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2 2-3 broad research ideas relevant to the workshop goals outlined above

A) Recent Award**: CRI:IAD A Real-Time Haptic Immersive Virtual Environment (RT-HIVE) http://nsf.gov/awardsearch/showAward.do?AwardNumber=0751132**

Abstract: Our goal is to create and validate the paradigm of a Real-Time Haptic Immersive Virtual Environment (RT-HIVE) as a suitable venue to expand, assist, train and monitor human sensorimotor skills/strengths using the case-study of a Virtual Cadaveric Anatomic Simulator (VCAS) for anatomical dissection training.

Intellectual Merit: The complexity of virtual-dissection requires the development of new techniques and methods and furthering the state-of-knowledge in the engineering/computational domains. These include: (i) creation of novel design and interaction-control architectures for enhanced Haptic User Interfaces; (ii) advances in distributed architectures/algorithms for real-time tool-interactions with irregular, inhomogeneous and nonlinear biological materials; and (iii) validation of transparent monitoring and quantitative assessment protocols for sensorimotor training.

Broader Impact: The integration of such a VCAS Simulator with a systematic education program will revolutionize the training of the next generation of health-care professionals (from novitiate nurses/ medical students to specialist surgeons/pathologists). We also see the VCAS as an important teaching and collaboration tool in research labs, classrooms, application settings or in conjunction with museum displays. Finally, the architecture, algorithms and validation efforts would be invaluable in development of other such Virtual Reality (VR) based simulators.

B) Virtual Musculoskeletal Analysis-based Study of Locomotion

Biologists who study animal locomotion have long speculated that evolution has optimized the control, structural and actuation of animals for locomotion. In the class of vertebrates, the focus of this paper, such locomotion is derived from cyclic/periodic motions of locomotory appendages (arms, legs, fins, wings), implemented in the form of integrated neuromusculoskeletal systems. The suitable coordination and neural control of the contraction of the muscles attached to an underlying skeletal structure allows for realization of desired periodic motion-trajectories (gaits). At the same time, co-contraction of the highly redundant musculature, has been shown to provide significant robustness to environmental disturbances (modulated force interactions).

Our long-term interests are in systematically studying natural systems, with the view of better understanding the underlying principles, for subsequently use in the design of robotic counterparts. There have been many efforts in trying to adopt a “bio-mimicry” paradigm – wherein scaled or unscaled robotic analogs of living animals have been created for purposes of scientific study. We, however, seek to adopt a “bio-inspiration” paradigm, wherein we propose to systematically study these natural and artificial counterparts from the view point of: (i) obtaining insights that will allow for better design of the robotic systems; and (ii) using the robotic counterpart as a scientific tool for studying hypothesis regarding the natural system.

C) Virtual Musculoskeletal Analysis-based Refinement of Rehabilitation Programs

Abstract: Rehabilitation is a complex multifaceted process with complexity and variability that depends not only on human patients and/or specialized equipment but also on the nature of their functional interaction. Rapid and effective customization of the functional interactions between the patient and the rehabilitation device thus becomes critical for any rehabilitation program. Two principal dimensions that govern the effectiveness of such functional interactions are geometric placement of user-device (ergonomics) and exercise selection and performance (regimen).

In this work, we discuss aspects of creation of a Virtual Design Environment, leveraging tools from musculoskeletal analysis, optimization, simulation-based design, that will permit a therapist to systematically and rapidly evaluate various candidate rehabilitation programs. Specifically, this framework will: (i) permit study of parametric performance variability due to ergonomic or regimen variability; and (ii) all design tools such as optimization to be effectively used to determine the best program. We illustrate various aspects of this customization using an illustrative case-study of a motor-rehabilitation haptic virtual driving environment.