A Feasibility Study on Body-Worn Inertial Energy Harvesting during Walking and Running

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Introduction

The ability to self-power electronic devices from the movement of the human body has application in a number of fields, including defence, sport and healthcare. To realise this vision, sufficient movement has to be experienced by such an energy harvester. In this poster, we present the results of a study that collected acceleration data from 10 people walking and running on a treadmill for 30 seconds each. Each participant was instrumented with six wireless tri-axial accelerometers at key locations around the body. This dataset was used to analyse the magnitude and frequency distribution of accelerations present on the human body, and subsequently estimate the theoretical maximum output power that can be obtained using an energy harvester.

Experimental Procedure

Ten participants (eight males and two females, aged 24 to 33 years) were recruited from the University of Southampton to participate in the experiment following informed consent. Participants were asked to wear an 'instrumented sweatband', 'instrumented sock' and 'instrumented belt' that monitor and record the acceleration of their elbow, wrist, hip, knee, ankle and instep while they were walking and running (shown in Figure 1).

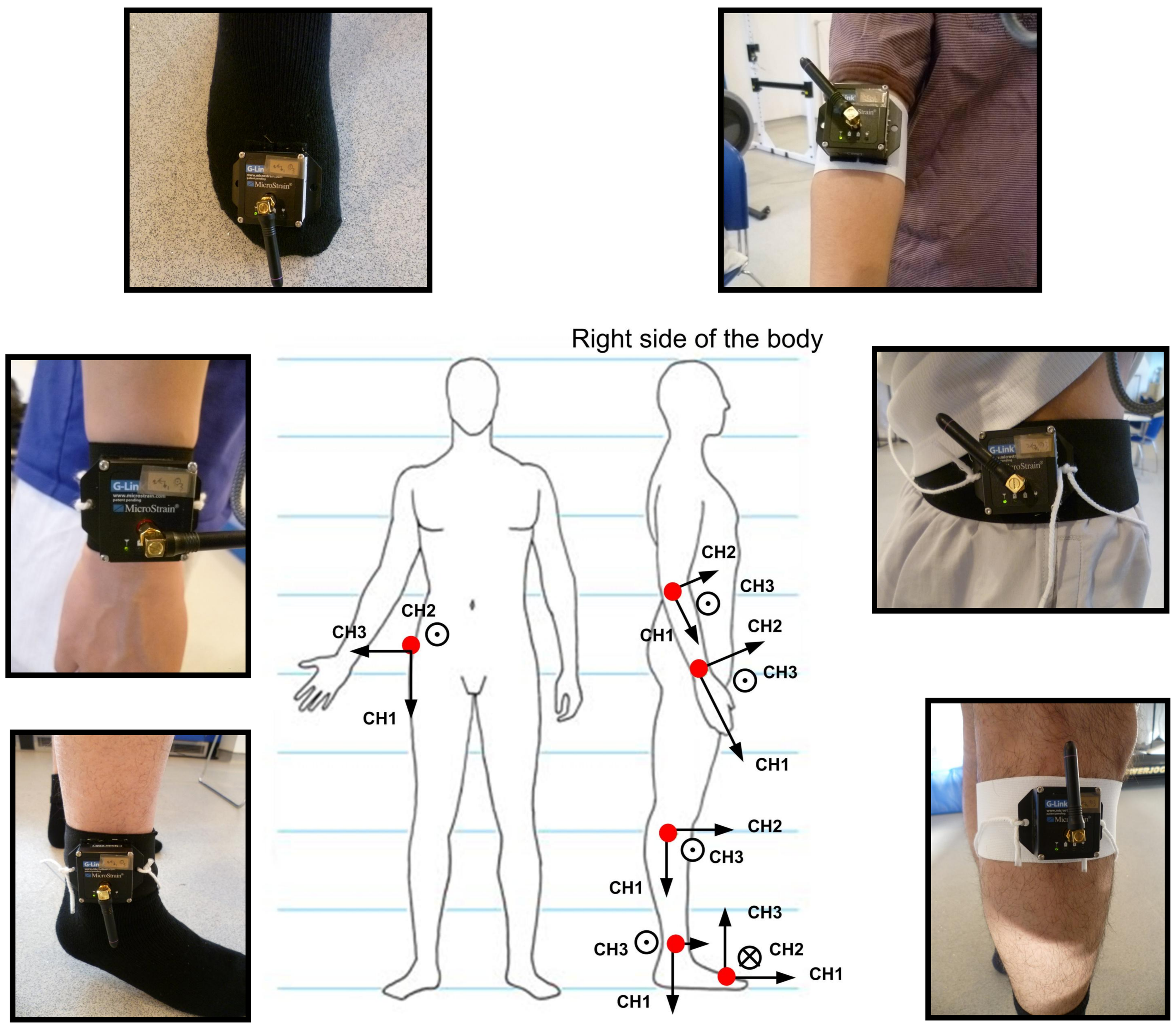

Fig. 1–Locations and orientations of the six accelerometers on the body

G-Link [1] wireless accelerometers and a base station connected to a PC were used, as shown in Figure 2. During the experiment the G-link locally stored the tri-axial acceleration data in its two megabit memory, sampling at 128Hz. Afterwards, the acceleration data were wirelessly downloaded via the base station.

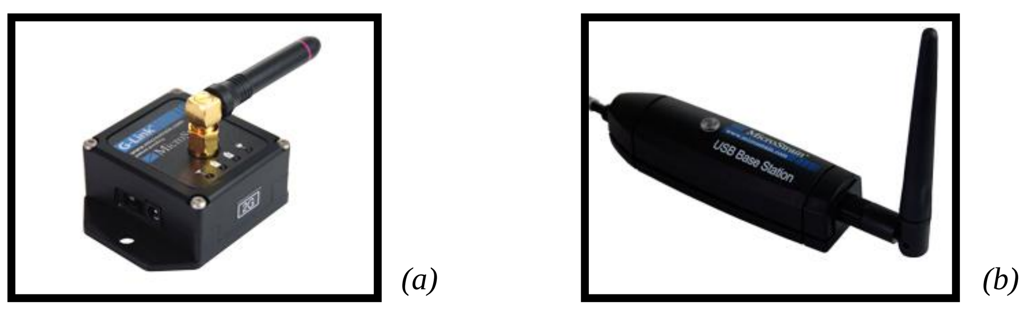

Fig. 2 – The G-Link (a) wireless accelerometer, and (b) base station (reproduced from [1])

The participants were asked to walk and run on a treadmill for 30 seconds, as shown in Figure 3.

Fig. 3 – One participant wearing accelerometers was walking on the treadmill

Data Analysis

First, a high pass filter (a fifth order Butterworth filter with 0.5Hz cut-off frequency) was used to eliminate the DC offset in the collected data to exclude the gravitational component. Then, an FFT was applied to transform the data from the time domain into the frequency domain, as shown in Figure 4. From this, the largest acceleration amplitude and relative resonant frequency used to estimate the largest output power in each of the three axes. We assume that the orientation of an inertial energy harvester will be aligned with one of the three accelerometer axes.

