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# On-board accelerometers, advancing in-field Biomechanics understanding.

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## 1. Introduction

In the field of biomechanics, which encompasses various domains such as sports, disability, and occupational ergonomics, understanding human movement in realistic settings is paramount. This involves analysing human motion in terms of both kinematics and dynamics. The gold standard for three-dimensional kinematics and dynamics is a marker-based motion capture system with force platforms, therefore mainly limited to in-lab experiments. Nowadays, in-field measurements have gained attention: video analyses, marker less systems, GPS tracking, or on-board sensors have recently grown to assess human movement under realistic conditions (Hood et al. 2012). In particular, on-board sensors such as accelerometers have been used to extract both, kinematic and dynamic information. However, the accelerometers' characteristics (e.g. frequency range, dynamics) directly affect the data quality and the processing and analyses options. As a result, it is

noteworthy to choose accelerometers with respect to the investigated task (e.g. duration, frequency content, intensity). Hence, the aim of this study was to propose an evaluation benchmark methodology (Bardarous, 2002) of wireless accelerometers for biomechanics application.

Among the different sensors available on the market, the present study focuses on the Blue Tridents IMU sensors from Vicon. This accelerometer, in addition to being recent, has gained popularity in the scientific field of sports and biomechanics for its close integration capabilities with motion capture systems (Winter 2023).

## 2. Methods

### 2.1 Experimental set-up

A closed-loop electrodynamic shaker (IMV compact shaker series m-120, Osaka, JPN; control accelerometer: PCB Piezotronics 333B32, ICP, Buffalo, USA, 100 mV/g,  $\pm 50$  g pk, [0.5 – 3000] Hz) was used to generate vertical signals (Figure 1.a). Five Blue Trident's accelerometers (Dual-g IMU, Oxford, UK, low-g  $\pm 16$  g sampling rate 1125 Hz, high-g  $\pm 200$  g sampling rate 1600 Hz) were simultaneously fixed on the shaker's plate and evaluated (Figure 1.a).

### 2.2 Tested signals

Two types of signals were generated by the shaker. First, 20-second sines with frequencies ranging from 2 to 2000 Hz and amplitudes from 0.1 to 35 g were generated. Table 1 summarizes the amplitude/frequency pairs of sines to which the assessed sensors were submitted. Secondly, shocks with peaks ranging from 10.5 to 35 g were generated. We selected frequency/amplitude pairs and shock amplitudes typical of "human" applications (Griffin 1990) and within the capacities of our excitation system and the capacities of the assessed sensors (Table 1). Each signal was generated five times.

### 2.3 Tested quantities

For the sines, the Fourier transform was applied to each sensor for each of the five similar trials. Then the amplitude norm and frequency of the peak with the highest energy were retrieved. The relative error with respect to the control sensor was then assessed for each quantity (Table 1). Inter-variability between the sensors was assessed for the frequency and amplitude retrieved (Table 1). For the shocks, the maximum amplitude peak in the temporal domain was retrieved for each sensor, and the relative error with respect to the control sensor computed.

Sensors/Trials	2 Hz at 0.1 g		3 Hz at 0.25 g		10 Hz at 0.1 g		40 Hz at 1 g		100 Hz at 1 g		100 Hz at 35 g	
	F[Hz]	Am[g]	F [Hz]	Am[g]	F[Hz]	Am[g]	F[Hz]	Am[g]	F[Hz]	Am[g]	F[Hz]	Am[g]
Sensor 1	-0.585	-2.32	0.39	7.088	-0.585	17.408	0.39	2.367	0.39	-4.37	0.39	0.811
Sensor 2	0.717	1.724	0.31	6.388	0.067	15.658	0.717	1.069	0.391	6.522	0.391	1.526
Sensor 3	0	-0.145	0.391	8.248	0.391	18.601	-0.049	10.1	-0.049	3.76	-0.049	1.493
Sensor 4	-0.049	-4.84	-0.049	8.9	0	6.522	0	11.943	0	3.73	0	1.748
Sensor 5	0	-0.07	0	2.412	0	6.992	0	10.591	0	2.284	0	0.272
Inter-Variability	0.011	0.001	0.007	0.004	0.031	0.003	0	0.258	0	0.195	0	4.595

Table 1: Assessed sensors relative error, frequency and amplitude wise, with respect to the control sensor, in percentage (%). Sensors inter-variability frequency and amplitude wise, in percentage (%).

### 3. Results and discussion

The percentage of amplitude relative error varied from 0,15 to 18 %. For the extreme pairs (2 Hz at 0,1 g and 100 Hz at 35 g) the errors were fully under 5%. As for the other pairs, the errors have exceeded the 5% threshold. Reaching 15% and above, for the 10 Hz at 0,1 g combination, for three sensors. Even though the percentage of error for some sensors differs, the intra-variability of amplitudes given by the sensors stays under 5% for all combinations.

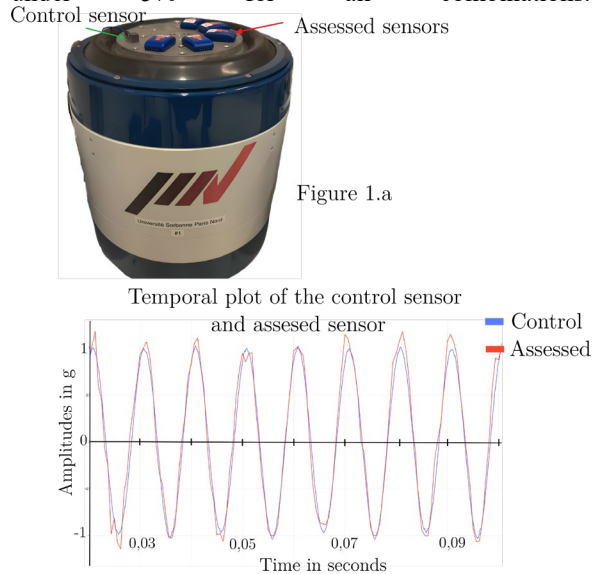


Figure 1.b

Figure 1.a: Experimental set-up, feedback-loop by the reference sensor PCB, and assessed sensors Blue Tridents

Figure 1.b: Temporal plot of the reference and a randomly chosen assessed sensor for the 100 Hz at 1 g pair.

The percentage of relative error with respect to the control sensor, for the dominant frequency, stayed for all combinations, under 1 %. The percentage of intra-variability of frequency given by the sensors stayed fully under 0,03%. Thus, all dominant frequencies were properly assessed.

The percentage of relative error for the amplitudes of shock testing, ranging from 10.5 g to

35 g, stayed fully under 1 %. Giving an overall precise assessment of the shocks. But the sensors intra-variability exceeded 20% for high levels of shock.

### 4. Conclusions

The drive to use on-field sensors for advancing human biomechanics underscores the need to rigorously test accelerometers and confirm the accuracy of the data collected. For the Blue Trident accelerometers, errors remained low for the combinations at upper and lower limits (2 Hz at 0.1 g and 100 Hz at 35 g). The duration to which they are carried out or exposed will add an essential information for the classification of said motion (common, deleterious, without effect). The sampling frequency intra-variability of Blue Tridents giving unsynchronized data also is a parameter to consider for upcoming studies. Further work will be conducted to characterize in greater detail these sensors, as well as other commonly used accelerometers to pinpoint the range to which each sensor is of optimum use.

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### Conflict of Interest Statement

The authors declare no conflict of interest.

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