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Fall detection system for elderly people using IoT and Big Data

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Abstract

Falls represent a major public health risk worldwide for the elderly people. A fall not assisted in time can cause functional impairment in an elder and a significant decrease in his mobility, independence and life quality. In that sense, the present work proposes an innovative IoT-based system for detecting falls of elderly people in indoor environments, which takes advantages of low-power wireless sensor networks, smart devices, big data and cloud computing. For this purpose, a 3D-axis accelerometer embedded into a 6LowPAN device wearable is used, which is responsible for collecting data from movements of elderly people in real-time. To provide high efficiency in fall detection, the sensor readings are processed and analyzed using a decision trees-based Big Data model running on a Smart IoT Gateway. If a fall is detected, an alert is activated and the system reacts automatically by sending notifications to the groups responsible for the care of the elderly people. Finally, the system provides services built on cloud. From medical perspective, there is a storage service that enables healthcare professional to access to falls data for perform further analysis. On the other hand, the system provides a service leveraging this data to create a new machine learning model each time a fall is detected. The results of experiments have shown high success rates in fall detection in terms of accuracy, precision and gain.

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Keywords: Fall detection; Internet-of-Things; Big Data, 6LowPAN; wearable sensor; Smart IoT Gateway; fall detection; decision tree learning algorithm; accelerometer; elderly people.

1. Introduction and related works

Life expectancy has increased by a rate of five years since 2000 due to advances in the medical field. According to the World Health Organization (WHO), by 2050, the current population of elderly people (8.5%) will increase, representing 20% of the world's population [1]. On the basis of these trends, many countries are adopting healthy

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aging policies with the aim of helping elderly people lead an active and independent life [2]. In particular, ensuring active and healthy aging (AHA) of the elderly people is one of the greatest challenges, but also a great opportunity for society in the coming decades. The notion of AHA has been lately characterized as a broad concept, which seeks to improve the quality of life (QoL) of the elderly people as they age, optimizing opportunities for health, participation and security [2]. In that sense, health problems of the elderly people have become increasingly urgent and falls are the most common accidents whose severity may often require medical attention. According to the WHO, approximately 30% of the people over 65 suffer accidentally one or more falls per year, and for the people over 80 years this rate increases to reach 50%. This figure is more alarming if one considers that falls often happen in indoor environments and are related to normal activities of daily living (ADL).

A serious consequence of suffering a fall is the “long lie”, which consists of remaining on the ground for long periods of time until help arrives [3]. The "long lie" can lead to serious health complications, including dehydration, pneumonia, and hypothermia, which in many cases, can lead to death within 6 months after a fall. Therefore, a fall not assisted in time in an elderly person can negatively impact their QoL and independence [4]. In this context, IoT systems that contribute to detect falls and alert emergency services on time are a social need.

At present, several solutions have been proposed for elderly fall detection. Such solutions are categorized [4] into three main types according to the sensor-technology used: Non-Wearable Based Systems (NWS), Wearable Based Systems (WS), and Fusion or hybrid based Systems (FS).

In particular, NWS systems that use vision based devices such as [5] [6] [7] has been proven to be powerful and robust for detecting falls. However, the main disadvantage of these systems is their high cost and consequent lack privacy for elderly people due to these systems require that the sensors need to be strategically distributed in the indoor environment in which the elderly lives. To overcome this limitation, WS systems like [8] [9] [10] has been proposed, which usually employ inertial sensors such as accelerometers and gyroscopes, typically attached to the body of the elderly for movement recognition when a fall takes place. In particular, accelerometers are being used increasingly in WS systems because they offer advantages such as low power consumption, low cost, low weight, ease of operation, small size, can be mounted on the various body locations and, most importantly, portability. As a result, one of the most commonly used method for fall detection involves the use of a tri-axial accelerometer along with a threshold-based algorithm, which has been used by some representative works [8] [9] [10]. These works detect a fall when the acceleration coming from a tri-axial accelerometer embedded in a wearable device is out of the set threshold. One of the biggest advantages for using the threshold-based methods is less complexity and computation cost compared to other methods. However, finding an appropriate value for the threshold that allows detecting all type of falls without getting confused with some ADL, has proved to be a complicated problem.

Recently, WS systems based on machine learning (ML) techniques has been proposed to deal with these disadvantages and improve accuracy in detecting falls. ML is a technique in computer science that involves statistical inference of models from data in order to make automated predictions. ML builds a model from training data to predict or solve the given problem. In several works, authors focus on use some ML techniques for fall detection. For example, Mezghani et al. [11] used the non-linear support vector machine technique to extract the features and obtain meaningful from the human body data captured by an accelerometer attached to a smart textile. Since it needs two feature extractions: the first to identify the peak and the second to detect the fall orientation, it requires more processing compared to the algorithms carrying out an only extraction. By extracting time series from human motion retrieved by a tri-axial accelerometer placed at human upper trunk Tong et al. [12] used hidden Markov model (HMM)-based method to detect and predict falls. The experiment results show an ideal success rate in the fall detection (100% sensitivity and 100% specificity). However, for training and setting the HMM (λ) and thresholds of the system, data samples of young people’s simulated activities were used. In addition, this system does not alert when a fall event occurs. Finally, Aguiar et al.[13] used a smartphone built-in accelerometer for continuously monitoring of the movement’s data of elderly people. These data were used to test offline three different learning classifiers: Decision Trees, K-Nearest-Neighbours (KNN) and Naive Bayes. The results show that the decision-trees-based algorithm presented the best performance, with more equilibrated sensitivity and specificity values compared with the other tested algorithms. Nevertheless, as a result of the relatively high energy consumption of smartphones, this system could only be active for a short period of time. The decision-tree-based algorithms is gaining acceptance and is probably the best approach to increase the accuracy and precision for the fall detection. We have followed a similar approach in this paper by using a decision trees-based Big Data model for fall detection, but we differ from previous works in the way the system is built. First, the data from the movements of elderly people in the indoor environment is captured by a 3D-axis accelerometer embedded into a 6LowPAN device wearable. Second, the fall of an elder is detected by a decision trees-based Big Data model which is built and training in the cloud. Initially, it is trained from historical knowledge from an open dataset that containing records of falls and ADL of elderly people. Subsequently, the model learns of the fall events detected by the system. One of