Special Session Title:

Activity Trackers in Healthcare: Signal Processing and Machine Learning for Monitoring and Detecting Health Conditions

Special Session Organizer Name & Affiliation:
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Special Session Speaker Name & Affiliation 1:

Dr. Brian Telfer
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Special Session Speaker Name & Affiliation 2:

Dr. Karl Freidl
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Special Session Speaker Name & Affiliation 3:

Dr. Catrine Tudor-Locke,
Dean, University of North Carolina at Charlotte|
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Special Session Speaker Name & Affiliation 4:

Dr. Bryan J. Hansen, Associate Principal Scientist,
Global Digital Analytics & Technologies

S Special Session Speaker Name & Affiliation 5:

Theme:

- ○ 01. Biomedical Signal Processing
- ○ 02. Biomedical Imaging and Image Processing
- ○ 03. Micro/Nano-bioengineering; Cellular/Tissue Engineering &
- ○ 04. Computational Systems &Synthetic Biology; Multiscale modeling
- ○ 05. Cardiovascular and Respiratory Systems Engineering
- ○ 06. Neural and Rehabilitation Engineering
- ◉ 07. Biomedical Sensors and Wearable Systems
- ○ 08. Biorobotics and Biomechanics
- ○ 09. Therapeutic &Diagnostic Systems and Technologies
- ○ 10. Biomedical &Health Informatics
- ○ 11. Biomedical Engineering Education and Society
- ○ 12. Translational Engineering for Healthcare Innovation and Commercialization

Special Session Synopsis— Max 2000 Characters
Data from activity trackers has been used in research to monitor health since the mid-nineties, but has seen a recent surge in publication activity given recent advances in gathering and analyzing data. Such research has evaluated the use of activity trackers to monitor and detect a wide range of medical/health related conditions, such as classifying user exercise activity, determining sleep-wake cycles, and detecting seizures, depression, and motor fluctuations in people with Parkinson disease. Today, the commercial market is

saturated with relatively low-cost activity trackers, yet their potential to monitor and evaluate diseases remains untapped. There is
an exciting opportunity to use the rich, individual data monitoring enabled by activity trackers, combined with the power of machine
learning and data science to improve health care.

The goal of the proposed special session is to bring together engineers, scientists and practitioners to:

- Assess the state-of-the-art in applicability of activity trackers to healthcare
- Describe challenges in the adoption of activity trackers for detecting and monitoring clinical conditions
- Identify new techniques that are needed in both the collection and analysis of individual user data
- Determine how accelerometer can be combined with other physiological sensors to improve detection and monitoring of health state.

Speaker 1: Dr. Brian Telfer
Senior Research Scientist
MIT Lincoln Laboratory

Advanced Signal Processing for Monitoring Health from Wearable, Free-Living Accelerometry

Traditional analysis of activity levels from wearable accelerometry has focused on statistical characterization through counts and cut points. Commercial wearable devices also use wearable accelerometry to count steps and track total sleep time. However, the health-related information in raw-waveform three-axis accelerometry from wearable devices is much richer. These waveforms provide information related to sensor orientation, gait, coordination, and subtle body motions, even including heart and breathing rate. This talk will provide examples of pathfinding analysis of health conditions from accelerometry collected on large free-living populations, including accelerometry for 100,000 subjects from the UK Biobank*. Examples will be shown for computing heart rate and breathing rate (not otherwise available for these particular UK Biobank collections). Other examples will include detailed sleep analysis and detection of Parkinson's Disease based on Parkinsonian tremor and bradykinesia. An important algorithmic requirement for performing these measurements on free-living populations is the ability to determine the portions of the data that are suitable for making a measurement. Methods for this data qualification will be described. In addition, unsupervised learning techniques will be applied to characterize sub-phenotypes from these measurements and conditions. The ability to combine these accelerometry-based measurements with other physiological information from the UK Biobank will also be explored. The purpose of the talk is to encourage the engineering community to develop additional algorithms to exploit these data for health applications, and to encourage the medical community to think of new ways in which wearable, free-living accelerometry may help healthcare.

*This research has been conducted using the UK Biobank Resource under Application Number 48759.

