GAIT ANALYSIS MEASUREMENT FOR SPORT APPLICATION BASED ON ULTRASONIC SYSTEM

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ABTRACT

Gait analysis is a very important procedure in assessing and improving many quality of life indicators. In sports, gait analysis can be used to improve athlete's performance and injury prevention. This paper presents the development of ultrasonic system in wearable instrumented shoes for gait analysis measurement in sport application. This paper begins with introduce to the requirement in the related literature. The explanation on the system configuration follows next that describes sensor properties and time of flight concept. Next, is a section that explains the experimental setup using the proposed instrumentation which is then followed by the result section. Finally, the planned future works shares in this paper.

Keywords: ultrasonic sensor; gait analysis; foot clearance;

I. INTRODUCTION

Gait analysis is the study of lower limb movement patterns and involves the identification of gait events and the measurements of kinetics and kinematics parameters. These include for example, toe-off, landing, stance, swing, displacement, speed, acceleration, force, pressure and the pressure-time-integral as stated in [1][2]. Gait analysis is broadly employed in sports, rehabilitation also health diagnostics. In sports training as well, gait analysis has been applied to recognize the faults athletes' performances in various sports events e.g., golf, swimming, running, etc [3-9]. At least in part by poor biomechanics, many injuries are often caused. To avoid future overuse injuries, sports runners and athletes whose require a high level of running and jumping should make sure they had a gait analysis and buy the correct footwear as described in [10]. The very important moment that can lead to the trip or fall occurrence is identified as when the foot movement in stage of mid-swing phase. This important stage of foot movement is referred to as minimum foot clearance (MFC). Study in [11] shows the minimum foot clearance is below 5 cm while the foot trajectory during gait may go up to 17 cm. These days, gait analysis is still mostly carried out in a specially set-up motion laboratory using high-end motion imaging systems, and magnetic tracking system as stated in [12-13]. In another measurement set-up, the analysis requires a physician to visually observe the gait. These two approaches are undoubtedly expensive as shown in [14].

Despite the current practices, the reality proves that the demand for real life portable measurement and monitoring devices are surging fast. As an example, a portable shoe integrated system should perform better in real environment to allow comprehensive analysis and intensive monitoring. In situ experiment as reported in [2] [15-17] where the actual activities and measurement are performed suggest that such system can reduces operation cost as well as the time requiring for presence of physician. Figure 1 shows the possible position for ultrasonic system during gait analysis for athlete usage. The ultrasonic system will be affixed at the front and back of the shoe.

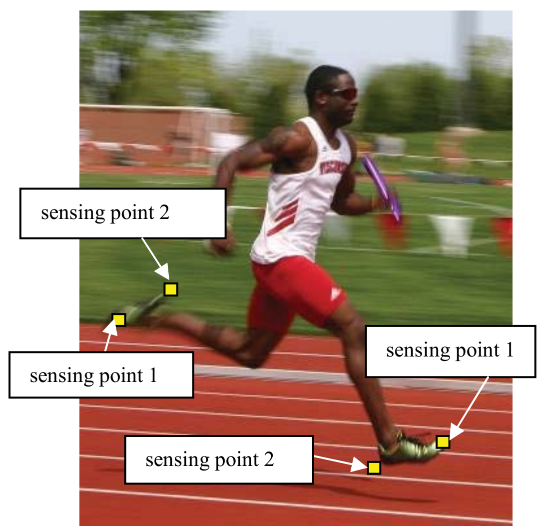

Figure 1. Possible Position for Ultrasonic System.

II. RELATED WORK

A very sophisticated approach using accelerometers are highly recommended, but double integration algorithm required for accelerometer based system to minimize the erratic data due to the drifting effect and error as described

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in [18]. The MFC measurement based on accelerometer are also not suitable on uneven and bumpy surface such as during descend and ascend on stairs as it computes clearance from acceleration data [1]. Even though it is able to detect rapid movement even when the corresponding displacements are relatively small, accelerometer gives no indication of a segment initial condition [19]. And it is susceptible to the integration drift errors. Therefore to overcome these errors; a drift correction method is required as stated in [20].

