Demo Abstract: Measuring Foot Pronation Using RFID Sensor Networks

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Abstract

Running efficiency is an important factor to consider in order to avoid injury. In particular, foot pronation, the angle of the foot as it hits the ground, is a common cause for many types of injuries amoung runners. Though pronation is common, diagnosing pronation is difficult and imprecise. Currently there is no method of diagonsis which can quantify the severity of pronation. In this paper we propose using WISP (Wireless Identification and Sensing Platform) sensors to help identify and quantify foot pronation.

Categories and Subject Descriptors

C.2.1 [**Networks**]: Wireless Communication; C.3 [**Special Purpose and Application-Based Systems**]: Real-Time Embedded Systems

General Terms

Design, Experimentation, Measurement, Performance

Keywords

RFID Sensor Networks, Physiological Monitoring

1 Overview

Running is a great exercise having many physiological benefits including weight loss, improved cardiovascular health, increased muscle mass and increased bone density. However, due to its high-impact nature, there are many injuries associated with this sport. Common injuries include shin splints, pulled muscles, iliotibial band syndrome, plantar fasciitis, and Achilles tendinitis. In a survey by the American Orthopedic Foot and Ankle Society, 63% of respondents reported having an injury related to their shoes. According to the American Academy of Orthopedic Surgeons, more than 43.1 million Americans suffer discomfort due to improperly fitted shoes costing the U.S. $3.5 billion a year [1]. Bio-mechanical efficiency is one of the most important contributory factors for injury prevention and enhancing performance, and also is the most overlooked issue when computing running efficiency. In particular, the angle of the foot when it hits the ground can significantly affect efficiency. This angle is broadly defined as pronation. Runners can be usually classified into one of three broad pronation categories (see Figure 1): neutral, overpronation, and underpronation (supination). Overpronation is the excessive inward roll of the foot after landing. In overpronators, the foot continues to roll when it should be pushing off. This twists the foot, shin and knee and can cause pain in all those areas. Supination is caused by insufficient inward roll of the foot after landing. Properly identified, pronation can be corrected with proper shoe selection or using sole inserts.

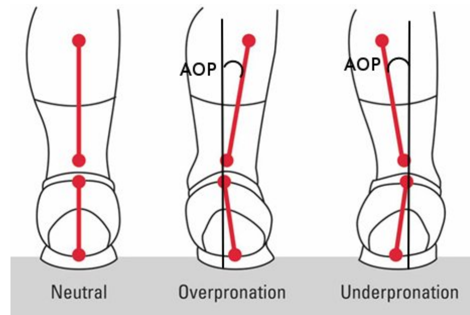

Figure 1. Different varieties of pronation in human beings. ***AOP*** **denotes the angle of pronation of the foot.**

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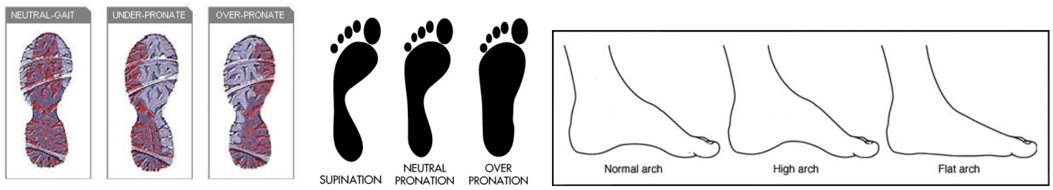
Determining foot motion

Apart from visiting a podiatrist, there are a few indirect means of measuring foot motion:

- Wear-pattern: The wear pattern on the outsole may represent the distribution of forces along the shoe and may help determine pronation (see Figure 2(a)).
- Footprint: Wet your feet and stand on a flat surface that will allow your footprint to be seen. Comparing the footprint with Figure 2(b) gives an idea regarding pronation.
- Arch-types: Generally, the higher the arch the less the foot will pronate and the lower the arch the more the foot will pronate (see Figure 2(c)). Arch height works best as an indicator of foot motion for people at the extremes. However, there are people with high arches that over-pronate and people with no arches that supinate.

