An innovative microprocessor-based system for Human Activity Recognition: A fast and reliable classification algorithm

An innovative microprocessor-based system for Human Activity Recognition: a fast and reliable classification algorithm

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INTRODUCTION

The aim of this study is to describe the implementation of a microprocessor-based system for Human Activity Recognition (HAR) able to recognize seven activities of daily life (ADLs). The system is based on a body-worn miniature inertial measurement unit (IMU) that is part of a microprocessor system based on a 32-bit CPU (ARM 4 Cortex). A Decision Tree (DT) classifier implemented on the microcontroller performs the classification of the daily activities.

METHODS

The experimental setup consisted of an IMU-based micro-processed platform (Medical Technology, Torino, Italy) for human activities recognition that is usually attached to the lateral side of the right thigh. The platform is based on a triaxial accelerometer and a triaxial gyroscope, and it acquires three axes of acceleration and of rate of turn with a sampling frequency of 80 Hz.

A group of 76 healthy subjects (36 males, 40 females) performed seven activities of daily life: sitting (A_1), upright standing (A_2), level walking (A_3), ascending and descending stairs (A_4, A_5), uphill and downhill walking (A_6, A_7). Each activity was repeated 5 times and lasted 60s. The activities were performed in indoor and outdoor areas without restrictions in speed and style of performing. Each subject signed an informed consent form.

Signals were segmented through a 5s-sliding window, with an overlap of 3s between subsequent epochs. For each window, 221 time-domain features were extracted. In particular, for each signal we extracted information about zero crossings and number, position, and duration of positive and negative peaks (33 features x 6 signals). Moreover, we computed single and double integration of the acceleration in the anteroposterior and vertical directions, and the single integration of the rate of turn in mediolateral direction. Other 23 features were extracted from these signals.

A DT was constructed using only 20% of the signal windows randomly selected from 50 subjects. Once the tree was obtained, it was validated by classifying all windows relative to the entire population of 76 subjects. A post-processing algorithm based on majority voting was implemented on the DT outputs, to reduce isolated classification errors: considering 5 subsequent windows, the most frequently recognized activity was assigned to the group of windows. The average performance across the 76 subjects was evaluated for each activity after post-processing.

RESULTS

Among the 221 initial features, the DT selected only 84 features. The overall recognition performance was equal to 90.5%. Specifically, the correct classification percentages for each activity after post-processing were the following (mean ± standard deviation across the 76 subjects): 99.9% ± 0.9% for A_1, 99.2% ± 4.2% for A_2, 87.3% ± 14.1% for A_3, 87.6% ± 7.4% for A_4, 95.8% ± 6.7% for A_5, 82.7% ± 17.5% for A_6, 80.8% ± 18.8% for A_7.

DISCUSSION

The purpose of this study was obtaining a classifier to be implemented on a wearable microprocessor system able to monitor a subject over a daylong period. To this purpose, the choice of a DT is favorable since it may be implemented in firmware as a set of nested *"if … then"* statements. Moreover, it was sufficient using a reduced set of only 84 features instead of the initial set consisting of 221 features, since only part of the initial set was used for constructing the DT. These two facts cause a strong reduction of the computational cost, making it possible to use a microprocessor with a 32-bit architecture without floating processing unit and, consequently, reducing the power requirements of the system.

In terms of classification accuracy, the HAR system herein described was able to recognize correctly 90.5% of ADLs. Among the entire group of activities, the lowest value of correct classification was obtained for uphill and downhill walking (83% and 81%), that sometimes were erroneously classified either as level walking or as ascending/descending stairs. This is probably due to the slight slope of the ramp used in our protocol, which ranged between 10% and 15% (wheelchair ramp).

In conclusion, we believe that results so far obtained are accurate enough for most applications of interest in clinics and rehabilitation. Battery life of the system is over 20 hours, making it suitable for a daylong analysis session.