Activity Recognition from User-Annotated Acceleration Data

Ling Bao and Stephen S. Intille

Massachusetts Institute of Technology
1 Cambridge Center, 4FL
Cambridge, MA 02142 USA
intille@mit.edu

Abstract. In this work, algorithms are developed and evaluated to detect physical activities from data acquired using five small biaxial accelerometers worn simultaneously on different parts of the body. Acceleration data was collected from 20 subjects without researcher supervision or observation. Subjects were asked to perform a sequence of everyday tasks but not told specifically where or how to do them. Mean, energy, frequency-domain entropy, and correlation of acceleration data was calculated and several classifiers using these features were tested. Decision tree classifiers showed the best performance recognizing everyday activities with an overall accuracy rate of 84%. The results show that although some activities are recognized well with subject-independent training data, others appear to require subject-specific training data. The results suggest that multiple accelerometers aid in recognition because conjunctions in acceleration feature values can effectively discriminate many activities. With just two biaxial accelerometers – thigh and wrist – the recognition performance dropped only slightly. This is the first work to investigate performance of recognition algorithms with multiple, wire-free accelerometers on 20 activities using datasets annotated by the subjects themselves.

1 Introduction

One of the key difficulties in creating useful and robust ubiquitous, context-aware computer applications is developing the algorithms that can detect context from noisy and often ambiguous sensor data. One facet of the user's context is his physical activity. Although prior work discusses physical activity recognition using acceleration (e.g. [17,5,23]) or a fusion of acceleration and other data modalities (e.g. [18]), it is unclear how most prior systems will perform under real-world conditions. Most of these works compute recognition results with data collected from subjects under artificially constrained laboratory settings. Some also evaluate recognition performance on data collected in natural, out-of-lab settings but only use limited data sets collected from one individual (e.g. [22]). A number of works use naturalistic data but do not quantify recognition accuracy. Lastly, research using naturalistic data collected from multiple subjects has focused on

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recognition of a limited subset of nine or fewer everyday activities consisting largely of ambulatory motions and basic postures such as sitting and standing (e.g. [10,5]). It is uncertain how prior systems will perform in recognizing a variety of everyday activities for a diverse sample population under real-world conditions.

In this work, the performance of activity recognition algorithms under conditions akin to those found in real-world settings is assessed. Activity recognition results are based on acceleration data collected from five biaxial accelerometers placed on 20 subjects under laboratory and semi-naturalistic conditions. Supervised learning classifiers are trained on labeled data that is acquired without researcher supervision from subjects themselves. Algorithms trained using only user-labeled data might dramatically increase the amount of training data that can be collected and permit users to train algorithms to recognize their own individual behaviors.

2 Background

Researchers have already prototyped wearable computer systems that use acceleration, audio, video, and other sensors to recognize user activity (e.g. [7]). Advances in miniaturization will permit accelerometers to be embedded within wrist bands, bracelets, adhesive patches, and belts and to wirelessly send data to a mobile computing device that can use the signals to recognize user activities.

For these applications, it is important to train and test activity recognition systems on data collected under naturalistic circumstances, because laboratory environments may artificially constrict, simplify, or influence subject activity patterns. For instance, laboratory acceleration data of walking displays distinct phases of a consistent gait cycle which can aide recognition of pace and incline [2]. However, acceleration data from the same subject outside of the laboratory may display marked fluctuation in the relation of gait phases and total gait length due to decreased self-awareness and fluctuations in traffic. Consequently, a highly accurate activity recognition algorithm trained on data where subjects are told exactly where or how to walk (or where the subjects are the researchers themselves) may rely too heavily on distinct phases and periodicity of accelerometer signals found only in the lab. The accuracy of such a system may suffer when tested on naturalistic data, where there is greater variation in gait pattern.

Many past works have demonstrated 85% to 95% recognition rates for ambulation, posture, and other activities using acceleration data. Some are summarized in Figure 1 (see [3] for a summary of other work). Activity recognition has been performed on acceleration data collected from the hip (e.g. [17,19]) and from multiple locations on the body (e.g. [5,14]). Related work using activity counts and computer vision also supports the potential for activity recognition using acceleration. The energy of a subject's acceleration can discriminate sedentary activities such as sitting or sleeping from moderate intensity activities such as walking or typing and vigorous activities such as running [25]. Recent work