In addition, the most common and accepted method of measuring pronation is simply watching the runner run. This is an imprecise approach; an accurate analysis of a runners pronation is highly dependent on the experience of the observer and what is detectable by the eye. In addition, there is no metric to quantify what is observed.



(a) (b) (c)

Figure 2. Common Indicators of Foot Pronation: (a) shows the shoe-sole wear for people with different kinds of pronation. (b) shows the typical wet foot imprint for different pronators. (c) shows the different foot-arch types.

2 Demo Description

The Intel WISP [2, 3] is a wireless, battery-free, RFID-based platform that is capable of sensing and computation due to the on-board ultra-low-power 16-bit flash microcontroller with analog to digital converters and light, temperature sensor, accelerometer, and strain gage sensors. The sensing modality we consider is the triaxial accelerometer, which can provide readings at rates of approximately 10 to 20 samples per second, depending on range.

We are interested in exploring aspects of running efficiency that could be captured by WISP sensors and solutions for correcting gait inefficiency. Once a measurement system is developed, it may be possible to develop more formal definitions for pronation. One of our goals is developing metrics that accurately describe and quantify pronation and running efficiency. These metrics would help analyze the effectiveness of shoes and inserts and determine which aspects of the stride are most important to bio-mechanical efficiency. This would also help evaluate the effectiveness of shoes and inserts that correct pronation. In addition to studying pronation, we are also interested in using the WISPs to explore the significance of other movements involved in running.

The proposed system would measure the angle of pronation (AOP, see Figure 1) for a user fitted with the WISP. The main function would be to accurately measure the orientation of the foot through the full stride using the 3D-accelerometer data provided by the WISP. Users would run on a treadmill with WISP sensors fastened to the leg and shoe. From the observed measurements, the system would identify the type of pronation observed and the severity of the pronation. Based on the observed measurements, the system could be used to suggest shoe and insert recommendations that would correct the pronation. This type of system would be very useful tool for shoe retailers trying to fit diverse customers.

3 Applications

The above system serves as a springboard for many other potential applications. In particular, the system could serve as a useful design tool. This system could be useful for shoe designers; feedback from the system would help fine-tune shoe structures for the various types of pronation. This would help create additional lines of shoes that would be more effective correcting specific types of pronation. Another related application would be customized shoe inserts. Since pronation can often be corrected using shoe inserts, it may be possible to create customized shoe inserts based on the systems pronation measurements. Gait analysis, an important concern of athletes, is typically accomplished through the use of high speed video. With some adaptation, the proposed system may provide an alternate analytical tool for gait analysis.

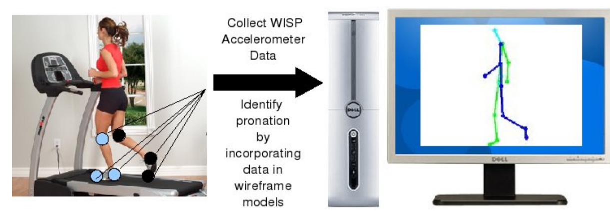


Figure 3. Demo Illustration: WISP sensors will be attached to the runner's leg and feet. Data from the sensor will be used to visualize pronation using a computerized pronation model (Note: Stick Figure from http://www-anw.cs.umass.edu/ mtr/research/biped/).

Additional sensor data from the WISP could help track changes in body and foot temperature while the athlete is running. This data is useful also for predicting foot wounds in diabetic patients. This was highlighted in a study by Armstrong et al. [4]. The study aimed to show that diabetic foot wounds which are caused by repetitive stress to the foot, causing inflammation and skin breakdown, can be avoided by checking skin temperature. The results showed that patients who measured their foot temperatures were far less likely to get foot sores than those who did not.

4 References

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