Run Surface Classification: a Digital Sports Embedded Application

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In this presentation, methods to analyze biomechanical data of runners to facilitate classification of the prevailing running surface situation are discussed. We are considering an embedded application example from the field of digital sports: A novel running shoe capable of acquiring parameters specific to the run and setting its cushioning accordingly. The developed classifier is used in the product version of the mentioned running shoe to correctly adapt the shoe cushioning setting.

1 Introduction

For many applications, the ability to perform accurate classification in real time is a key factor. This is not only true when computationally powerful hardware is employed. It is also often crucial in the restricted hardware environment of power-efficient, mobile microprocessors used in embedded systems. The most important question is which of the complex algorithms known in pattern recognition can be used and implemented in the context of the restricted computational power and memory capacity of the microprocessors that are used. Special considerations must be made to adapt those algorithms to the specific hardware and classification task. A lot of areas of engineering can benefit from the possibility of reliable classification in this restricted environment. Examples include communications, automotive solutions, speech recognition, industrial automation and medical care.

In this paper, we show the application of these concepts to the adidas_1, which is the first running shoe featuring an embedded system. The shoe is built to adapt to various running conditions, e.g. the prevailing surface situation. A precise classification of the mentioned conditions is mandatory to guarantee this functionality. In order to facilitate this, the step heel compression signal of the runner is continually sensed and processed by the embedded microcontroller. A description of the adidas_1, its functionality and embedded system hardware can be found in section 2 and in (2). We describe the analysis methods that lead to accurate surface classification in real-time. To our knowledge, we are the first group researching step signal classification on an embedded system. The presented example of a classification system has been implemented in the current product version of the adidas_1 running shoe. It is significantly contributing to the functionality of the shoe and thereby offering runners an ideal cushioning adaptation during each phase of their run.

2 Materials and Methods

2.1 The adidas_1 Running Shoe

The adidas_1 is a running shoe that possesses a built-in 8-bit microcontroller, a sensor for heel compression measurement and a motor for cushioning adaptation. This shoe is designed for avid runners, and is constantly adjusting itself to the running situation. In this presentation, we will focus on the classification of the surface that the athlete is running on. The general demand to establish constant cushioning when a change of running surface takes place and all other running conditions remain constant is to have

- a soft shoe on hard surfaces (asphalt, concrete)
- a hard shoe on soft surfaces (grass, trail).

The automatic adaptation ideally takes into account the athlete's weight, speed, fatigue level and furthermore the current surface condition, elevation profile and shoe condition.

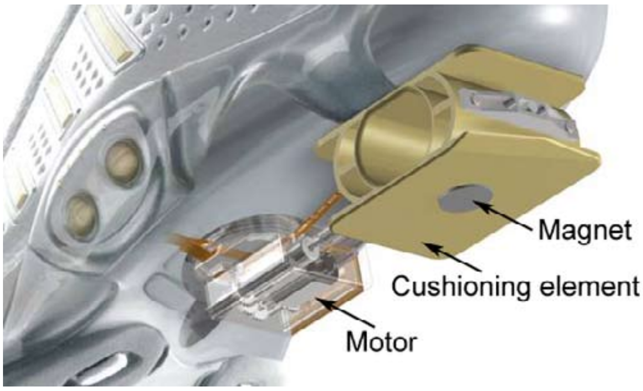

Figure 1: The adidas_1 shoe.

To facilitate this adaptation, the shoe features a cushioning element (Fig. 1), whose ability to give way in vertical direction can be regulated by a motor-driven cable system. The regulating cable is running from the motor through the middle of the cushioning element to its opposite end and is fixated there. The motor shown in Fig. 1 can adjust the attenuation setting by turning a screw which lengthens or shortens the cable. When the cable is shortened, the cushioning element is tensed and compresses very little when external forces are applied. When the cable is longer, it allows the cushioning element to compress further by giving it more room to expand in the x-axis direction (forward-backward direction), effectively making the shoe softer. For more details on the shoe design the reader is referred to (2).

Compression measurement is made by a hall sensor that is mounted at the top of the cushioning element. It detects the magnetic field strength induced by a small magnet, see