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Master of Science
Robotic Systems Development

Statement of Purpose

What if you could travel to Mars cheaper than flying in an airplane and faster than going to your local grocery store? What if amputees with '*special needs'* could be upgraded to athletes with *'special speeds'?* These possibilities give me the same rush of adrenaline and freedom to look past my fears that a skydiver would experience as he jumps off a plane. Robotics gives me the power to conceptualize technological prospects that I wouldn't otherwise be able to devise in my dizziest daydreams.

I was motivated to restore independence in people with disabilities through Robotics after witnessing the struggles of my maternal uncle. In 2004, he suffered a stroke which completely paralyzed his left limbs and compromised the motor functionality of his right limbs. Due to this experience, during the first year of my undergraduate degree, I conceptualized a head-motion and voice-controlled wheelchair that could restore his independent mobility. I built a miniature prototype with an accelerometer affixed on a wearable hat. The accelerometer data actuated the wheelchair in the same direction that the user's head tilted. Voice commands were enabled using an offline personalized natural language processing platform, 'snowboy.kitt.ai'. My goal is to develop a brain-controlled wheelchair that is as seamless and intuitive to control as one's own body. I would like to take technical elective courses such as Neural Signal Processing (18-698) and Machine Learning for Signal Processing (11-755/18-797) during my 3rd/4th semester and develop the technical expertise required to address the challenges of decoding noisy and erratic neural activity from EEG devices.

Currently, I am working closely with my uncle on the full-scale implementation of this wheelchair with added functionality for SLAM based autonomous navigation using a KINECT sensor by harnessing the power of the Robot Operating System (ROS). I also developed proficiency in ROS, control algorithms and path planning when I took part in India's largest Robotics competition, '*e-Yantra Robotics Competition (e-YRC)'*. I developed a drone that emulated the flight patterns that birds exhibit to gather food and feed their offspring. An overhead camera along with WhyCon and ArUco markers were used for localization of the drone and a PID controller written using Python stabilized it. I used a ROS plugin to interface VREP and ROS for simulations and the *Rapidly Exploring Random Trees (RRT)* algorithm to carry out path planning. Despite the algorithm working perfectly in simulation, the biggest challenge was tuning the PID parameters of the real hardware, which kept varying with battery voltage. The reproduction of results from simulation to the real world was arduous and is still a problem faced by Roboticists worldwide. I hope to harmonize this incongruity, a vision shared by renowned Roboticists like Dr. Howie Choset by exploring methods like Bayesian Optimization. We later realized that the dynamic auto-tuning of the parameters in an adaptive PID controller could mitigate this issue. I want to revisit this problem statement after taking courses in non-linear control to design a more robust and reliable controller.

Realizing the profound impact Robotics could make in medical aid and rehabilitation, I teamed up with *'Apollo Hospitals'* at the *'Smart India Hackathon 2019'* to develop a robot that could safely lift and turn unconscious patients while alleviating nurses of the physical strain associated with this task. We built a hydraulically actuated robot that could lift heavy loads and used a joystick to control the actuating signals. The system was able to retain hydraulic pressure even during a power failure, making it safe for our application. I used OpenCV to implement the OpenPose library developed by CMU's Perceptual Computing Lab to detect all the joints of the patient and deduce if the patient's posture was safe for lifting and turning by the robot. Having no prior knowledge, I'm very proud that we designed a hydraulic actuation system from scratch with some help from industry experts and convinced them to manufacture it affordably. Upon talking to the nurses and patients, I realized that for this product to be commercially viable, we needed stringent safety measures such as a soft inflatable exterior and a strong focus on design aesthetics that wouldn't intimidate the end user.

When researching about existing robots that met these needs, I discovered Dr. Chris Atkeson's profile and his efforts in building a real-life Baymax from Disney's Big Hero 6 at CMU. It was a perfect solution to our problem and ever since I have used this project as a reference in trying to incorporate a soft inflatable exterior for my robot as well. I later realized that controlling this robot would be easier and more intuitive when nurses' motions are mimicked using a teleoperated wearable suit with embedded IMUs. Upon researching more about the field of teleoperation, I stumbled upon research papers on multimodal teleoperation authored by Dr. Burak Cizmeci from ETH's Robotic Systems Lab. I contacted Dr. Cizmeci for assistance with this project and was fortunate to have been interviewed

and **accepted for an internship position at ETH Zurich's Robotic Systems Lab**, which is expected to begin from January 2020. I will be working under the mentorship of Dr. Cizmeci on teleoperation robotics. The prospect of transferring human consciousness to manipulate physically inaccessible or hazardous environments through robots fascinated me. I am inspired by the possibility of humans on earth building colonies on other planets through robots, especially due to the recent proliferation of private space exploration companies, exponential advances in processing power and communication technologies.