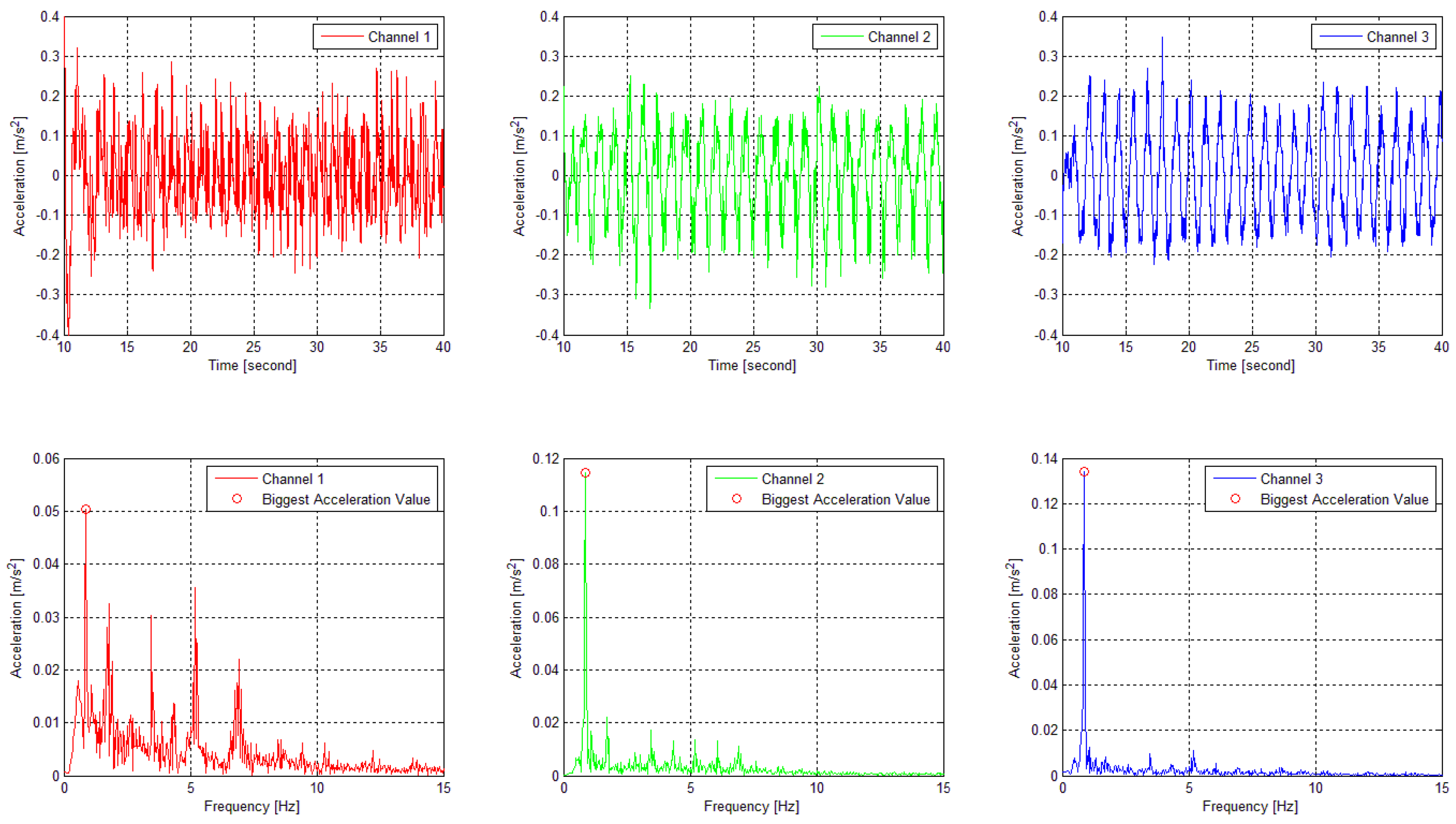

Fig. 4– Time domain and frequency domain of tri-axial acceleration data at the wrist position during walking

The output power from general second-order, spring-mass systems (shown in Figure 5a) can be calculated using the following equation [2]:

$$P = m\xi_e A^2 \big/ 4\omega_n(\xi_e + \xi_m)^2$$

We set the parasitic and transducer damping ratios as the same value, i.e. $\xi_p = \xi_e = 0.01$ [3], to maximise the output power. The mass was set at 10g. The results showed that, out of the six locations, the ankle and instep would produce the largest output power during walking, providing 1.72mW and 1.70mW respectively, as shown in Figure 5(b). Table 1 shows the standard deviation of output power at each position among the ten participants.

