BIOMEDICAL ENGINEERING RESEARCH GROUP (BME)

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Scientific Progress

Cardiovascular and respiratory system research

We are studying methods of synthesizing VCG-like signals from measurements with a reduced number of leads. In this way, fewer electrodes than normal need to be used in measurements, but the signal can be reconstructed with high enough accuracy to perform vectorcardiographic or standard ECG lead based analyses. We are exploring novel non-linear systems theory based approaches. Similarly to the ECG, respiration flow yields important information on many disorders and problems such as cardiac disorders, asthma, obstructive pulmonary diseases and sleep apnea. We have developed novel ECG-derived respiration (EDR) methods. The performance is proven to surpass that of many current methods in the literature, as the new EDR-signal has a strong correlation and coherence with chest band based respiration measurements.

The multiple linear regression technique with two predictor variables has been used commonly since the 1980's for calibration of respiratory effort belts. However, this method yields only crude predictions of the waveforms in the airflow signal. We developed an improved calibration method that uses an optimally trained FIR filter bank and Multiple-Input Single-Output system model. Our FIR filters perform optimal linear transforms of the belt signal waveforms in order to match them to the spirometer signal waveform, which makes the result of the prediction much more accurate than with the standard method. The method can be used in pulmonary and critical care medicine.

Central nervous system research

Hypoxic ischemic encephalopathy (HIE) is a severe complication of cardiac arrest (CA). At the moment, no reliable technological solution for early estimation of HIE after CA exists. Even though quantitative EEG analysis has recently shown promising results as a tool for diagnostic monitoring of HIE, the effects of anaesthetics during intensive care can potentially disrupt the interpretation of the signal. We gathered a unique data set from CA patients in the early phase of recovery, in which the combined effects of HIE and anaesthetics on EEG are investigated. In the future, this data will be used in the development of a novel technology for diagnosing HIE.

Emotions are fundamental for our everyday life, affecting communication, learning, perception, and decision making. Including emotions into human-computer interaction (HCI) would be a significant step forward, offering great potential for the future in the development of novel technologies. We investigated the selection of a subject-independent feature set for EEG-based emotion recognition. Features were selected to classify a person's arousal and valence while watching videos with emotional content. Optimization of the feature set was carried out. The best classification rate, substantially improving the rate reported in the literature, was obtained with a set containing power spectral features.

Musculoskeletal system research

Current clinical diagnostic tools have only limited ability to assess fracture risk or early osteoarthritis at an individual level. Using a biomechanical approach and advanced image analysis, we have shown that structural parameters can discriminate femoral neck fractures from controls. Assessment of the trabecular structure using texture analysis of radiographs appears to be a promising method. We showed that a homogeneity index assessed by texture analysis of conventional radiographs can explain 50% of experimental failure load and determines bones with high fracture risk with similar accuracy to bone mineral density (BMD). We have developed computational finite element (FE) models and shown that FE analysis can yield reasonable accuracy in the assessment of experimental failure load. We also showed that dual-energy digital radiography (DEDR) can be applied for bone assessment, and it correlates well with the mechanical properties of bone. We also demonstrated that the novel axial transmission ultrasound technique can discriminate fracture subjects from controls with similar accuracy to that of DXA.

In collaboration with researchers from the University of Eastern Finland and Mikkeli Hospital, we have developed multimodal technology for the detection of early degenerative changes of articular cartilage. We have demonstrated quantitative magnetic resonance imaging (MRI), ultrasound, and spectral infrared spectroscopy as potential tools for improved clinical diagnostics. Novel quantitative MRI techniques have been developed and proven to be more sensitive to osteochondral degeneration when compared to established techniques. Furthermore, biomedical imaging techniques suitable for quantitative 3D imaging of osteochondral tissue samples are actively developed within the group. Specifically, micro/nano-CT and MRI based techniques are being investigated. These 3D techniques improve our understanding of the pathogenesis of early osteoarthritis.

We have performed studies on the extra-skeletal risk factors, showing that reduced physical performance is a significant determinant of a fracture. We also presented a detailed wireless body area network (WBAN) scenario

utilizing the recent IEEE802.15.6 standard as applied to a multi-accelerometer system for monitoring Parkinson's disease and fall detection. Additionally, we presented an interactive, gamified activation method for increasing physical activity among young people.

Personnel

professors, doctors	13
doctoral students	20
others	2
total	**35**
person years	28

External Funding

Source	**EUR**
Academy of Finland	213 000
Ministry of Education and Culture	51 000
Tekes	375 000
other domestic public	112 000
private	6 000
total	**757 000**

Doctoral Theses

Keskinarkaus A (2013) Digital watermarking techniques for printed images. Acta Univ Oul. Technica C 441.

Koivumäki J (2013) Biomedical modeling of proximal femur: development of finite element models to simulate fractures. Acta Univ Oul. Medica D 1198.

Määttä M (2013) Assessment of osteoporosis and fracture risk - axial transmission ultrasound and lifestyle-related risk factors. Acta Univ Oul. Medica D 1192.

Selected Publications

Ahola R, Pyky R, Jämsä T, Mäntysaari M, Koskimäki H, Ikäheimo TM, Huotari ML, Röning J, Heikkinen HI, Korpelainen R (2013) Gamified physical activation of young men - a multidisciplinary population-based randomized controlled trial (MOPO study). BMC Public Health 13(1): 32.