I firmly believe in a future where Robots become a natural extension of our biology to compensate for our inherent flaws. I am inspired by Dr. Katherina Muelling's work in creating semi-autonomous robot manipulation for the disabled. I am excited about her work on 'Autonomy Infused Teleoperation with Application to BCI Manipulation' and the shared-control framework to develop an intuitive control system. Through my interaction with hospital nurses and patients when I was building the hospital humanoid robot, I was able to empathize with their need for a solution that is intelligent enough to recognize their intents and perform some low-level tasks autonomously, while giving the end-user control authority over all high-level tasks. I believe Dr. Muelling's work is crucial for robotics solutions involving human interaction to be practical in the real world, and thus something I would love to contribute to. I am curious to explore the possibility of blending Dr. Muelling's work on the intuitive hybrid control framework applied to BCI and vision-guided autonomous robotics with Dr. Hartmut Geyer's work on powered neuroprosthetic legs to improve human neuromuscular control and thus achieve human-like gait stability and dexterity.

My interests are a perfect fit with the goals of the **Human and Robot Partners (HARP)** lab led by Dr. Henny Admoni. The work done in *Assistive Manipulation Through Intent Recognition* which takes robot teleoperation a step further by simultaneously understanding human verbal and nonverbal behaviors to predict user intent during a task is truly fascinating. I believe there is scope for further enhancement of intent recognition during a task by augmenting EEG devices to the framework to ultimately reduce operator fatigue and task duration. It would be an honor to work on integrating EEG datasets into the existing model as a part of my master's thesis. I want to build robots that work coherently with our biology to evaluate and understand our needs much before *we* can recognize them. In such a scenario, there will be a true transfer of consciousness to an extracorporeal entity. I also look forward to the possibility of being a part of CMU's ANA Avatar XPrize competition team to develop an Avatar system to transport human senses, actions, and consciousness to a remote location in real-time. It would give me the opportunity to access the wealth of knowledge and experience from roboticists like Dr. Dimitrios Apostolopoulos, who has played a pivotal role in several robotics programs for discovery and exploration in hazardous environments across his prolific career.

I am applying for a Master's in Robotics Systems Development at CMU as the unique course structure provides the best blend of Robotics System Engineering and Project Management to thrive in the industry as an entrepreneur. My personal goal is to start my own Robotics venture within the next five years to develop medical assistance robots that can understand, evolve and blend coherently with our biology. I hope to make rehabilitation and medical care robotics solutions more ubiquitous, affordable and accessible to a large population across the world. I would like to implement hybrid control systems and state-of-the-art teleoperation technologies to make these robots easier to use and more commonplace. I would also like to contribute to the development of robust robotics systems in space exploration and human colonization. I share the same vision as Dr. Katherina Muelling in bringing robots out from the labs and into the real world to make a wide-spread impact on people's lives, for which I need to confront the numerous practical considerations in the product life cycle of a robot. The extensive industrial exposure offered in the curriculum along with CMU's corporate partnerships with companies like M*Modal and Sony, will make me more aware of these practical challenges and thus enable me to be better equipped to make decisions that could make or break a business.

Through my experiences as a team leader for several project and competition teams, I have realized that it is vital to have efficient managerial skills for the team to trust in me as their leader. I have learned that good leadership and a clear vision generate loyalty, motivation, and a collective synergy that propels the team forward from difficult situations. I am inspired to emulate the profound successes of CMU's teams at various global challenges such as Team Explorer's victory in the recently concluded DARPA event. Above all, the prospect of working with a passionate team to reconstruct an ambiguous figment of imagination into an engineering problem with sound mathematical models that can extrapolate imagination into the realms of reality is really exciting. CMU fosters an environment conducive to radical thinking and innovation unlike any other place in this world, which is exactly what I need to bring my goals to fruition. I sincerely hope that the admissions committee believes in my drive and passion to make a significant contribution to the universe of Robotics.