue saturation (complete extraction during arterial occlusion) and increased blood volume fraction.The xiSpec camera capture both tissue saturation and blood volume fraction changes with dynamics similar to the reference EPOS system. While blood volume fraction values are relative, saturation measures correlate well to the reference measures in absolute values, ranging from 0% (late occlusion) to well over 80% (immediately after release) for almost all subjects.

Conclusion
With our camera-based technique, it is possible to capture the same dynamic changes in tissue saturation and blood volume fraction during occlusion tests, as we do with the EPOS probe system used as reference. With faster analysis methods, it is possible to present spatially and temporally resolved tissue saturation and blood volume fraction data with high resolution.



Abstract: 148

Microwave technology for detecting abdominal bleeding

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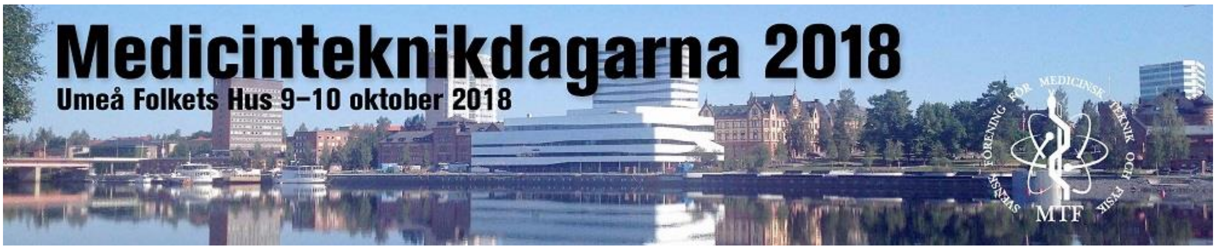
Background
Injury accounts for 10 % of global mortality, and tens of millions new victims every year face lifelong disabilities. A significant proportion of traumatic deaths are preventable if detected and treated earlier. Hemorrhage represents a substantial proportion of preventable deaths. Hemoperitoneum (abdominal bleeding) is one injury that is frequently lethal and challenging to detect in the prehospital setting. Ultrasound can be used for detection, but it requires a trained operator and is currently rarely used in prehospital care. In this study, we have evaluated the potential for microwave technology to detect hemoperitoneum.

Material & Methods
A porcine model of hemoperitoneum using anesthetized pigs was developed. A belt with eight microwave antennas was strapped around the pig's abdomen. Measurements spanning a frequency interval of 0.1–2.0 GHz were performed on ten pigs, and hemoperitoneum of 500 mL and 1000 mL were induced using the pig's own blood and compared to baseline (no bleeding).

Results
The blood accumulated predominantly around the midaxillary line on both sides of the body, as confirmed by ultrasound. Therefore, we compared the transmission coefficients for the two outer antennas of the belt, placed close to the midaxillary line. Visual inspection revealed that the bleeding dampened the magnitude of the signal, as was expected due to the high electrical conductivity of blood. An ANOVA test confirmed that the reductions of the magnitude, derived by calculating and comparing the area under the curves, for both the 500 mL and 1000 mL levels were statistically significant for both sides ($p < 0.05$).

Conclusions
The results indicate that microwave technology has potential for detecting and monitoring hemoperitoneum. However, the baseline signals for the different pigs varied substantially, likely due to anatomical differences, which complicates detection. This warrants further studies to explore how the changes in magnitude due to hemoperitoneum can be effectively identified despite baseline variations.