Danilov A, Muhonen V, Tuukkanen J, Jämsä T (2013) Role of phase stress in variations of cell behavior on NiTi. Mater Sci Forum 738-739: 559-565

Enwald HPK, Kortelainen T, Leppäluoto J, Jämsä T, Oinas-Kukkonen H, Keinänen-Kiukaanniemi S, Herzig KH, Huotari MLA (2013) Perceptions towards fear appeal and preferences for feedback in tailored health communication. An explorative study among prediabetic individuals. Information Res 18(3): 584.

Herlin M, Finnilä M, Zioupos P, Aula A, Risteli J, Miettinen H, Jämsä T, Tuukkanen J, Korkalainen M, Håkansson H, Viluksela M. New insights to the role of aryl hydrocarbon receptor in bone phenotype and in dioxin-induced modulation of bone micro¬architecture and material properties. Toxicol Appl Pharmacol 273(1):219-26.

Hirvasniemi J, Kulmala KAM, Lammentausta E, Ojala R, Lehenkari P, Kamel A, Jurvelin J, Töyräs J, Nieminen MT, Saarakkala S (2013) Comparison of dGEMRIC and contrast enhanced computed tomography in imaging of articular cartilage. Osteoarthritis Cartilage 21:434-42.

Junno JA, Paananen M, Karppinen J, Tammelin T, Niinimäki J, Lammentausta E, Niskanen M, Nieminen MT, Järvelin MR, Takatalo J, Tervonen O, Tuukkanen J (2013) Influence of physical activity on vertebral strength during late adolescence. Spine J 13:184-9.

Kobrina Y, Rieppo L, Saarakkala S, Pulkkinen HJ, Tiitu V, Valonen P, Kiviranta I, Jurvelin JS, Isaksson H (2013) Cluster analysis of infrared spectra can differentiate intact and repaired articular cartilage. Osteoarthritis Cartilage 21(3):462-9.

Kortelainen J, Seppänen T (2013) Electroencephalogram-based depth of anaesthesia measurement: combining opioids with hypnotics. Trends in Anaesthesia and Critical Care 3, 270-8.

Liukkonen J, Hirvasniemi J, Joukainen A, Penttilä P, Virén T, Saarakkala S, Kröger H, Jurvelin JS, Töyräs J (2013) Arthroscopic ultrasound technique for simultaneous quantitative assessment of articular cartilage and subchondral bone: an in vitro and in vivo feasibility study. Ultrasound Med Biol 39(8):1460-8.

Moilanen P, Määttä M, Kilappa V, Xu L, Nicholson PHF, Alén M, Timonen J, Jämsä T, Cheng S (2013) Discrimination of fractures by low-frequency axial-transmission ultrasound in postmenopausal females. Osteoporos Int 24(2): 723-30.

Niinimäki S, Niskanen M, Niinimäki J, Nieminen M, Tuukkanen J, Junno J-A (2013) Modeling skeletal traits and functions of the upper body: Comparing archaeological and anthropological material. J Anthropol Archaeol 32:347-351, 2013.

Podlipská J, Koski JM, Pulkkinen P, Saarakkala S (2013) In vivo quantitative ultrasound image analysis of femoral subchondral bone in knee osteoarthritis. Scientific World Journal:182562.

Pulkkinen P, Saarakkala S, Nieminen M, Jämsä T (2013) Standard radiography: Untapped potential in the assessment of osteoporotic fracture risk. Review. Eur Radiol 23(5):1375-82

Rautiainen J, Lehto LJ, Tiitu V, Kiviranta O, Pulkkinen H, Brunott A, van Weeren R, Brommer H, Brama P, Ellermann J, Kiviranta I, Nieminen MT, Nissi MJ (2013) SWIFT Imaging of Osteochondral Repair in an Equine Model. Radiology 269:113-21.

Rieppo L, Närhi T, Helminen HJ, Jurvelin JS, Saarakkala S, Rieppo J (2013) Infrared spectroscopic analysis of human and bovine articular cartilage proteoglycans using carbohydrate peak or its second derivative. J Biomed Opt 18(9):097006.

Rieppo L, Saarakkala S, Jurvelin JS, Rieppo J (2013) Prediction of compressive stiffness of articular cartilage using Fourier transform infrared spectroscopy. J Biomech 46(7):1269-75.

Räsänen LP, Mononen ME, Nieminen MT, Lammentausta E, Jurvelin JS, Korhonen RK; OAI Investigators (2013) Implementation of Subject-Specific Collagen Architecture of Cartilage into a 2-D Computational Model of a Knee Joint – Data from the Osteoarthritis Initiative (OAI). J Orthop Res 31:10-22.

Seppänen TM, Alho O-P, Seppänen T (2013) Reducing the Airflow Waveform Distortions from Breathing Style and Body Position with Improved Calibration of Respiratory Effort Belts. Biomedical Engineering Online 12:97

Thevenot J, Hirvasniemi J, Finnilä M, Pulkkinen P, Kuhn V, Link T, Eckstein F, Jämsä T, Saarakkala S (2013) Trabecular homogeneity index derived from plain radiograph to evaluate bone quality. J Bone Miner Res 28(12):2584-2591.

Toljamo P, Pulkkinen P, Lammentausta E, Tervonen O, Jämsä T, Nieminen MT (2013) Bone mineral density and bone geometry parameters determined from dual-energy digital radiography images in the assessment of bone fragility. Acta Radiol 54: 961–965.