The development of a three-dimensional spinal motion measurement system for clinical practice

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The purpose of this research is to describe a new clinically meaningful method of capturing three-dimensional motion of the spine in real time, expressed in the tilt/twist [1] joint parameters of twist, flexion/extension and lateral bending. Applications for this method include diagnostics, assessment, and rehabilitation of human spinal and balance problems.

Real-time tracking of human body segments is based on rigid body approximations of the segment being measured. Rigid body orientation tracking has widespread applications in robotics, aerospace, virtual reality, automotive, and others. Several techniques have been previously employed for tracking human motion and orientation, including optical tracking systems, electromagnetic tracking systems, radiology and inertial tracking systems. Complex optical tracking systems are limited to in-lab use, involving large amounts of equipment and restrict the movements of the body. Radiology is insufficient to determine the complete kinetics of orientation and involves health concerns associated with x-ray photography. Electromagnetic systems are adversely affected by the presence of ferromagnetic materials, which involves time consuming correction. Inertial tracking combined with new innovations in micro-electromechanical systems have resulted in micro-inertial lightweight and accurate tracking systems that are capable of recording real-time non-inhibited everyday motion of human body segments [2].

The first step in our technique lies in the representation of spinal motion using a PC based device that employs three small state-of–the-art IMUs, which are mounted on the head, torso and hips of the subject. Each IMU, XSens MT9, is a miniature gyro-enhanced Attitude and Heading reference System (AHRS) that provides drift free 3 dimensional (3D) orientation as well as calibrated 3D linear accelerations (micro accelerometers), 3D angular velocities (micro gyroscopes) and 3D data from micro magnetometers. Data from the sensors is combined using Xsens proprietary data fusion algorithm (Kalman filter) to compensate for the drift errors from the integration of the angular velocity data. This, combined with our tilt/twist notation transformation algorithms and motion model, enables the host PC to track 3D meaningful motion of the body (spine) segments in real time.

The result is a successfully modeled representation of spinal motion and orientation in global (world) space. The sensors are easily calibrated to each subject's anatomical planes and geometry, and comfortably attached to the body. The head sensor is attached to a helmet which is placed on the head and the sensors for the torso and hips are attached using a fixture and Velcro straps. The subject's calibration involves a few seconds standing motionless, relaxed, facing forward in a natural balanced position. Once calibrated the sensor records orientation of the subject's body segments, incorporated into a full body model of each subject. Output of the sensor is expressed in tilt/twist notation: degrees of twist, lateral bending and flexion/extension of each segment plotted against time. Rate of change (velocity) of each tilt/twist parameter is also noted.

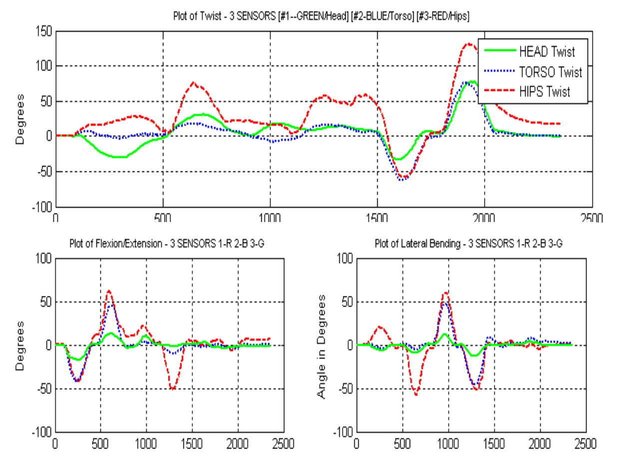

Fig. 1. Real-time motion capture of the head, torso and hips.

The result is a new method of modeling and expressing meaningful real-time motion and orientation of the human spine. Motions can be accurately interpreted and reconstructed from graphical information and are also displayed in a moving model representing each individual subject. The method is clinically meaningful, easily calibrated and useful for capturing everyday non-constricted motions. In addition to the tilt/twist notation parameters of twist, lateral bending and flexion/extension, the linear and rotational accelerations of each rigid segment is also recorded and will eventually be used to evaluate stability of the subjects.

References:

[1] Crawford, Yamaguchi, Dickman, '*A new technique for determining 3-D joint angles: the tilt/twist method',* Clinical Biomechanics, 14 (1999) 153-165.

[2] Lee, Laprade, Fung, '*A real-time gyroscopic system for the three-dimensional measurement of lumbar spine motion*', Medical Engineering & Physics 25 (2003) 817-824