COLLEGE OF ENGINEERING AND COMPUTER SCIENCE
FLORIDA ATLANTIC UNIVERSITY

Announces the Ph.D. Dissertation Defense of

Moaed A. Abd

for the degree of Doctor of Philosophy (Ph.D.)

“Artificial Intelligence (AI) Enables Sensorimotor Integration for Prosthetic Hand Dexterity”

January 24, 2022, 1:00 p.m.
Virtual Dissertation

Zoom
Meeting ID: 832 3524 5031
Passcode: uQ9Zqz

DEPARTMENT:
Ocean and Mechanical Engineering

ADVISOR:
Erik D. Engeberg, Ph.D.
PH.D. SUPERVISORY COMMITTEE:
Erik D. Engeberg, Ph.D., Chair
Javad Hashemi, Ph.D.
Edgar An, Ph.D.
Mehrdad Nojoumian, Ph.D.
Oscar Curet, Ph.D.

ABSTRACT OF DISSERTATION
Artificial Intelligence (AI) Enables Sensorimotor Integration for Prosthetic Hand Dexterity

Hand amputation is a devastating feeling for amputees, and it is lifestyle changing since it is challenging to perform the basic life activities with amputation. Hand amputation means interrupting the closed loop between sensory feedback and motor control. The absence of sensory feedback requires a significant cognitive effort from the amputee to perform basic daily activities with prosthetic hand. Loss of tactile sensations is a major roadblock preventing amputees from multitasking or using the full dexterity of their prosthetic hands. One of the most significant features lacking from commercial prosthetic hands is sensory feedback, according to amputees. Many amputees abandoned their prosthetic devices due to the lack of tactile feedback. In the field of prosthetics, restoring sensory feedback is the most challenging task due to the complexity of integration between the prosthetic and the peripheral nervous system. A prosthetic hand with sensory feedback that imitates the intact hand would improve the lives of millions of amputees worldwide by inducing the prosthetic hand to be a part of the body image and significant impact the control of the prosthetic. To restore the sensory feedback and improve the dexterity for upper limb amputee, multiple components needed to be integrated together to provide the sensory feedback. Tactile sensors are the first components that needed to be integrated into the sensorimotor loop. In this research two tactile sensors were integrated in the sensory feedback loop. The first tactile sensor is BioTac which is a commercially available sensor. The first novel contribution with BioTac is the development of an ANN classifier to detect the direction a grasped object slips in a dexterous robotic hand in real time, and the second novel aspect of this study is the use of slip direction detection for adaptive robotic grasp reflexes. The second tactile sensor is the liquid metal sensor (LMS), this sensor was developed entirely in our lab (BioRobotics lab). The novel contribution for LMS is to detect and prevent slip in real time application, and to recognize different surface features and different sliding speeds.

The second components integrated into sensory feedback loop is the soft actuator haptic feedback armband, which was used to inform the amputee about the applied grip forces and of a dexterous artificial hand. The goal of the bimodal haptic armband is to convey both low-frequency pressure changes and high-frequency vibrations from a dexterous robotic hand to a human's upper arm, to guide the control of the artificial limb. Controlling the artificial hand effectively through surface EMG electrodes while haptic feedback is activated was the third component that needed to be integrated into the sensorimotor loop. The main goals of this research are to investigate the ability to integrate multiple channels of haptic feedback into the motor control strategies to perform a complex simultaneous object grasp control task and to simultaneously control the grip forces applied to two different objects grasped at the same time with an artificial limb. Exploring the potential for time savings in a simultaneous object transportation experiment compared to a one-at-a-time approach. This research presents a novel experiment demonstrating the first time that people have used surface EMG to proportionally control the grip forces applied to two objects simultaneously during object transportation with a dexterous artificial hand. People can integrate multiple channels of haptic feedback into their dexterous artificial hand control strategies to grasp and transport two objects simultaneously, without breaking or dropping them, even when they were unable to see the objects. Slip detection and prevention on multiple channels through vibrotactile stimulator feedback was also investigated. Amputees were able to integrate the sensory feedback into their motor control strategies to improve object manipulation tasks (sensorimotor integration).

Finally, we explored the integration process between biological neural networks cultured in multichannel microelectrode arrays (MEA) with an artificial prosthetic hand. A novel noninvasive neuroprosthetic research platform was developed to offer well-controlled experimental opportunities with biological neurons that can electrically communicate bidirectionally with a dexterous artificial hand. Our novel noninvasive neuroprosthetic platform was used to investigate the relation between the neural dynamics and the haptic restoration and the ability to improve the control of an artificial hand. Our results shows that the method of encoding the tactile information impacted the dynamic behavior of the neurons cultured in the MEA and that impacted the closed-loop behavior of a dexterous robotic hand.

