Invited session proposal for 2018 IEEE AIM Conference

Invited Session Title: **Physical Human-robot Interactions and Human Assistive Systems**

Organizers:

1. Jun Ueda, Georgia Institute of Technology (Lead Organizer), jun.ueda@me.gatech.edu
2. Jingang Yi, Rutgers, The State University of New Jersey, jgyi@rutgers.edu
3. Kok-Meng Lee, Georgia Institute of Technology, kokmeng.lee@me.gatech.edu

Abstract: The objectives of this invited session are to identify challenges and opportunities in the design and control of physical human-robot interactions and human assistive systems, and to promote a discussion among participants. We encourage submissions from multidisciplinary areas including areas such as work-related safety, ergonomics, and physiology. Papers are invited on original investigations relating to design, modeling, analysis, and control of physical human-robot interactions and human assistive systems. Specific topics of interest include, but not limited to:

- Modeling and control of physical human-robot interactions
- Exoskeleton robots and power-assisting devices
- Sensors and actuators for human-assistive systems
- Argumentation of motor and sensory functions
- Human-centered systems design
- Haptic device design, control and stability analysis
- Assistive devices and systems
- Human neuromuscular motor physiology
- Human safety mechanism and design

Sponsored by: ASME DSCD Mechatronics Technical Committee; Bio-Systems and Health Care Technical Committee.

In addition to the confirmed papers listed above, the organizers will reach out and invite researchers in the area to this session including: ASME DSCD Mechatronics Technical Committee members, ASME DSCD Robotics Technical Committee members, ASME DSCD Bio-Systems and Healthcare Technical Committee members, Authors and Guest Editors of the International Journal of Intelligent Robotics and Applications (IJIRA), Authors of the IEEE Transactions on Mechatronics Focused Section on Soft actuators, sensors, and components (SASC).

List of confirmed papers (a total of 5 papers):

Paper 1
Title: Coordination of whole body muscles during robot-assisted assembly tasks
Authors: Yingxin Qiu*, Keerthana Murali, Dalong Gao and Jun Ueda

Corresponding author: Yingxin Qiu (yqiu47@gatech.edu), Georgia Institute of Technology
Abstract:: This paper reports muscle coordination strategies in human workers who operate a non-powered and powered lifting device for general assembly (GA) tasks. Principal component analysis will help to identify key body muscles that should be measured for the future muscle activity based assistive device control.

Paper 2
Title: A Real-time Pre-impact Fall Detection and Protection System
Authors: Zhichao Zhong, Feiyu Chen, João Paulo Ferreira, Yanjie Liu, Jingang Yi, and Tao Liu*
Corresponding author: Tao Liu, Zhejiang University, email: liutao@zju.edu.cn
Abstract: As the problem of population aging aggravates, the problem of fall has aroused more attention. We have proposed a novel pre-impact fall detection algorithm and protection system. The real-time algorithm uses the thresholds of vertical velocity and displacement profile to detect fall events in switching periods of fast motion. It can effectively solve the problem of false alarms of jump and jogging for daily-life applications. A second-order lag filtering algorithm method was utilized to reduce the drift of the vertical velocity with good performance. In addition, the vertical displacement profile was calculated by using the vertical velocity estimation. The algorithm gets 93.6% sensitivity and 95.6% specificity, which is higher than the algorithm without displacement with 75.6% specificity. The results demonstrate the effectiveness of the proposed detection method, which were evaluated by subjects wearing fall detection and airbag system.

Paper 3
Title:Estimation of Physical Capabilities of Human Upper Limb in Human-Robot Interactions using Muscle Synergy Models
Authors: Siyu Chen, Jingang Yi, Dikai Liu, and Tao Liu
Corresponding author: Jingang Yi, Rutgers University, email: jgyi@rutgers.edu
Abstract: Assistance-as-needed design is one of the main concepts to design physical human-robot interactions for assistive and rehabilitation robotics. One of the challenges in designing assistance-as-needed devices is to determine the physical capability of the human musculoskeletal systems without carrying testing experiments to reach these capability envelopes. We present an estimation scheme of the physical capabilities of the human upper limb using the muscle synergy model. The estimation scheme identifies the model parameters in muscle synergies and then combining with the muscle model, the physical capability envelopes of the upper limbs are estimated. The simulation and experiments are also presented to demonstrate the performance of the estimation scheme. The proposed estimation method can be further integrated with the control design of the physical human-robot interactions.

Paper 4

Title: Human-in-the-loop Optimization of Transmission Strategies for Biomechanical Energy Harvesters

Authors: Yutaro Ikawa, Taisuke kobayashi, and Takamitsu Matsubara
Corresponding author:Takamitsu Matsubara, Nara Institute of Science and Technology, email: takam-m@is.naist.jp

Abstract:In this paper, we introduce a novel biomechanical energy harvester that can harvest electrical energy from various human motions. Our harvester equips a continuously variable transmission (CVT) system. To exploit the benefit of CVT system, a transmission strategy needs to be designed. However, it is not easy to properly design it since there would be a trade-off between the capacity of electric-power generation and the degree of inhibition for user's natural movements. In this paper, we propose a human-in-the-loop optimization approach for adapting the reduction ratio of the harvester as a constant transmission strategy to be suitable for the user and his/her walking speed. Preliminary experimental results are shown as a proof-of-concept.

Paper 5

Title: Design Criteria of an Anatomy-based Ankle-Foot-Orthosis for Rehabilitation following Stroke

Authors: Jiaoying Jiang, Kok-Meng Lee and Jingjing Ji
Corresponding authors: Kok-Meng Lee, Georgia Institute of Technology and Jingjing Ji, Huazhong Univ. of Sci. and Tech. (kokmeng.lee@me.gatech.edu; jijingjing@hust.edu.cn)

Abstract: Stroke is an acute cerebrovascular disease caused by localized or whole brain dysfunction, which is a common disease that endangers the life and health of the elderly, leading to death and different degrees of dysfunction to the survivors. The sequelae of the ankle-foot (such as foot drooping) after stroke affect the walking rhythm and stability. The ankle-foot- orthosis (AFO) is currently used to assist the ankle-foot fixation or plantarflexion/dorsiflexion movement in the mid-term and late stage of rehabilitation following stroke. Motivated by recent studies revealing that early rehabilitation of stroke patients is effective for the recovery of their motor functions, design criteria based on musculoskeletal models are established for developing anatomy-based AFOs for rehabilitation at different stages; ranging from the in-bed acute stage when re-emerging of motor control occurs, to early-recovery period when sit-to- stand and balance training is carried out, and to the mid- and late-recovery stages where the focus, among other task training, is to correct abnormal gait patterns and improve walking speed for daily activities. The design criteria, along with the kinematics and kinetics of the human ankle and foot, provide a basis for analyzing the musculoskeletal-AFO interaction involved in the different stages of motor recovery after stroke. Specifically, three musculoskeletal-AFO interaction are analyzed; 1) no-load open-chain mechanism to maintain muscle flexibility and to facilitate motion functions during in-bed acute stage, 2) weight-support closed-chain mechanism formed between the ankle-foot and the ground for sit-to- stand/balance

training during the early-recovery period, and 3) periodic open- and closed-chain configurations for improving gait patterns and walking stability/speed. The findings provide physically intuitive insights into the effects of different AFO designs on the recovery of motor functions, and establish a rational basis for developing practical AFOs. Although the design criteria are developed in the context of rehabilitation following stroke, the models presented in this paper can be extended to other applications which may include the studies of gait disorder and pathologies related to the foot, and the development of custom-design insoles for improving athletic performance.