B. PROJECT SUMMARY

Overview: Stroke, Parkinson's disease, and osteoarthritis affect roughly 15% of the U.S. adult population and often impair walking ability, leading to an increased risk of serious health conditions (e.g., heart disease, diabetes, high blood pressure, obesity) and a decreased quality of life. Traditional approaches for assessing patient function and delivering rehabilitation prescriptions require that the patient make repeated visits to the clinic, which is expensive and time consuming for the patient, the clinician, and the health care system. Ideally, clinicians would be able to gather quantitative information about patient walking function, as well as deliver rehabilitation prescriptions that improve patient walking ability, when the patient is at home or in the community. While the advent of inexpensive wearable technology such as wireless inertial measurement units (IMUs) could make remote assessment of function and remote delivery of treatment a possibility, such capabilities have not yet become a reality.

Given that numerous companies now market relatively low cost IMU-based human motion measurement systems, why haven't these systems become ubiquitous for clinical use, both inside and outside clinical and laboratory environments? The problem is not with the hardware – the problem is with the software that turns IMU data into joint kinematic data. That being the case, what does the software need to do for IMU-based motion measurement systems to achieve widespread clinical utilization?

1) The software should require data from as few IMUs as possible to make IMU attachment to the body segments fast, easy, and repeatable.
2) The software should be able to calibrate patient-specific kinematic models automatically, rapidly, and with minimal effort.
3) The software should provide joint motion measurements of comparable accuracy to those available from marker-based motion capture systems.
4) The software should be fast and flexible enough to support both off-line data logging and real-time feedback applications.
5) The software should be so easy to use that any patient, family member, or caregiver can use it anywhere – indoors or outdoors - with no technical expertise and minimal training.

The objective of this proposal is to develop novel software that achieves these goals without requiring magnetometer data that is susceptible to the presence of metal in the test environment. The proposed software will combine several novel computational ideas to convert IMU accelerometer and gyroscope data into accurate joint kinematic data. The proposed project will 1) DEVELOP the necessary computational algorithm using pre-existing IMU- and marker-based motion capture data collected simultaneously, 2) EVALUATE the algorithm's ease of use and accuracy by having 10 healthy subjects collect their own IMU-based motion capture data, and 3) DEPLOY the algorithm on a Windows tablet to demonstrate that it can be used for real-time feedback applications.

Intellectual Merit: The intellectual merit of the proposed project involves the development of novel computational approaches that lead to _more accurate_ joint kinematic measurements using _fewer_ IMUs than with existing methods. These approaches take advantage of joint constraints in kinematic models, use _measured_ and _differentiated_ IMU data in addition to commonly used _integrated_ IMU data, and include a potentially more accurate way to numerically integrate IMU linear acceleration data.

Broader Impacts: If successful, this project could have wide-reaching benefits to the field, society, and education. For the field, human motion measurement could be moved outside the laboratory environment, allowing fast, easy, accurate, and inexpensive measurements to be made under uncontrolled real-life conditions. For society, remote real-time measurement of human motion could facilitate the development of effective remote monitoring and telerehabilitation methods that reduce the need for clinician time and patient office visits, resulting in a reduced cost to the healthcare system. For education, "at risk" middle school students from underrepresented groups will experience first-hand ways that IMU technology is being used to improve human health, encouraging them to pursue a college education in a STEM-related field.