

METHOD FOR TESTING MOVEMENT ANALYSIS LABORATORY MEASUREMENT SYSTEMS

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1. Summary/conclusions

In this study, we have developed method for testing correct configuration and combined working status of force platform (FP) and three-dimensional acceleration measurement system of a movement analysis laboratory.

2. Introduction

Accelerometers have become popular measurement devices in gait and movement analysis research [1,2]. In [3] Holden *et al.* presented testing method for force platforms and motion capture components. This study presents method for testing combined working status of a FP and accelerometer measurement systems. Test is performed by using rigid rod-shaped testing device, which is pivoted on FP. Device has two triaxial accelerometers at different locations for estimating rod's orientation relative to floor plane, which can be compared to rod orientation derived from FP data.

3. Statement of clinical significance

Proposed method can be used to test and validate proper installation and calibration of force platforms and accelerometer devices used in clinical movement analysis laboratory.

4. Methods

Acceleration was measured using a portable biosignal data-acquisition unit (Biomonitor ME6000[®] T16, Mega Electronics Ltd, Kuopio, Finland) and ground reaction forces using AMTI[®] OR6-7MA (Watertown, MA USA) force platform. Two triaxial (range ± 10 g) accelerometers (Meac-x[®], Mega Electronics Ltd, Kuopio, Finland) were firmly attached into testing device and their z-axes were calibrated to align with the long axis of the rod and all axes were calibrated to form orthonormal basis. Testing devices orientation from FP measurements was estimated using Eq. (1)-(2), where $F_{x,y,z}$ are measured forces into x, y and z directions respectively.

$$F_{xy}(t) = \sqrt{F_x(t)^2 + F_y(t)^2} \quad (1) \quad \alpha_{FP}(t) = \cos^{-1} \left(\frac{F_{xy}(t) \text{sign}(F_x(t) + F_y(t))}{\sqrt{F_{xy}(t)^2 + F_z(t)^2}} \right) \quad (2)$$

Orientation of the test device and accelerations measured from two triaxial accelerometers are correlated according to Eq. (3), where z_1 and z_2 are measured accelerations into z-directions and s_1 and s_2 are calculated from accelerations into x- and y-directions, Eq. (4). Measured accelerations are combination of gravitation, g, centrifugal acceleration, a_z and tangential acceleration, a_x resulting from testing rod's movement. Distances of accelerometers from the bottom tip are r_1 and r_2 (Fig. 1.).

Equation 3 forms a nonlinear least squares problem (Eq. 5), which can be solved using Gauss-Newton method [4].

$$\begin{aligned}
z_1(t) &= a_z(t) + g \sin \alpha(t) \\
z_2(t) &= \frac{r_2}{r_1} a_z(t) + g \sin \alpha(t) \\
s_1(t) &= a_x(t) + g \cos \alpha(t) \\
s_2(t) &= \frac{r_2}{r_1} a_x(t) + g \cos \alpha(t)
\end{aligned} \tag{3}$$

$$s(t) = \sqrt{x(t)^2 + y(t)^2} \tag{4}$$

$$\mathbf{z}(t) = \mathbf{H}(a_z, a_x, \alpha, t) \tag{5}$$

where $\mathbf{z}(t) = (z_1(t), z_2(t), s_1(t), s_2(t))$ is vector of measurements and \mathbf{H} is a nonlinear function that connects the parameters to measurements.

5. Results

Test measurements were performed three times at different points on FP, measurement time being approximately 30 seconds. Mean absolute error between orientation estimates was 2.37 degrees. Figure 1.b. shows an example of estimated orientations.

6. Discussion

Proposed estimation algorithms can be effectively used to calculate testing device's orientation. Most significant errors between estimated orientation angles take place when the direction of test device's movement changes and when it's orientation crosses 90 degree angle. In the first case the error is caused by missing inertial terms associated with change of direction of the movement. Discontinuity points around 90 degree angles are caused by the test rod's orientation, which is not perfectly orthogonal to z-axis of the floor plane.

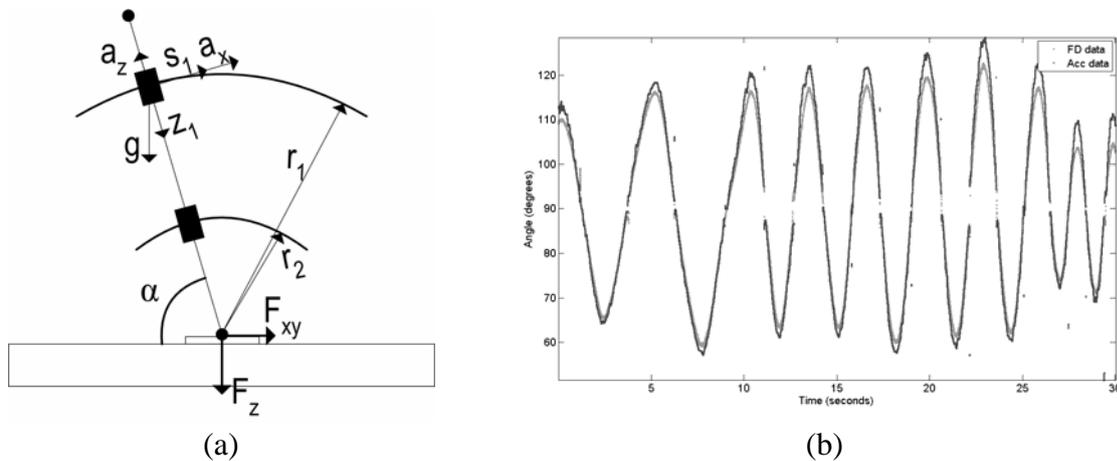


Figure 1. (a) Schematic diagram of measured and true acceleration components of one accelerometer and measured force components. (b) Testing device's orientation estimated from accelerometry and force platform data.

7. References

- [1] Mayagoitia RE, Lötters, JC, Veltink PH, Hermens H, Standing balance evaluation using a triaxial accelerometer, (2002), *Gait and Posture*, 16, 55-59
- [2] Moe-Nilssen R, Helbostad JL, Trunk accelerometry as a measure of balance control during quiet standing, (2002), *Gait and Posture*, 16, 60-68
- [3] Holden JP, Selbie WS, Stanhope SJ, A proposed test to support the clinical movement analysis laboratory accreditation process, (2003), *Gait and Posture*, 17, 205-213
- [4] C. L. Lawson and R.J. Hanson, *Solving Least Squares Problems*, SIAM, 1995