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Real-time gait event detection using a miniature gyroscope to improve rehabilitation for artificial lower limb users*

H. F. Maqbool, M. A. B. Husman, M. I. Awad, A. Abouhossein, and A. A. Dehghani-Sanij

***Abstract*— This paper presents a simple heuristic rule based on real-time gait event detection algorithm for transfemoral amputees based on gyroscope signal and validate with footswitches for ramp activities with different inclination.**

I. Introduction

Accurate detection of human gait events such as initial contact (IC) and toe off (TO) and/or phases is vital in gait analysis and has important applications in assistive devices such as prosthetics/orthotics for rehabilitation purposes [1]. Among wearable sensors, gyroscopes are being widely used for long term monitoring of ambulatory systems. Less soft tissue movement on the anterior side of the shank than thigh and less signal variability between the subjects compared with foot signal are primarily the main advantages of attaching gyroscope on shank [2]. This study presents a simple algorithm for event detection and evaluated on transfemoral amputee for two inclined surfaces (5^o and 8.4^o).

II. Experimental Setup and Algorithm Description

A gyroscope and a base unit containing circuitry and battery unit were placed on the anterior side of the shank with the help of Velcro straps. For validation purposes, an insole consisting of four footswitches located at the heel, 1^{st} and the 5^{th} metatarsals and toe was placed inside the shoe shown in Fig.1. One transfemoral amputee (age: 53 years old; weight: 66.7 Kg; height: 166.1 cm) who uses Orion2 (knee) and echelon (foot) with no other neurological problems other than his amputation participated in this study. Once the participant was equipped, he was asked to walk on two surfaces with inclinations of 5^o and 8.4^o respectively and data from gyroscope signal and four footswitches were captured through wireless gait detection system.

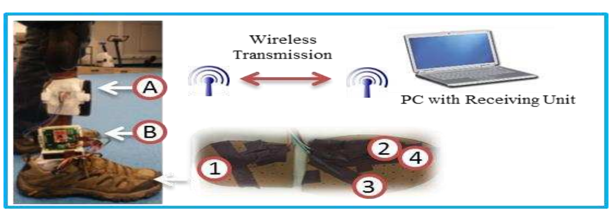

Figure 1. Placement of (A) Gyroscope (B) Base Unit and an insole with footswitches at 1-Heel, 2,3-1^{st} & 5^{th} Metatarsals, 4-Toe

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H. F. Maqbool, M. A. B. Husman, M. I. Awad, Member, IEEE A. Abouhossein, Member, IEEE, A. A. Dehghani-Sanij: School of Mechanical Engineering, University of Leeds, Leeds, LS2 9JT, UK (e-mail: mnhfm@leeds.ac.uk; mnmabh@leeds.ac.uk; m.i.awad@leeds.ac.uk; a.abouhossein@leeds.ac.uk; A.A.Dehghani-Sanij@leeds.ac.uk). H. F. Maqbool is on study leave from University of Engineering and Technology Lahore, Pakistan.

Gyroscope signal at shank shows prominent peaks and troughs corresponding to mid-swing (M-Sw), IC and TO. A sample of real-time event detection for prosthetic side during ramp ascending is shown in Fig. 2.

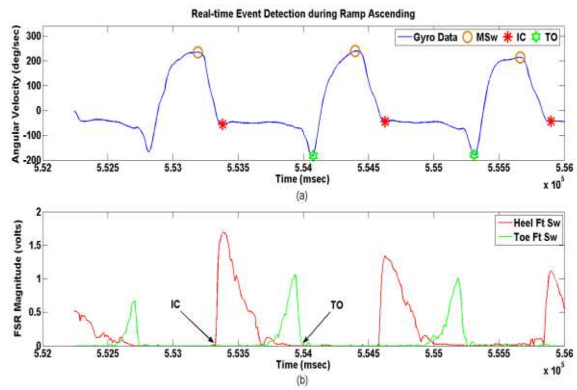

Figure 2. Real-time event detection using (a) gyroscope at shank and validation with (b) footswitches at heel and toe

III. Results

The timing difference was evaluated using; difference = $T_g - T_{ftsw}$ where T_g and T_{ftsw} indicate the timings of the detected events from gyroscope and footswitches respectively. The mean difference and standard deviation for IC and TO on both inclinations showed quite similar results during ramp ascending for both prosthetic and intact side as shown in Table 1. There are little variations during ramp descending, particularly on prosthetic side. The proposed algorithm showed promising results for both inclined surfaces.

TABLE I. Event Detection Time Differences (ms) between Gyroscope and Footswitchs: Mean Difference ± Standard Deviation

	Ramp Ascending		*Ramp Descending*	
Angle	**5°**	**8.4°**	**5°**	**8.4°**
		Prosthetic Side		
IC	39 ± 18	39.5 ± 20	9 ± 40	0.7 ± 5
TO	51± 12	58± 14	23.7 ± 13	-45.7 ± 31
		Intact Side		
IC	20 ± 17	28.5 ± 28	20.3 ± 26	33.6 ± 62
TO	21 ± 9.5	32.3 ± 24	-3.9 ± 19	13.5 ± 15

References

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[2] P. Catalfamo, S. Ghoussayni, and D. Ewins, "Gait event detection on level ground and incline walking using a rate gyroscope," *Sensors,* vol. 10, pp. 5683-5702, 2010.