Ensuring Authenticity in Sensing Systems with Shimmer at BSN2015

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Wearable sensors have gone mainstream! Widespread availability of wearable sensors for kinematic and physiological data capture, with compelling form factors and lower costs, means that these types of data are easily accessible by researchers and consumers alike. For researchers, authenticity becomes a key challenge in the development of trustworthy sensing systems against a wave of new devices and intense commercial competition. Independent verification and validation is de rigueur for clinical applications, and highly valued for applications in sports and movement science, behavioural studies and aging-in-place or assistive technology.

This workshop will explore the theme of authenticity and validation for every aspect of a sensing system: from hardware and the data capture process to the algorithms that convert captured data into derived metrics and culminate in decisions that affect user outcomes. Invited speakers will present their ongoing work on the development and deployment of sensing systems based on the Shimmer platform. Each will highlight the importance of accurate performance measures and validated outcomes. During panel discussions, invited speakers and Shimmer representatives will take questions from attendees, enabling a discussion around the opportunities and challenges for authentic, validated sensing systems, and focus areas for future developments.

Workshop Schedule: 9am - 12pm, Friday, June 12th, 2015

Introduction to Shimmer
A brief overview will be provided to introduce the Shimmer platform as a tool for data-driven research and applications for those unfamiliar with the technology.

Robust and reliable data capture for large scale deployments
A Shimmer solution will be presented for the capture of data in large scale deployments, such as recording from many subjects simultaneously, while meeting requirements for robustness and reliability and ensuring confidence in the quality of captured data. This approach allows researchers to focus on the innovative aspects of their system.

Focus Area 1: Human Emotion
Shimmer will present findings from an investigation into emotional responses to media, measured from a large group of participants simultaneously. Invited speakers will present on the topic of human emotion measurement, with applications in stress detection and management, as well as relating stress to performance. See below for invited speaker abstracts.

Panel Discussion - Measuring Emotions

Focus Area 2: Human Movement
Shimmer will present the outcomes of our ongoing work in the field of gait analysis. Invited speakers will present on the topic of human movement measurement, with applications in gait analysis, balance assessment, sports and exercise, as well as clinical settings. See below for invited speaker abstracts.

Panel Discussion - Measuring Movement
Focus Area 1: Human Emotion

Stress detection using Shimmer3 biosensors

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ABSTRACT
In the ELTAB project we are examining tools to enhance the well-being of elderly people. Stress is a feeling of inexplicable anxiety, anguish and fear that can hurt the well-being of any person. In the case of elderly people, stress is the first symptom in the reaction of adaptation to physical disease that can then elaborate as depression. Physical disease in elderly usually is chronic and may deteriorate over time. In combination with other losses such as income, social status, death of friends and relatives can cause the development of adjustment disorder with depressive illness. Although there are effective methods of dealing with stress, this is often overlooked, underestimated or treated in the wrong way. Tools that can detect stress presence and provide reliable measurements in everyday environments are of paramount importance, both in a clinical context, to identify and monitor the progress of stress and in a research framework for its valid and reliable recording.

We have developed an approach to detect and monitor stress that combines and correlates on the one hand psychometric tests and on the other hand biological signals. The state-trait anxiety inventory is used to assess the stress at the moment being examined (state anxiety) and as a feature of one's personality (trait anxiety). Shimmer3 Platinum Development Kit is used to measure and log bio signals that are related to stress detection. In particular, the ECG and GSR modules are used to measure heart rate variability features (mean heart rate, mean heartbeat interval) and galvanic skin response features (skin conductance level, skin conductance response, amplitude, latency). The accelerometer is also used to differentiate between a standing and a sitting person.

Currently, we are performing a user study with the participation of 12 elderly people. Our preliminary results show that heart rate, heartbeat interval (RR intervals) and the mean GSR are good indicators of stress.

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Individual Performance Calibration using Physiological Stress Signals

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ABSTRACT
The relation between performance and stress is described by the Yerkes-Dodson Law but varies significantly between individuals. The aim of this work is to use the Yerkes-Dodson Law to design an individual performance curve using physiological responses. We developed a method for determining the individual's highest performance as a function of physiological signals. This method is based on Stroop-type color and mathematical operation tests. Four physiological signals are simultaneously monitored: Blood Volume Pressure (BVP), Galvanic Skin Response (GSR), Heart Rate (HR), and Electromyogram (EMG).

Three sensors were used for data acquisition: Shimmer3 "GSR Unit" was used to capture BVP and GSR signals, placed in the arm. A second Shimmer3 "ExG Unit" was used to collect EMG signals and the last Shimmer3 "ExG Unit" acquired ECG signals.

The experiment consists on five consecutive stages: deep breathing (4 minutes), Stroop naming test (4 minutes), deep breathing (4 minutes), maths operations (5 minutes) and deep breathing (3 minutes). Each test was divided in seven consecutive parts of increasing complexity. We consider the number of correct responses in percentage as the performance level for each individual. Fifteen healthy volunteers were recruited to undergo the experiment. The average age of the participants was 28.13 years (SD = 4.22).

From this experiment we obtain the following conclusions:
1. Two of the signals, GSR and ECG, have discriminative power to distinguish between relaxation and stress periods.
2. There exists a positive correlation between the complexity level of the tests and the GSR and ECG signals.
3. The part just before the number of correct responses decrease is considered the highest performance level of the Yerkes-Dodson Law.

