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Integrating a functional calibration procedure and usability study towards the digitalization of upper limbs rehabilitation

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Introduction: Neuro-motor rehabilitation has a primary relevance among healthcare services since it helps patients affected by acute or chronic conditions to optimize functional capabilities and maintain independence to achieve a good quality of life. When impairments occur, there is a need for effective rehabilitative therapies which medical devices can support. Among the available technologies, the combination of Virtual Reality using serious games and inertial measurement units (IMUs) results promising to maximize functional recovery: serious games merge engagement and rehabilitation purposes providing task-oriented activities in contextualized scenarios [1]. Moreover, IMUs provide for the gathering of kinematic parameters useful to monitor the therapy; thus, there is a need for accurate calibration procedures to reduce sources of errors, which depend on the measurement system itself and misalignments of sensor readings for underlying body segments. These latter are managed by Sensor-to-Segment (STS) calibration procedures, which estimate anatomical segment orientations. The validity and accuracy of the IMU-based system must be assessed through the comparison with the optoelectronic system.

Objective: This work focuses on the assessment of NiuRion. This digital rehabilitation device enables patients affected by neuromotor disorders or musculoskeletal conditions to perform rehabilitative sessions for upper limbs at home using a sensorized shirt interacting with software of serious games. Two main purposes have been identified: the integration of a functional STS calibration procedure to deal with the misalignment between sensor readings and underlying body segment, and the design of a usability study to assess the intuitiveness of the device as well as the adequateness of the user interface, from the perspective of both patients and therapists.

Methods: A. Integration of a model-based functional calibration procedure. An upper limb mechanical multibody model has been designed to implement and test the STS method proposed in [2]. Simulating the acquisition of five sensors arranged as in the Niurion mesh, the quaternions related to a static pose (Neutral pose) and a functional motion necessary for the calibration procedure were obtained. Sensors' readings have been exploited to estimate reference directions necessary to define the matrix which relates the sensors' reference frame to the anatomical one and to compute anatomical joint angles. The application of the calibration procedure has provided for the compensation of the STS misalignment, producing the expected anatomical joint angles.
B. Validation study protocol. The validation protocol has been designed to assess NiuRion as an effective measurement device after applying the STS calibration procedure. Thus, sensor data gathered from NiuRion during movements have been compared to the measurements simultaneously acquired by the Vicon system for 20 healthy subjects.
C. Usability study protocol. A usability test protocol has been designed according to [3] to examine the use scenario and identify errors. Since NiuRion is equipped with two executable interfaces,

usability tests have been submitted separately to 15 medical professionals and 15 patients regarding questionnaires and received comments.

Results: A. Validation protocol results. Applying the STS calibration procedure has resulted in coherent outcomes for orientation and ROM values along the principal axis of functional movement. The comparison between calibrated data concerning optoelectronic system outcomes has shown significant correlations along the principal axis of movement, while differences in measurements have occurred on the other axis. Thus, the combination of effective strategies for the optimization of initialization and calibration procedures could demonstrate the device's reliability.
B. Usability protocol results. Usability test results have revealed a general willingness to use NiuRion, which has proven to be an easy-to-use and engaging tool for rehabilitation therapies.

Conclusions: Pursuing the purposes of assessing NiuRion from both a technical and a usability perspective, results have suggested it to be a promising digital rehabilitation device. Integrating the STS calibration procedure has been essential to estimate anatomical joint angles. From both the perspective of patients and therapists, NiuRion has proven to be an easy and engaging tool. Hence, results will lead to the further development of AuReha and could contribute to the digital transformation already in place.

References:

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