Abstract: 100

Assessing visual quality and optimization of intraocular lenses with numerical 3D ray tracing based on measured corneal elevation data

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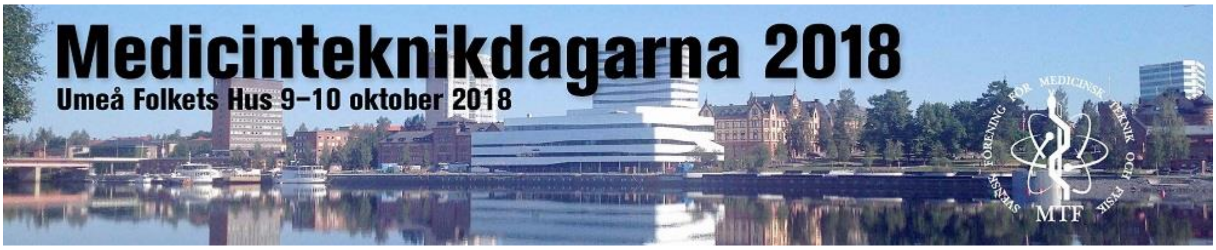
Background
Certain non-inflammatory conditions in the cornea of the eye result in advanced refractive errors that cannot be corrected with regular glasses or contact lenses. Keratoconus is an example of such a condition when the cornea gradually becomes thinner with an irregular shape. About 1/1500 suffer from the disease [1], which corresponds to approximately 7000 individuals in Sweden. By means of a 3D ray-tracing model, based on measured corneal elevation data, we evaluate the long-term visual effects of two regimens of corneal crosslinking (CXL) treatment of 48 patients suffering from keratoconus. We also show a new procedure to optimize the geometry of a personalized intraocular lens (IOL) to compensate for the aberrations as a result of the corneal irregular shape.

Methods
The 3D ray tracing procedure is based on Snell's law of refraction and numerical computation of the ray-intersection coo-ordinated at the refracting surfaces of the eye optical system [2]. The shape of the cornea surfaces is measured by Scheimpflug photography (Pentacam® HR; Oculus, Inc. Lynnwood, WA). Spot diagrams, RMS-values and Strehl ratios were evaluated for the patients prior to and 1, 3, 6 and 12 months after CXL-treatment, respectively [3]. For the lens optimization procedure, we introduced a mathematical shape description of the posterior IOL surface by means of a tensor product cubic Hermite spline. We also optimize the IOL lens surface for a combined on-axis and a set of off-axis incident rays [4].

Results
We analyzed the change of visual quality for 22 patients treated with standard CXL (applied uniformly across the corneal surface), and for 26 patients who underwent a customized, refined treatment only at local zones on the cornea (Photorefractive Intrastromal Crosslinking; PiXL). It was found that the group of patients treated with PiXL attained a long-term improvement of the corneal optical performance, whereas only minor changes of the optical parameters were found for group treated with standard CXL. For the lens optimization, it was shown that it is possible to considerably reduce the aberrations with only minor perturbations of an ideal spherical lens. In the combined analysis of on- and off-axis incident rays, the optimized lens results in significantly smaller aberrations; the RMS values reduce by a factor of 18.3 and 7.9 for on- and off-axis rays, respectively.

Conclusions
Our results confirmed that standard CXL-treatment stabilizes the corneal optical quality over time. In addition to stabilization, the PiXL-treatment also might improve the optical quality over time. Moreover, the lens optimization procedure is promising as a basis for the design of personalized IOLs.

References*: [1] Rabinowitz Y., Keratoconus, Surv Ophthalmol 42, 297–319 (1998). [2] Schedin S., Hallberg P., Behndig A., Three-dimensional ray-tracing model for the study of advanced refractive errors in keratoconus. Appl. Opt. 55(3),507-514, (2016). [3] Schedin S., Hallberg P., Behndig A., Analysis of Long-term Visual Quality with Numerical3D Ray Tracing after Corneal Cross-Linking Treatment, Applied Optics, 56 (35), 9787-9792, (2017). [4] Wadbro, E; Hallberg; Schedin, S, Optimization of an intraocular lens for correction of advanced corneal refractive errors, Appl. Opt. 55(16), 4378-4382, (2016).*



Abstract: 141

Biomedical imaging spectroscopy using structured illumination: Arterial occlusion experiments

