Development of a Low-Power Microcontroller-Based Wrist-Worn Device With Resource-Constrained Activity Detection Algorithm

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***Abstract*—This article deals with the development of a resource-constrained activity detection algorithm for microcontroller-based wrist-worn devices. The various market available activity detection devices lack adequate agility and ease of use in certain applications, as they heavily rely upon computationally intensive algorithms to detect physical activity and step count. Therefore, by extension, they always need to stay connected with a smartphone that can perform these computations. To address this problem, this article introduces a standalone wearable device with the simplified algorithm for activity detection in a human being. The developed system consists of microelectromechanical systems (MEMS) triaxial accelerometer connected to a low-power microcontroller with a wrist anchor-able form factor. The step detection algorithm uses a moving average threshold filter to detect the change in acceleration data to identify specific events. A detailed comparative study considering power consumption and the step detection made between the developed device (with the resource-constrained algorithm) against market available devices shows that the average detection error of the developed algorithm is approximately 2% under various test conditions (i.e., walking, fast walking, and running) and has an accuracy of 94.96% for activity detection. This study reveals that the use of the proposed algorithm for activity detection not only brings down the cost of the overall device but also reduces the power consumption (<45.7 mW) with a minimal covering size (12.56 cm^2) for the wearable part that can extend the application area of such devices.**

***Index Terms*—Activity detection, microelectromechanical systems (MEMS) accelerometer, resource-constrained algorithm, wearable device, wrist-worn.**

I. Introduction

According to a World Health Organization (WHO) report that claims that in 2018 alone, there were more than 1.9 billion adults, 18 years and older, who were overweight, of these over 650 million were obese [1]. The numbers from this survey points toward the need for the development of a system that can monitor potential health habits through daily activity (i.e., resting, sitting, and movement) while remaining discrete, low in cost and not dependent on a smartphone/operating system (OS) as various other market available devices do [2]–[4].

The early days of activity detection were mostly done using mechanical pedometers that had a pendulum-like structure in them [5]. This pendulum rocked back-forth for every step taken by the wearer. This method is inherently inefficient and prone to errors as there is no way to check the validity of the data generated. Thus, with the advent of modern microfabrication techniques as microelectromechanical systems (MEMS) accelerometers replaced mechanical pedometers with the far more versatile and multimodal data output, it became easy to analyze most of the data generated by these tiny sensors [6].

As found in the literature, the various applications related to human activity using mobile phone/smartwatch accelerometers are widely popular and are well studied [7]–[9]. However, these methods mostly depend on the use of computationally intensive techniques, such as the fast Fourier transform (FFT) [10]/discrete wavelet transform (DWT) [11] to extract the maximum frequency component of accelerometer signal or some other machine learning tools, such as a deep neural network (DNN) to extract the correct activity [12]. In the case of the learning-based models, the determination of physical activities is done with the assistance of trained classifiers, such as support vector machine (SVM), hidden Markov model (HMM), or DNNs [13]–[15]. Although machine learning or frequency analysis techniques can significantly enhance a system's robustness toward detection, the algorithm implementation always requires high computing resources, which limits their application in wearable platforms that need to perform standalone detection of physical activities [16].

The work presented in this article tries to eliminate the aforesaid problems by implementing an AVR microcontroller-based wearable bracelet having a triaxial MEMS accelerometer for detection of physical activities, as in the general block diagram shown in Fig. 1. The device being developed here targets application areas where the presence of a ubiquitous smartphone [17] is not always expected or desired, such as in the case of nursing home/hospitals/elderly home or baby crèches where there is a need to characterize the activities that an elderly/patient/kid performs without restricting their mobility [18], [19]. The algorithm developed here for activity event

Manuscript received December 7, 2019; revised March 3, 2020; accepted March 18, 2020. Date of publication March 30, 2020; date of current version September 15, 2020. The Associate Editor coordinating the review process was Jagadeesh Kumar. *(Corresponding author: Debjyoti Chowdhury.)*

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Digital Object Identifier 10.1109/TIM.2020.2984142