A wearable device for measurement of kinematic parameters of the sit to stand
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\textbf{Introduction}

The analysis of the mechanics of the musculo-skeletal system during execution of the sit-to-stand requires the determination of the instantaneous Position and Orientation (P&O) of the body segments involved, generally modeled as rigid bodies, relative to an inertial reference system. This result is most frequently achieved by tracking the movement of clusters of light emitting or reflecting point-markers associated with the body segments of interest, using a plurality of optoelectronic sensors (Furnèè, 1997). Similarly, ultrasound emitting point-markers and microphonic sensors may be used (Andrews and Youm, 1979). The above techniques exhibit different characteristics, however they share the drawback of having a definite measurement volume within which the movement must take place. A disadvantage of these motion analysis methods is the encumbrance and the necessity to perform double differentiation to obtain acceleration, with introduction of noise and needing of filtering. The wearable device is based on accelerometric techniques alternative to the previous methods (Padgaonkar 1975) (Morris 1973). In particular it utilizes gyrostars components. The sit to stand motor task is fully utilized for motor ability analysis.

Two different algorithms are used for the sit-to-stand locomotor task analysis:
1) A reconstruction of trajectory one.
2) A dedicated timing and acceleration measuring one.

\textbf{Methods}

The wearable device we designed (Giansanti et al. 2001) and constructed is alternative to the purely accelerometric systems, it uses three mono-axial accelerometers (3031-Euro Sensors) and three sensors of angular velocity (Gyrostar ENC-05E-Murata). Zeroing algorithms were utilized for drift compensation. Matlab procedures were utilized for the trajectory reconstruction. Accelerometers and gyrostars are arranged according to Figure 1, for the complete equipment see Figure 2.

\textbf{Final Spatial Disposition of three accelerometers and gyrostars}

![Figure 1 Final Spatial disposition](image-url)
The accelerometers and gyrostars signals are sent to a pc and by means of dedicated algorithms are calibrated using two matrices and then trajectory reconstruction is performed using kinematic algorithms (Giansanti et al. 2001). For the evaluation of timing parameters and acceleration peaks it has been utilized a different approach. Acceleration is directly available from the accelerometers, the signal is calibrated by means of a matrix. From the gyrostars is available angular velocity, the signal is calibrated by means of a matrix too; then there can be performed a normalized kinematic energy of the point where the device has been positioned. Timing calculation isn’t banal, for the presence of noise and human tremor. Adaptative algorithms have been developed; these algorithms utilize the measurement done
before, during and after the locomotor task. For both acceleration vector modulus and the square value of the angular velocity, on-off signals are generated according to the exceeding of thresholds which are established to be over the natural tremor of the still subject which is observed for a time interval of 3 s. The algorithm recognizes both the still-movement transition by applying the boolean OR operator to these signals and movement-still transition by applying to the same signals the AND operator. The flow is in figure 3.

A lot of acquisitions have been performed with an optoelectronic equipments during sit to stand locomotor tasks. These acquisitions have been performed to study the waveforms. In lab these waveforms were sampled and digitized in order to be given as input to a special equipment named MLG2000. (motor laws generator 2000). This equipment that has been developed in lab utilizes a servomechanism who is able to impose predefined timing laws by means of customized programs. The wearable device was fixed to MLG2000; it was then possible to study accuracy in the following two cases:

1) Reproduction of trajectory.
2) Determining of important timing parameters.

Results & Discussion

By means of MLG2000 it has been possible to perform the following two results:

1) The maximum errors were respectively 3 cm in the vertical axis, and 1.4 cm in horizontal plane for the sit to stand trajectory reconstruction.

2) The comparison between the algorithms utilizing the purely accelerometric signals and the algorithms utilizing both accelerometric and gyrostar signals

The latter, which is the really one utilized, was more accurate; at a 100 Hz sample frequency the maximum absolute error in determining start/stop timing points was of 4 sample (0.04s), which for our applications is acceptable; with a pure accelerometric algorithm the error was of 15 samples (0.15s).

The results showed that for the reproducing of the sit-to-stand movement the device was suitable to the application. The introduction of a motion-model could improve the trajectory reconstruction.

References