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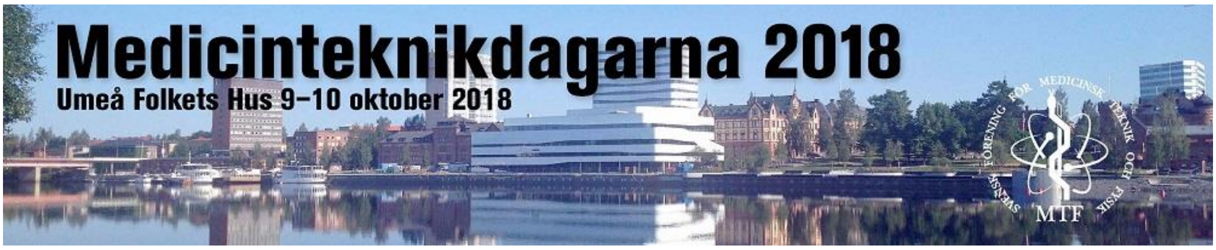
Spectroscopic imaging of human tissue analyzes backscattered light intensity separated by wavelength. In this study four cameras with optical bandpass filters in the 450-700 nm range were used during structured illumination with white light. We used a DLP-projector illuminating sinusoidal patterns with varying phase and varying spatial frequency on forearm skin. The detected images were processed with a demodulation scheme, assessing tissue optical parameters, involving light absorption. Calibration was done using an optical phantom with known optical properties. From the absorption coefficient the concentration of skin blood and its oxygenation was determined. We will present results from forearm arterial occlusion and release experiments using two set-ups with varying optical filter properties. Specifically, the effect of the filter bandwidth will be evaluated.



Abstract: 94

Microwave Sensor System for Biomedical applications

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Background
Stroke and trauma together affect over 30 million patients annually and create substantial economic burden to the society. Early action is crucial for an effective treatment. Due to the lack of early detection solutions on the market, stroke and trauma patients suffer a high death rate, and a large portion receive inadequate treatment. Microwaves has proven its high potential as a prehospital diagnostic tool, which could largely improve the survival rate. During medical diagnosis, the measurement and monitoring of vital sign such as heart rate, and respiratory rate are important as they can provide critical information needed to make life-saving decisions. we developed a time domain microwave sensor system which was completely based on off-the-shelf components. In this work we will investigate the system for both medical diagnosis and vital sign detection.

Method and results
A realistic measurement scenario was considered. It is an experimental imaging tank for breast cancer detection developed by our group. Inside the tank, there is a circular antenna array composed of sixteen monopoles. A cylindrical plastic box resembling a breast was placed at the center of the antenna array, and the box was filled with the mixture of water and glycerin, which has the similar dielectric properties as the breast tissue. The surrounding space was filled with a lossy matching liquid which is also the mixture of glycerin and water, but with a different ratio. We chose one antenna for transmitting, and then measured the signals acquired by the two antennas which are closest and most distant to the transmitting antenna by using the developed system and a conventional vector network analyzer (VNA) respectively.

The results show that the transmission coefficient between the neighbouring antennas obtained by using the presented system agrees well with the VNA measurement. For the farthest antenna pair, the obtained results agrees well with the VNA data when the attenuation is less than 100 dB. It is indicated that the developed system has a comparable measurement accuracy as the VNA. For the investigation on the vital sign detection, in total seventeen tests were made on three different persons who tried to breath according to the BPM set by a metronome. People stood (or sat) with different distance (5 ~ 50 cm) to the antennas. The received data was processed and the success rate is 100%. Then we made a study on the detection of both the respiratory and heartbeat rate. In the test, the person sat with his back towards the antennas and the distance is about 3 cm. The metronome was set at 18 BPM and the heartbeat rate was measured by a an electrocardiogram (ECG)(Plessey PS25003 EPIC Demonstration Kit) device.

The results shows that both the respiration rate and heartbeat rate are successfully detected. Conclusion This work presents a high performance time domain microwave system for biomedical applications and it suggests the possibility to use the same hardware for medical diagnosis and vital sign detection.