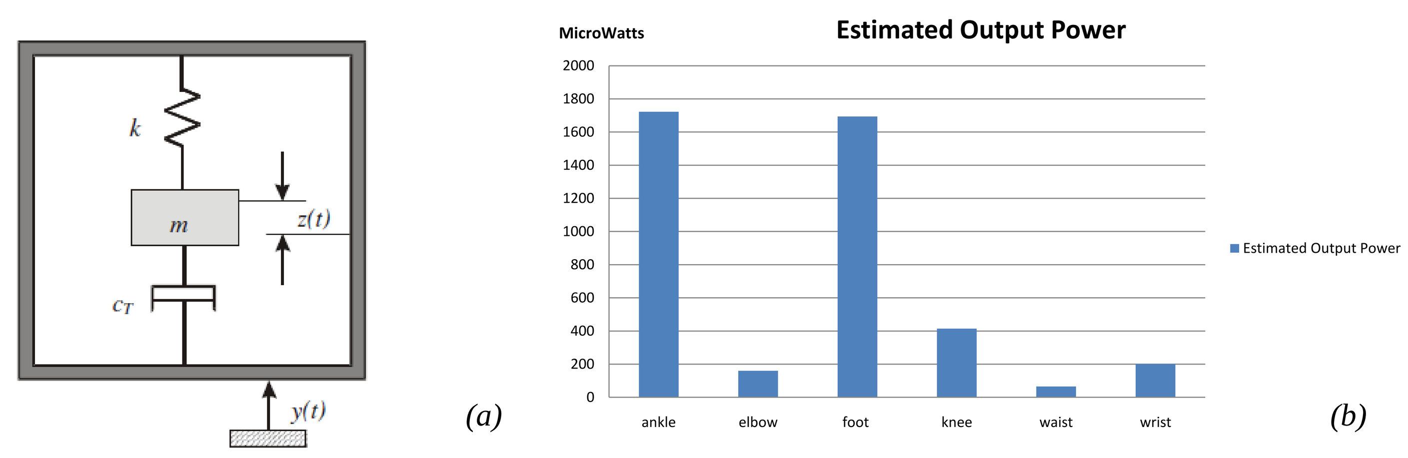

Fig. 5 – (a) Model of a linear, inertial generator (reproduced from [2]); (b) The theoretical maximum output power at the different locations on the body, during walking

	Ankle	Elbow	Instep	Knee	Waist	Wrist
Standard Deviation (Microwatts)	871	114	606	148	27.2	141

Table 1 – The standard deviation of output power for each position

Discussion

Two daily exercises, six key locations on the body, and ten participants have been investigated during this experiment. Our results have indicated that energy harvesters on the lower body, i.e. ankle, instep and knee, can produce more energy during walking than on the upper body, i.e. elbow, waist and wrist. In addition, differences in gait between participants will influence the output power, and this is more significant when on the ankle. From the frequency distribution, it is noticed that the resonant frequencies range from 1.08Hz to 2.09Hz during walking, and that the ankle and instep have a larger acceleration amplitude than positions on the upper body. These properties will allow the design of more effective body-worn inertial energy harvesters.

References

[1] MicroStrain, Inc., "G-Link –mXRS™ Wireless Accelerometer Node", Online, available: http://www.microstrain.com/g-link.aspx, [Last accessed: Feb. 01, 2011].

[2] Beeby, S. P., Tudor, M. J. and White, N. M. , "Energy harvesting vibration sources for microsystems applications," *Measurement Science and Technology*, vol. 17, pp. R175-R195, 2006.

[3] Shad Roundy, Jan Rabaey, "Energy Scavenging for Wireless Sensor Nodes with a Focus on Vibration to Electricity Conversion," *Thesis*, 2003.