NSF/CCC/CRA Research Roadmap Proposal

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Rationale

The aging population in the U.S. and worldwide is expected to increase significantly over the next 2-3 decades[1]. In association with the aging population, there is a projected increase in the prevalence of many diseases, including cardiovascular diseases and stroke. Additionally, neurodevelopmental and cognitive disorders in young people is also increasing. The projected economic, human, and social costs of such illnesses will constitute an increasing burden for society. In parallel with the aging of society and the associated increase in healthcare requirements, the infrastructure of the healthcare system is facing a critical resource challenge. There is a significant shortage of support personnel such as nurses and physical therapists, with concomitant reductions in the availability and quality of care. The result is an urgent need for strategies to improve the efficiency of care, particularly in the labor-intensive sectors such as physical and occupational therapy. Rehabilitation robotics is an extremely promising avenue to address this need by allowing therapists the ability to provide more consistent, effective training and to monitor multiple patients simultaneously. Robotic devices that are designed to improve the efficacy, accessibility, and cost of medical and rehabilitative care are likely to become both socially important and commercially viable. A clearly defined roadmap is essential to the overall success for medical and healthcare robotics over the next 5-15 years.

Background

Intelligent Automation, Inc. (IAI) focuses on translating cutting edge research into real-world applications. IAI is very effective at developing a technology from the concept stage through design, building and testing of a prototype system. In addition to Rehabilitation Robotics, IAI's core competencies are in the areas of Intelligent Robotics, Electromechanical Systems, Signal Processing, Sensing and Communications, Distributed Intelligent Systems, and Educational and Training Technology. By combining expertise across these core areas, IAI is developing groundbreaking biomedical technologies in the area of rehabilitation robotics, medical informatics, and medical sensors that address the technological challenges as well as the socioeconomic impact of rehabilitation robotics.

IAI has most recently developed two rehabilitation robotic devices: MACARM and LSS. The Multi-Axis Cartesian-based Arm Rehabilitation Machine (MACARM) is designed to enable novel robot-based rehabilitation therapies for individuals with upper extremity impairments[2]. In contrast to other upper limb robotic systems, MACARM's large work volume and high flexibility allow patients to engage the full limb through a wide range of joint angles. Furthermore, MACARM provides haptic feedback in a more realistic operating environment, and can simultaneously measure progress and respond to that progress by titrating the robot's assistance or resistance to maximize therapeutic efficiency. The MACARM was designed in collaboration with the Rehabilitation Institute of Chicago and is an extension of prior work with the Multipurpose Multiaxial Isokinetic Dynamometer at NASA JSC. The Load Support System (LSS) is a novel bodyweight support system that maintains constant force (rather than a fixed cable or spring system) to offload a percentage of a patient's body weight during treadmill-based physical therapy. Designed and built for the National Institutes of Health Physical Disabilities Branch, the

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LSS can support continuous loads up to 150 kg (peak loads up to 340 kg), at speeds up to 2.76 m/s, with a wide range of motion.

Education and training is also important for the adoption and acceptance of new technology. Educational and Training Technology, one of IAI's core competencies, can supplement robotics technology especially for individuals with neurodevelopmental and cognitive disorders[3]. Examples of our work in this area include TalkTiles™ and TechMates™. TalkTiles™ is a language development tool with electronically enhanced letter tiles and speech synthesis for children with speech and language related disabilities. TechMates™ is a system of motion sensing figurines with auditory and visual feedback that allow children to practice language development, creative play, and social skills.

Challenges and Future Goals

While the potential benefits of rehabilitation robotics are clear to those in the field, end-user requirements and associated research and development challenges still need to be addressed. These challenges include, but are not limited, to:

- Cost effectiveness, safety, and reliability
- Accessibility and usability for clinical and/or home use
- Effective rehabilitation paradigms and protocols
- Engaging the patient and adapting to patient needs and limitations

Devices that are inexpensive and portable enough to be taken home by a patient are of particular value because the patient will have much better access to the therapy, particularly if coupled with tele-presence capabilities. On the other hand, clinical/research devices need to accommodate a variety of users in order to offset the increased cost of a larger, more complex device. End-user requirements should also address physical and mental limitations of the user as well as economic and social impacts of the technology. A robot can only be effective if it is willingly used, so the potential for patient entertainment while engaged in therapy should be fully explored (e.g. virtual reality and game play).

IAI has started to address these needs through our comprehensive approach to rehabilitation robotics. A primary focus of rehabilitation robotics at IAI will continue to be in augmenting the abilities of the researcher and therapist. Researchers and therapists can leverage the capabilities of rehabilitation robotics that have more precise control, provide larger assistance forces, and provide consistent training. IAI is also expanding the MACARM software suite to enable clinicians to operate the robot in an intuitive manner, and also allow researchers to customize the robot's behavior to suit their own needs. Additionally, the potential for remote assessment and interaction (tele-presence) is a compelling use of robotic devices in healthcare. Lastly, we believe that we can build upon our successes in the educational and training area by incorporating game play and social interaction to encourage patients and keep them engaged in therapy.

IAI also plans to expand on recent successes with the MACARM and LSS to develop robotic devices that are beneficial for researchers and clinicians alike. IAI envisions a suite of devices that can be used together or individually for upper and lower extremity, whole body, or individual joint rehabilitation. Furthermore, we plan to develop more portable devices that can be used at home especially for individuals that have limited access to clinics.

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[1] National Institute on Aging. Why population aging matter: A global perspective. Bethesda.MD: National Institute on Aging, National Institutes of Health, forthcoming 2007.

[2] Mayhew D, Bachrach B, Rymer WZ, Beer RF. Development of the MACARM – a novel cable robot for upper limb neurorehabilitation. Proceedings of the IEEE International Conference on Rehabilitation Robotics 2005; 299-302.

[3] Intelligent Automation: Overview of Educational and Training Technology. http://www.i-a-i.com/view.asp?tid=6