Our results show that the increment of HR during the maths operations test is more sensitive to increase than in the Stroop color test. We can also observe for each individual how much HR and GSR features increase. Taking into account that one of the main aims of this paper is to study individuals response to stress situations, the results show how the subjects psychological signs behave in different ways.
Use of Inertial Sensors and Depth Cameras for Application in Exercise Feedback and Functional Screening Tools

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ABSTRACT

Athletic screening is an important component of injury prevention and rehabilitation. However, screening can prove time consuming and the data collected is often unreliable. This leads to inefficient time management and poor decision-making. Recent developments in Inertial Measurement Units (IMUs) and Red Green Blue Depth (RGBD) cameras may allow for automated screening tools that can produce valid and reliable data. It is expected that by using sensor fusion techniques, inertial and RGBD sensor technologies will provide a comprehensive biomechanical analysis of human movement. These can then be adapted to aid the collection of data using common screening tools.

RESEARCH CHALLENGE

An inertial motion capture system needs to be developed that allows real-time analysis of the results. The system needs to be able to accurately track and distinguish between symmetrical and asymmetrical movement patterns. This will require the use of advanced machine learning algorithms to process the raw sensor data. The system needs to be able to adapt to different body types and movement styles, and it must be able to handle a large amount of data efficiently.

RESEARCH OUTPUTS

Initially a suitability study involving 22 strength and conditioning trained participants was conducted to ascertain whether IMUs and RGBD cameras can be used to statistically discriminate between different levels of performance in the squat, lunge, single leg squat, deadlift and tuck jump. Data were analysed in order to extract common features to allow recognition and evaluation of these exercises. Preliminary data analysis displayed the ability of a single sensor on the lumbar spine able to detect good vs bad squat technique with 83% accuracy.

FUTURE DIRECTIONS AND TRANSLATION

It is hoped that further data collection will help in the development of a robust classification system that will allow for the recognition and evaluation of movement. This will aid the development of automated screening tools to detect potential deficiencies in form and enable low cost biomechanical analysis for screening and rehabilitation purposes. It is expected that these tools will be evaluated in a clinical setting against therapists who screen athletes regularly. During this period qualitative data will be gathered from the therapists highlighting how the system could be improved or modified.

The Use of Inertial Sensors in Health Applications

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ABSTRACT

Between 37 and 70% of recreational runners sustain an overuse injury every year due to high impact forces and accelerations, produced when the foot strikes the ground. Given the unilateral (one-sided) nature of many injuries, asymmetrical running may be a primary cause of injury as associated compensatory actions could place excessive loads on tissues within the body. Alternatively, if not the cause, asymmetries may be an early indicator of an underlying injury. Either way, identifying running asymmetry may facilitate more effective injury detection and/or management.

Human motion analysis technologies have been widely employed to identify injury-determining factors, including asymmetries, and provide objective and quantitative feedback to athletes to help prevent injury. However, most of these technologies are: expensive, restricted to laboratory environments, and can require significant post processing. This reduces their ecological validity, adoption and usefulness. We present a novel wearable inertial sensor framework (Shimmer 3, Shimmer, Ireland) to accurately distinguish between symmetrical and asymmetrical running patterns in an unconstrained environment, and evaluate the use of inertial sensors placed on the tibia and femur bilaterally, and the central upper back. High-g sensors (range 200g) were used on the tibia. We evaluated the ability of the framework to detect asymmetry with: (i) different classification methods, (ii) different data domains - time, frequency and combined time-frequency domains, and (iii) the minimum number of sensors needed. The best results were obtained using Shimmer 3 devices (9DoF) as their gyroscope is able to detect angle velocity up to 2000 degrees per second and we appreciate the opportunity of having two accelerometers – one for wide range acceleration detection and another with ultra-low noise for accurate micro motion detection.

RESULTS

After validating our system against a state-of-the-art lab-based motion capturing system using VICON achieving sound results we conducted the “Partial Knee Clinics” study mentioned above (as well as other clinical studies like investigation of the impact on knee joint behavior in patients suffering from chronic lateral patella instability).

Demanding activities in the load limits for knee joint like walking stairs or running with abrupt stops revealed quantifiable fatigue effects that were hardly visible in moderate activities like walking. Marginal changes in motion behavior over time could be identified that could hardly been seen within the short-time clinical visits after surgery during rehabilitation phase.

APPLICATIONS

Our main topics using Shimmer are fall prediction and motion analysis. Within the scope of outcome measurement after knee arthroplasty, ambulatory monitoring during daily activities can give insight into changes in activity level and can promote identifying medio-lateral instabilities of the knee joint and pathological motion patterns. Within our ongoing study “Partial Knee Clinics” we use 3 Shimmer2R (9DoF) devices attached to the patient’s sacrum, thigh and shank with kinesiotape while worn under normal clothes. Data sampled at 100Hz can either be (self-) calibrated, synchronized, recorded and annotated by self-developed software running on a windows tablet pc or directly be stored on SD card. We use R to calculate pelvis and knee angles, stability parameters as well as motion patterns; with a focus on joint function. In our next step, an unsupervised 24/7 field study, we will switch to Shimmer 3 (10DoF) devices as their gyroscope is able to detect angle velocity up to 2000 degrees per second and we appreciate the opportunity of having two accelerometers – one for wide range acceleration detection and another with ultra-low noise for accurate micro motion detection.

Using Body Sensor Networks based on Shimmer Platform in Orthopedic Studies

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ABSTRACT

We developed, validated and deployed a motion monitoring system from artificial lab setting to clinical use applicable to support outcome measurement after orthopedic treatment and we like to share experiences, lessons learned and problems solved during the progress of our time-consuming clinical research projects.