The current method of MFC measurement requires a laboratory setting with the use of reflective or active markers, one or more video cameras, thread-mill or suitable floor and computer software running on suitable computers [11]. This approach is limited to certain level of precision as it is not suitable in natural environment such as at home, stadium or outdoor as stated in [21-22], wearable instrumented shoe method are more convenient and should be more preferred.

III. REQUIREMENT

The measurement should be done in real life activities to ensure the study of foot clearance is accurate and precise. This means, the general requirements for gait analysis are the ability to be attached to the subject's own shoes, the device must not affect movement, un-tethered and capable of measuring parameters for both feet as stated in [2][30-33]. From the requirement, the device should be as small and as light as possible with weight under 300g as stated in [14] in order to have such ability. To avoid athlete discomfort and obstructions during gait performance, micro sensors were used for the purpose of data acquisition and a wireless sensor system is being developed [26].

IV. SYSTEM CONFIGURATION

The ultrasonic system presented in this paper consists of one transceiver, microcontroller, data acquisition software and wireless communication as shown in Figure 2.

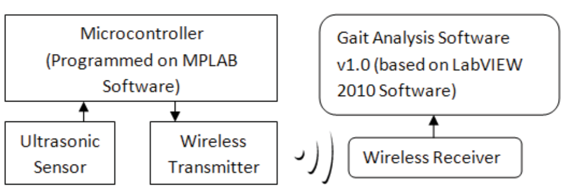

Figure 2. Block diagram of Ultrasonic System.

Accurate distance can be obtained by measuring the time of flight (t_{of}) value of the ultrasonic sensor as stated in [27]. Figure 3 shows the using of t_{of} method, after an ultrasound signal is transmitted by a transmitting transducer (transmitter), the distance, $\boldsymbol{l}$, can be calculated based on the time $\boldsymbol{t}$, taken by the ultrasound echo to return to the receiver [1].

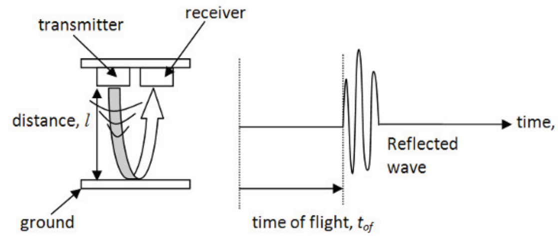

Figure 3. A simple time of flight concept.

All the data will be processed using a pre-programmed microcontroller and data acquisition software through IEEE 802.15.4 wireless communication protocol [2]. This sensory board is capable to be used in real-time as it is equipped with the wireless capability. The IEEE 802.15.4 wireless transceiver can transmit wirelessly up to 1500m (line of sight). The IEEE 802.15.4 wireless communication protocol is elected because of its relatively smaller size, economically charged and lower power consumption as recorded in [2][28-29]. The result is presented as graph by the data acquisition software based on LabView development software.

V. EXPERIMENTAL SETUP

The experimental work begins with the development of the sensory board. This sensory board is small, compatible for any shoes and is intended to be attached to the shoes wirelessly with a 9V power supply. Once the system is attached to the shoes and the shoe is worn by the subject, the system can be operated immediately. Figure 3 shows the placement of sensory board during experimental work. Its purpose is to capture the athlete gait pattern. This can be used to avoid athlete's sports injury.

Upon powered up, the sensory board will transmit data continuously and recorded in the software and can be viewed as a graph of gait pattern. Figure 4 shows the placement of the wireless sensor board on top of the shoe and ultrasonic sensor at the back of the shoe. The weight of the board is nearly 81grams. This law weight of the board is to ensure that the subject feel comfortable while wearing the instrumented shoes during gait.

