INFORMING PATIENT, CARER AND PROFESSIONAL IN IMPROVED STROKE REHABILITATION: FEEDBACK IN THE EXERCISE REHABILITATION REGIME

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INTRODUCTION

Over two-thirds of stroke patients are impaired in activities of daily living due to partial paralysis of the more affected upper limb [1]. The effectiveness of stroke therapy has been shown to depend on the intensity and frequency of treatment, especially in the months immediately following the stroke. While appropriate available treatments can help improve or regain function, standard treatment planning remains empirical, and the assessment of the patient's progress may vary between assessors. Studies [3, 4] and informal feedback from patients, carers and physiotherapists suggest that the provision of metrics which provide information on the quality of the exercises performed (e.g. the timing sequence of muscle groups, the trajectory of joints compared with the 'norm') would be beneficial in encouraging patients to take charge of their own rehabilitation regime, and perform their exercises accurately and frequently. For this to be monitored, a reliable, low cost method of measurement is needed. In this paper we assess the application of this technology through comparing measurements from a state-of-the-art low cost motion sensor, Xsens™ (Motion Technologies), with a multi-camera Vicon™ (Oxford Metrics, U.K.) motion capture system, which acts as a 'gold standard' in a set of functional exercises which are typical in rehabilitation. We then describe and test a framework to improve the reliability of measurements by imposing simple anatomical constraints.

METHODS

A trial was carried out to track and measure upper limb movements in three dimensions. The trial comprised six typical movement patterns, each repeated three times. A 12-camera Vicon (MX F40) system was used to capture the movements, with 39 (9 mm) passive reflective markers placed on the right/left upper limbs, the trunk, and pelvis (**Fig. 1**). A geometric model (**Fig. 2**) was developed based on the International Society of Biomechanics recommendations. Joint angles were defined using Euler angles. In addition, 5 inertial Xsens MTx sensors (3-D accelerometers, gyroscopes, magnetometers; 3 shown in **Fig. 1**) were placed on the same segments; and tracked by Vicon at the same time. The two sets of measurements (Vicon, Xsens) were related to a common co-ordinate system.

RESULTS AND DISCUSSION

Results for forearm pronation/supination, (**Fig.3a-b**) suggest a correlation (r = 0.87) between the angles measured by the Xsens system on the forearm and the angles generated by the upper limb model developed in Vicon (**Fig.3a**) (rmse = 2.521). There are significant errors when the angle is small, as shown in **Fig**. **3b**, probably caused by lack of resolution in the sensor or a sensor drift.

Fig. 1.Marker/ sensor placement

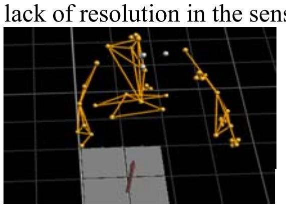

Fig. 2. Upper limb model (in Vicon)

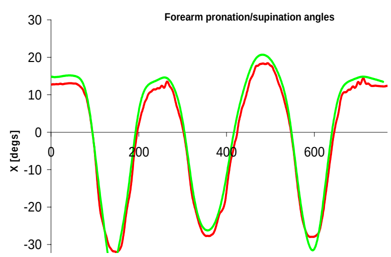

Fig. 3a: Forearm pronation/supination (x)

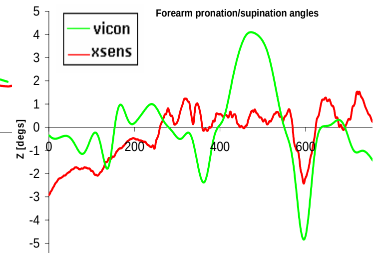

Fig. 3b: Forearm pronation/supination (z)

Sensor measurement errors may be reduced by imposing simple anatomical constraints for a given movement; e.g. forearm pronation/supination takes place mainly about the longitudinal axis of the forearm and is minimal about the lateral axis. To test this, we simulated a range/bearing sensor on the body watching movement of a target on the wrist in one dimension predicting both its position and velocity. The range sensor has errors to simulate skin movement and slippage in mounting; these are superimposed on sensor measurements of the motion of skeletal structures where movement occurs. The true vs. estimated plots of range and bearing are given in **Fig. 4** (top, bottom) respectively. As can be seen, the estimated values of the wrist position converge to their corresponding true values in spite of sensor errors. Results illustrate too the difficulties associated with Cartesian/polar transformations which can give 2π ambiguity non-linearity (tangent) in the (see midway of **Fig. 4** bottom). This might imply using a quaternion axis system.

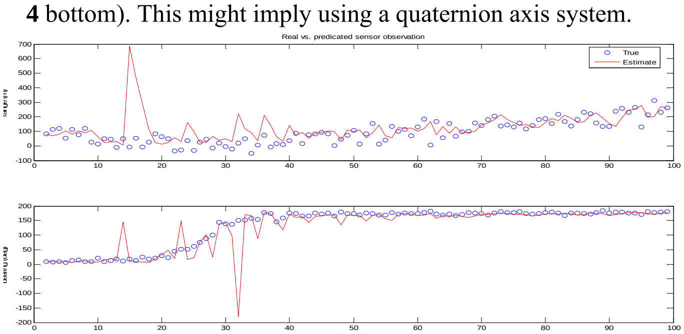

Fig. 4 Sensor range/bearing: true vs. estimate

Early results have shown good agreement between inertial sensors and the Vicon system. There are difficulties when angular velocity is low (within 5°/sec, clinically seen as acceptable). Algorithms with anatomical constraints have shown promise to improve sensor measurements.

CONCLUSIONS

A 3D biomechanical model was developed to measure upper limb motion using both Xsens and Vicon systems. Correlation (r = 0.87) was found in the angular graphs between the systems. A novel method to improve sensor measurement reliability by incorporating anatomical constraints was found promising.

REFERENCES

1. M. Caimmi et al. *Neurorehabil. Neural Repair*, **22**, 31-39, 2008.
2. J. M. Winters, A. R. o. B., 287-320, 2002.
3. Rohrer et al. J. *Neurosci*, **22**, 8297-8304, 2002.