BIOGRAPHICAL SKETCH
Born in: Diyala / Iraq
B.S., University of Baghdad, Baghdad, Iraq, 2007
M.S., Duisburg-Essen University, Duisburg, NRW, Germany, 2011
Ph.D., Florida Atlantic University, Boca Raton, Florida, 2022

CONCERNING PERIOD OF PREPARATION
& QUALIFYING EXAMINATION
Time in Preparation: 2017-2022
Qualifying Examination Passed: Fall 2016

Published Papers:
Moaed A. Abd, Joseph Ingicco, Douglas Hutchinson, Emmanuelle Tognoli, Erik D. Engeberg. “Multichannel Haptic Feedback Unlocks Prosthetic Hand Dexterity”. Accepted in Nature Scientific Report 2022.

Moaed A. Abd., Rudy Paul, Aparna Aravelli, Ou Bai, Leonel Lagos, Maohua Lin, and Erik D. Engeberg. "Hierarchical Tactile Sensation Integration from Prosthetic Fingertips Enables Multi-Texture Surface Recognition." Sensors 21, no. 13 (2021): 4324.

Lin, Maohua, Moaed A. Abd, Alex Taing, Chi-Tay Tsai, Frank D. Vrionis, and Erik D. Engeberg. "Robotic Replica of a Human Spine Uses Soft Magnetic Sensor Array to Forecast Intervertebral Loads and Posture after Surgery." Sensors 22, no. 1 (2022): 212.

Moaed A. Abd, Craig Ades, Sarah Du, Jianning Wei, Emmanuelle Tognoli, Erik D. Engeberg. Robotically Embodied Biological Neural Networks to Investigate Haptic Restoration with Neuroprosthetic Hands. Accepted in IEEE Haptics Symposium 2022.

Olson, S., Abd, M. and Engeberg, E.D., 2021. Human-Inspired Robotic Eye-Hand Coordination Enables New Communication Channels Between Humans and Robots. International Journal of Social Robotics, 13(5), pp.1033-1046.

Abd, M.A., Gonzalez, I., Ades, C., Nojoumian, M. and Engeberg, E.D., 2019. Simulated robotic device malfunctions resembling malicious cyberattacks impact human perception of trust, satisfaction, and frustration. International Journal of Advanced Robotic Systems, 16(5), p.1729881419874962.

Abd, M.A., Al-Saidi, M., Lin, M., Liddle, G., Mondal, K. and Engeberg, E.D., 2020. Surface Feature Recognition and Grasped Object Slip Prevention with a Liquid Metal Tactile Sensor for a Prosthetic Hand. In 2020 8th IEEE RAS/EMBS International Conference for Biomedical Robotics and Biomechatronics (BioRob) (pp. 1174-1179). IEEE.

Abidalkareem, A.J., Abd, M.A., Ibrahim, A.K., Zhuang, H., Altaher, A.S. and Ali, A.M., 2020, July. Diabetic Retinopathy (DR) Severity Level Classification Using Multimodel Convolutional Neural Networks. In 2020 42nd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC) (pp. 1404-1407). IEEE.

Cannestro, G.A., Abd, M.A., Engeberg, E.D. and Tognoli, E., 2020, October. Human Neuromarkers of Tactile Perception: State of the Art in Methods and Findings. In International Conference on Neurorehabilitation (pp. 635-639). Springer, Cham.

Abd, M.A., Gonzalez, I.J., Colestock, T.C., Kent, B.A. and Engeberg, E.D., 2018, July. Direction of slip detection for adaptive grasp force control with a dexterous robotic hand. In 2018 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM) (pp. 21-27). IEEE.

Abd, M.A., Bornstein, M., Tognoli, E. and Engeberg, E.D., 2018, July. Armband with soft robotic actuators and vibrotactile stimulators for bimodal haptic feedback from a dexterous artificial hand. In 2018 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM) (pp. 13-20). IEEE.

Ingicco, J., AlSaidi, M., Abd, M., Ades, C. and Engeberg, E., 2018, May. Force and Pressure Control of Soft Robotic Actuators. In Proceedings. Florida Conference on Recent Advances in Robotics (Vol. 2018, p. 39). NIH Public Access.

Abd, M.A., Gonzalez, I., Nojoumian, M. and Engeberg, E.D., 2017. Trust, satisfaction and frustration measurements during human-robot interaction. In Proceedings of the 30th Florida Conference on Recent Advances in RoboticsMay 11-12 (Vol. 2107).

Abd, M.A., Ades, C., Shuqir, M., Holdar, M., Al-Saidi, M., Lopez, N. and Engeberg, E.D., 2017. Impacts of soft robotic actuator geometry on end effector force and displacement. In 30th Florida Conference on Recent Advances in Robotics, May (pp. 11-12).

Abd, M., Gonzalez, I., Nojoumian, M. and Engeberg, E., 2017. Impacts of robot assistant performance on human trust, satisfaction, and frustration. RSS: Morality and Social Trust in Autonomous Robot