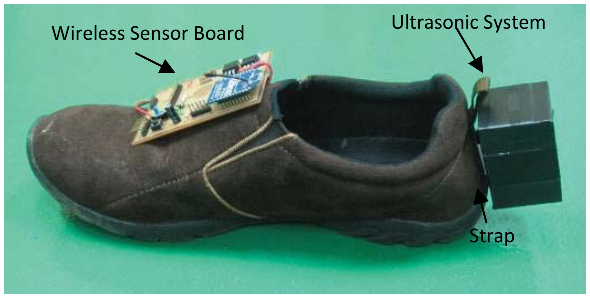

Figure 4. The placement of the wireless sensor board on the shoe. Also shown is the ultrasonic system at the back of the shoe.

VI. RESULT

This section discusses the output of hysteresis of ultrasonic sensor measurement. The output comes from the clearance measurement from 1cm until 15cm. This range is chosen to satisfy the requirement for foot clearance measurement. It will continue to measure until 30cm but is not shown here. [23][34][35] explain in detail the requirements for any devices to be used in gait analysis. Sensors with low hysteresis are preferred. Figure 5 shows the hysteresis by increasing and decreasing distance of ultrasonic sensor. This result proves that the measurement of foot clearance using the proposed custom designed ultrasonic sensing board is very practical because of low hysteresis.

Figure 6 show the graph for foot clearance pattern recorded using LabView 2010 software for male subject during running. This figure clearly shows the ultrasonic system can be enhanced to operate automated using advance classification technique along with the report generation in real time for future used.

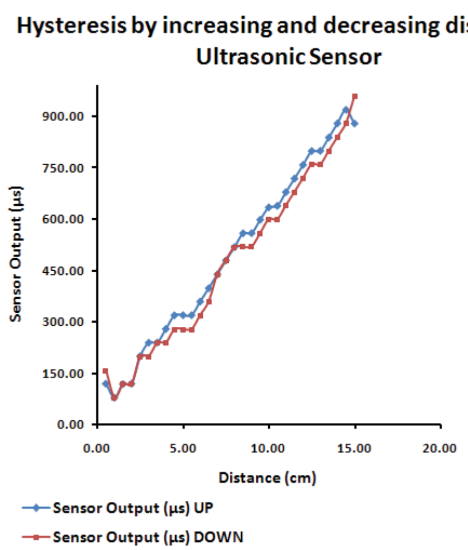

Figure 5. Hysteresis Graph.

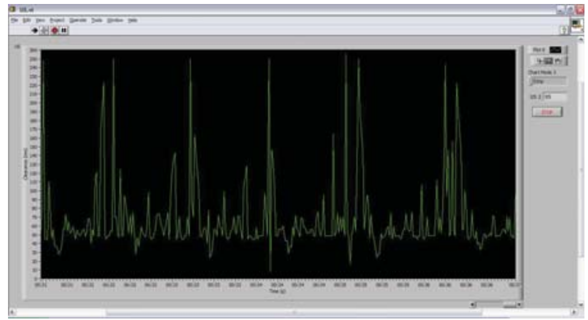

Figure 6. Graph for Foot Clearance Pattern.

VII. FUTURE WORK

Using statistical analysis, data collection from huge athletes group can be evaluated using ultrasonic system. The group will be categorizing based on their age, sex and type of movement. Our intention is to design a fully integrated MEMS based ultrasonic sensing system monolithically.

VIII. CONCLUSION

In this paper, using a newly proposed custom designed ultrasonic sensing board the measurement of foot clearance during sport activity is reported. The low hysteresis of the ultrasonic distance measurement is proven to produce reliable and accurate foot clearance data for realization of a real time wireless gait analysis data acquisition and processing system for sport application. From the result, clearly shows the ultrasonic system can be enhanced to operate automated using advance classification technique along with the report generation in real time for future used.

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