Carleton UNIVERSITY Canada's Capital University

2014-2015

ONTARIO GRADUATE SCHOLARSHIP PROGRAM

Research/Program Statement

Must not contain more than 3,950 characters (with spaces)

Name: [redacted]

Student Number: [redacted]

Safety in Human-Robot Interactions is paramount, especially in emerging rehabilitation robotics. Traditional human-robot isolation to prevent injury is not an option; new safety mechanisms must be developed. While collision avoidance by planning can reduce dangerous impacts, it cannot prevent all undesired contact. Robots require a means to detect and respond to collisions.

Collision detection and mechanical compliance can reduce injury by limiting maximum impact forces. While colliding, compliance will delay peak forces as the robot senses and reacts to the collision to prevent harm. Previous experiments [1] proved the effectiveness of collision detection for safety; however, this method uses softer joints, requiring robot redesign and degrading control bandwidth. Compliant tactile sensors (i.e. smart skins) offer soft contact and collision detection without compromising robot rigidity. Despite the potential of smart skins, no current sensor has the combined spatial resolution, rapid response time and minimal wiring required in practice.

The proposed research seeks to develop a compliant tactile sensor and associated control methods to guarantee safety. Based on knowledge from my fourth year and USRA projects, I will develop a smart skin consisting of a novel point of application (POA) sensor overlying an available custom force sensor. While applicable to all robots, the sensor will be applied to a virtual gait rehabilitation robot (ViGRR) for early mobilization of stroke patients. An innovative admittance-impedance control law will be developed to minimize impact forces using the sensor output. The research plan includes:

- Collision Simulation: A robot dynamic simulation will be developed and human-robot collision will be simulated to determine required sensor compliance and sensitivity. Simulations will examine the affect of sensor properties on the severity of head collisions using existing biomechanics models.
- Sensor development: The POA sensor will use conductive fabric switches, resistor arrays and specific analog to digital conversion circuits to reduce response time and wiring. Sensor materials will be chosen to meet the required compliance and sensitivity, while the data acquisition will seek noise resistance with minimal response time. Once integrated with ViGRR, the sensor will be characterized and the properties will be used in subsequent simulations.
- Impedance Control: The novel reactive controller will detect contact points and forces and yield to impact while minimizing the deviations from the desired trajectory. Simulations will be used to study controller performance and stability, before it is experimentally validated on the ViGRR platform.
- Comparisons: Control strategies will be compared experimentally based on maximum impact forces generated and the observed trajectory after collision. Experiments will include collisions between a biomimetic skull and ViGRR under braking, zero gravity force control, joint reversal, and the proposed impedance control.

Carleton University provides an ideal location for this research. Carleton offers access to biomedical research facilities across various engineering departments as well as rehabilitation robotic platforms at the Advanced Biomechatronics and Locomotion Laboratory. Located near numerous medical institutions, Carleton can offer medical collaborators to aid in the development of the rehabilitation robot controller. The interdisciplinary nature of the M.A.Sc. in Biomedical Engineering program compliments this research by providing courses in diverse topics, including biomechanics, and controls engineering. Performing the research at Carleton will assist in the successful completion of the project as I develop the skills required to continue into my PhD.

1. Haddadin et al., "Requirements for Safe Robots: Measurements, Analysis and New Insights." Int. J. Robot. Res., vol. 28, pp. 1507-1527, 2009.