I am a fourth-year electrical and computer engineering student at Carnegie Mellon University specializing in robotics and neural signal processing. I am writing this research proposal in support of my application for a Fulbright Award to fund a 12-month project at the Swiss Federal Institute of Technology in Lausanne (EPFL). At the Translational Neural Engineering Laboratory (TNE), I will work under the supervision of Prof. Silvestro Micera developing a novel robotic rehabilitation technique for post-stroke recovery. Switzerland is the ideal place to do neuroscientific research that translates into meaningful treatment methods, especially with the recent creation of Campus Biotech in 2012 which the TNE is a part of. This muti-development facility, located in Geneva, houses research groups from the University of Geneva, the EPFL, and the Wyss Center for Bio- and Neuro-Engineering resulting in a dynamic environment which fosters collaboration, innovation, and the translation of technology. A Fulbright research grant for Switzerland would give me the opportunity to demonstrate the excellence of United States research through my collaboration with an international community on the development of a novel rehabilitation framework at a world-class research facility.

Stroke is the leading cause of adult disability in western countries and the second leading cause of death worldwide. More often than not, stroke victims suffer upper-limb dysfunction making reaching and grasping tasks very difficult or even impossible. With the increasing of life duration, it is expected that the stroke related impairments will be ranked to the fourth most important causes of disability in 2030, prompting the need to understand functional motor recovery and the design of novel rehabilitative treatments. Robot-aided motor rehabilitation methods help stroke victims recover their motor function and their muscular coordination through the use of robotic devices that guide the arm of the patients through reaching movements. Robotic-aided rehabilitation became increasingly popular in the last two decades because it provides intensive and highly repeatable therapy which has been shown to improve the coordination of the neuromuscular system [?]. However, studies aimed at quantifying the clinical effectiveness of these devices showed that their use contributes mainly in increasing the intensity of the standard physical therapy and that the improvements are not always transferred to activity of daily life. This can be due to the fact that the rehabilitative interventions proposed by the robotic devices are standardized rather than personalized on the residual abilities of the patients and to the fact that the rehabilitation strategies and evaluations are based only on the analysis of kinematic and muscle activation data. My project will focus on the development of a personalized rehabilitation strategy that incorporates analysis of cortical activity patterns recorded using noninvasive electroencephalography (EEG) recordings.

This project will be an extension of the research I have already conducted at the Translational Neural Engineering Laboratory in the summer of 2015. The objective of this preliminary research project was to find links between the brain activity recorded via EEG and the activation of coordinated muscle groups or muscle synergies measured with noninvasive electromyographic (EMG) recordings. We successfully developed a strategy for analyzing cortico-muscular activity in healthy subjects, which included the extraction of EEG microstates and a multiple block partial least squares analysis framework [?]. We strongly believe that motor rehabilitation treatment for stroke patients could be improved by leveraging this analysis of cortico-muscular dynamics to determine personalized rehabilitation strategies. Indeed, rather than simply working to restore particular muscle activation patterns, our method could boost the development of new strategies for restoring proper cortico-muscular patterns for neuromuscular control. A year-long Fulbright Award would fund my contribution to the development, implementation, and evaluation of a personalized robot-aided rehabilitation strategy that will use the analysis framework developed by my previous research project at the TNE. The stroke-patients data that I will use in my project will be acquired during a multicentric clinical trial between the University of Geneva Hospital (HUG) and the Cisanello Hospital in Pisa, Italy, which will start on January 2016. 50 sub-acute stroke patients will be included in the clinical trial. Each patient will undergo four weeks of rehabilitation with 3 rehabilitation sessions of 45 minutes each week. Once a week, EMG and EEG data will be recorded during one session of rehabilitation.

An exciting aspect of this project is the opportunity to collaborate in an academically diverse environment with two specialists at the cutting-edge of their field. Indeed, the Translational Neural Engineering Laboratory, previously located on EPFL’s campus in Lausanne, has just moved to Campus Biotech in the fall of 2015, and the head of the laboratory is Prof. Silvestro Micera, who owns the Bertarelli Foundation Chair in Translational Neuroengineering at EPFL. The rehabilitation strategy development, experimental design, and clinical trial execution will all happen within the operations of the TNE. I will also continue working with Prof. Dimitri Van de Ville, head of the Medical Image Processing Laboratory, to develop novel signal processing and machine learning techniques for effective cortico-muscular analysis. As a note, my research project will be entirely conducted in an English speaking environment. By the end of my research project, we will look to present our results at a neuro-rehabilitation conference.

My education and diverse research projects give me the skills and experience necessary to carry out this proposed project successfully. This spring, I will graduate from Carnegie Mellon University with my bachelor’s degree in Electrical and Computer Engineering. I have taken rigorous courses in discrete signal processing, cognitive neuroscience, robotics, and a graduate course in neural signal processing which give me the academic training necessary for this project. I have a wide variety of research experiences ranging from humanoid robot development to neural network reconstruction algorithm design. Working for Carnegie Mellon’s DARPA Robotics Challenge team, I boosted my knowledge on systems engineering, validation testing and software development in a team-oriented environment. My undergraduate research project with Prof. Jelena Kovacevic resulted in the publication of a faster, more accurate algorithm for determining functional connectivity in cortical networks. From this experience, I learned how to work independently and get through research roadblocks. Sponsored by an undergraduate fellowship from the Center for the Neural Basis of Cognition, a joint program between Carnegie Mellon and the University of Pittsburgh, I work with Prof. Byron Yu on the development of a dimensionality reduction framework for analyzing membrane potential population recordings. By working with Prof. Yu on this untouched area of neuroscientific research, I have really grown in my ability to think creatively and design experiments. And lastly, my summer internship at EPFL under Prof. Micera sponsored by a ThinkSwiss scholarship gave me a lot of momentum going into a full-year research project with the same group. I am already familiar with the lab resources, and I will be able to use the large programming code base I have written for this analysis. These experiences have shown me what it takes to be a successful scientist, and I am confident in my ability to do meaningful research in my area of expertise.

While in Switzerland, I will continue my involvement in youth education joining the EPFL Science Outreach Department. In collaboration with the Swiss National Centre of Competence and Research, this organization runs workshops for kids ages 4 to 18 which teach the fundamentals of engineering and encourage youth to pursue careers in science. I can use my experience with ECE Outreach at Carnegie Mellon, to develop new courses and educational tools. This will also be a great way to use my French language skills which increased substantially during my summer internship at EPFL, and will benefit from two courses at Carnegie Mellon my senior year. I will also have the opportunity to engage the broader international community by traveling to both hospitals in Geneva and Pisa to conduct experiments and interact with patients. In addition to French, the Italian interns have taught me quite a bit of their language which will enable me to have a diverse international research experience.