Speaker 2: Dr. Catrine Tudor-Locke
Dean, College of Health and Human Services
University of North Carolina at Charlotte

Re-imagining Physical Activity Guidelines using Practical Metrics Common to Most Wearable Technologies

Government- and agency-issued physical activity guidelines worldwide have been traditionally based on decades of accumulated evidence derived from self-reported behavior. Reflecting this traditional data source, guidelines for healthful physical activity (e.g., walking) are commonly expressed in terms of frequency (e.g., days/week), intensity (e.g., moderate to vigorous), and time (e.g., minutes). In contrast, step counting is now a widespread and acceptable approach to self-monitoring physical activity courtesy the recent surge in wearable technologies. A step is a fundamental observable and therefore verifiable unit of human bipedal locomotion. Rate of stepping tracked across time (i.e., cadence) presents a valid and intuitively interpretable indicator of intensity. Yet there remains no recommendation for steps/day or cadence in federal physical activity guidelines. Rather than simply attempting to force translations of traditional expressions of dose components, there is an opportunity to re-imagine physical activity guidelines using practical configurations of step-based metrics that are common to most wearable technologies. Such metrics include steps/day (volume), cadence (steps/min; intensity), peak 30-min cadence (steps/min; composite index of frequency, intensity and duration), zero-cadence (proxy for sedentary behavior), and also patterns of these combined elements. Communicating physical activity guidelines by optimally using step-based metrics could facilitate individuals' ability to comprehend and realize a physically active lifestyle.

Speaker 3: Dr. Bryan Joseph Hansen
Associate Principal Scientist
Global Digital Analytics and Technologies
Merck Research Laboratories

Digital Dodgeball: Quickly Capturing Data, Devices, and Opportunities

The speed at which the field of digital health is evolving offers a significant opportunity to overhaul clinical trials. Our objective is to transform clinical trials through pre-competitive collaboration, the evaluation and introduction of new technologies into the clinical trial paradigm to reduce patient burden, improve adherence, enable higher quality, faster, more frequent data collection, and obtain a more meaningful understanding of patients outside of the clinical site. The Internet of Things technologies are able to provide metrics by means of active (prompted) or passive (unnoticed) measurements, offering considerable flexibility in approach and unprecedented insights into both behavior and disease. The ability to integrate these devices, will provide objective measurements of biological processes and improve how we derive clinical endpoints today. More importantly, this strategy will position us to identify novel biomarkers to support the ever-increasing complexity of the pipeline of tomorrow. Our focused approach is aligned with neuroscience programs particularly movement-related disorders such as Parkinson's disease (PD). Surprisingly, drug development aimed at modifying the clinical course of PD is hindered by a lack of validated biomarkers. The current clinical trial approach lacks a reproducible and scalable process for rapid testing and evaluation of digital technologies for future use in clinical trials. To address both challenges, we have developed a relationship with the Dell Medical School with a vision of creating a rapid learning ecosystem. Through this thought-partnership, we will explore various analyses of wearable data for specific activities that may better reflect the disease state. While our initial focus with the Dell Medical School is on measurements from patients with PD, we believe this approach has the opportunity to make an impact across therapeutic areas by acting as a model for combining and analyzing digital data from multiple devices.

Vision: Reduce patient burden, improve adherence, enable higher quality, more frequent data, and more rapid and informed clinical decisions.

Value: Address areas of improvement in the current clinical trial paradigm and identity drivers to guide the development of digitally-enabled trials.

Validation: Explore cutting-edge technology that utilizes sophisticated data analytic approaches to identify novel neuroscience biomarkers.

Speaker 4: Dr. Karl Friedl
Senior Research Scientist
SES, US Army Research Institute of Environmental Medicine

Military Applications of Information to be Derived from Wearable, Free-Living Accelerometry

Military need has been a key driver of research and new advances in wearable monitoring technologies for free-ranging healthy active men and women. Wearable accelerometry is particularly useful in estimating human states because in life there is always motion, and patterns of motion provide a rich source of insight into human behavior and performance status. Wearable accelerometry provides an important bioengineering approach to human ethology. Even a comatose patient provides small movement signals associated with pulse and respiration; neuropsychological state affects speed and patterns of movement, ranging from hyperactivity to sluggish movements and purposeful direction or random meandering of the lost and confused; estimates of energy expenditure can be derived from sustained physical exercise, and patterns of purposeful daily activity can provide feedback on healthful behaviors. Information derived from accelerometry may be improved with other sensor data but, at least for the example of combining accelerometry with heart rate data for estimation of energy expenditure, activity appears to be an independent predictor, not improved by other sensor data. There are clear early applications in movement disorders like Parkinson's Disease where activity is such an important part of disease mitigation and movement patterns provide an important clinical record of disease progression and response to treatments including gait abnormalities, sleep disruption, exercise compliance, apathy and depression. Research important to Parkinson's disease management provide "big signal" understanding that can also be applied to more subtle signals in healthy individuals. For soldiers, this includes predicting impending physical overuse injury or heat injury from changes in movement patterns, restorative sleep and mental readiness status, and monitoring and guiding training load in premilitary preparation for service and in recruits. Emerging findings from current Army research in each of these areas will be provided.