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STATEMENT OF RESEARCH EXPERIENCE AND VISION

Previous Experience

I began my research career with a medical device company working on the development and minimally invasive surgical application of a robotic system. Minimally invasive surgery provides benefits for patients such as: decreased pain and trauma, shorter hospital stays, smaller scars, and lower healthcare costs. Despite these advantages, cardiac surgery employs a highly invasive approach due to the difficulty of suturing tiny vessels on the heart using a minimally invasive technique. Advances in robotic applications that I helped develop have made it possible to perform minimally invasive heart surgery. I have traveled throughout the United States, Germany, Finland, China, and Japan participating in animal and human operations. I have published 3 scientific papers and given 10 presentations related to the medical device I helped develop.

I built upon my clinical research and medical device experience as a doctoral student by developing and applying simulation software to predict post-treatment outcome for gait-related disorders. Clinicians often use intuitive models based on clinical experience or regression models based on population studies to plan treatments of gait-related disorders. Because such models are constructed using data from other patients, the predicted clinical outcome for a particular patient is unreliable. I developed a new approach using computational models based on engineering mechanics and optimization to predict post-treatment outcome using pre-treatment data on an individual patient basis. I have published 8 scientific papers and given 6 presentations related to the modeling and simulation software I developed.

Current Work

I draw from my clinical research and simulation software experience as a research associate to develop and apply physics-based simulations to study the dynamics and function of human health and disease. Gait abnormalities commonly observed in children with cerebral palsy are typically treated by surgically altering muscle function. Unfortunately, this treatment strategy does not consistently result in improved outcome. I am investigating the utility of patient-specific simulations to determine the potential efficacy of surgical correction. In the end, I would like to determine whether favorable outcomes are more likely when treatment is consistent with biomechanical causes determined from these simulations. Based on the ratio of staff members to graduate students within my research group, I currently supervise one student in her second year of graduate school. I presented our work at two recent conferences. I have submitted 2 scientific papers and I am in the process of preparing another related to simulation-based treatment planning.

Future Directions

I will continue to use simulation tools as a faculty member to improve surgical and rehabilitation treatments for movement related disorders. I aim to identify problems which are both scientifically rewarding and have high impact on patients. I propose three projects that utilize a common set of engineering tools.

The first project involves patient-specific stroke rehabilitation. Stroke is one of the leading causes of long-term disability in the United States, resulting in an estimated $30 billion in lost productivity and health care costs each year. Speed is the most common clinical measure of post-stroke walking ability, but it provides no insight into how to improve function. Patient-specific computer models offer objective assessment of functional limitations during walking and will allow clinicians to test targeted rehabilitation protocols to improve post-stroke walking ability.

The second project involves joint replacement optimization. Arthritis afflicts approximately 70 million, or 1 in 3, people in the United States. Although it is not preventable, the resulting disability can be reduced by implanting artificial joints. Unfortunately, like all medical devices, total joint replacements fail over time. Currently available tools for evaluating designs do not study the artificial joint function within the larger musculoskeletal system. Dynamic simulations of joint mechanics can predict motion of implants and will allow designers to test artificial joint models and surgical implantation techniques to improve the longevity of joint replacements.

The third project involves microgravity exercise design. Although this research is not currently applicable to the larger populations of the previously proposed projects, future human space travel beyond our planet will require resourceful solutions. With the decreased need to provide support against gravity, muscles atrophy, lose peak force and power, and fatigue more rapidly. The ideal microgravity exercise program to prevent or limit these changes remains undefined. Muscle-actuated, dynamic simulations provide muscle forces to produce a given movement (with or without gravity) and will allow the optimization of both the exercise device and user motion that reproduces beneficial muscle forces generated on earth.

Conclusion

My background in developing and applying computational tools to complex dynamic systems has uniquely positioned me to become a leader in the use of patient-specific simulation to improve treatment for movement disorders. I seek a primary faculty appointment in Mechanical Engineering or Bioengineering, but I understand that maintaining close clinical collaborations will be essential to my future success. As a new faculty member, research in my lab will focus on projects linking cutting edge engineering simulation tools to clinically relevant neuromuscular biomechanical problems.