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Technical note

Smartphone application for emergency signal detection

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ABSTRACT

Currently, a number of studies focus on the study and design of new healthcare technologies to improve elderly health and quality of life. Taking advantage of the popularity, portability, and inherent technology of smartphones, we present an emergency application for smartphones, designated as knock-to-panic (KTP). This innovative and novel system enables users to simply hit their devices in order to send an alarm signal to an emergency service. This application is a complete and autonomous emergency system, and can provide an economic, reliable, and unobtrusive method for elderly monitoring or safety protection. Moreover, the simple and fast activation of KTP makes it a viable and potentially superior alternative to traditional ambient assisted living emergency calls. Furthermore, KTP can be further extended to the general population as well and not just be limited for elderly persons. The proposed method is a threshold-based algorithm and is designed to require a low battery power consumption. The evaluation of the performance of the algorithm in collected data indicates that both sensitivity and specificity are above 90%.

1. Introduction

Elderly people are an important and rapidly growing section of our society. According to some studies [1], it is estimated that the number of people over 65 years of age will increase from 375 million in 1990 to 761 million in the year 2025. Therefore, ensuring the well-being and fast medical assistance to the elderly is an important necessity in the domain of health care services around the world. Many ambient assisted living (AAL) systems have been developed for monitoring solitary elderly people and traditionally, these systems are categorized into three groups [2]: assessment of patient's condition [3–8], patient monitoring and safety providing for the entire household [9–15], and emergency calls [16–18]. The category of emergency calls consists of much simpler systems than the previous two, it focus on lower cost, easy implementation, and easy use. In their simplest designs they consist of a button-equipped device, carried by the elderly, that when pressed sends an emergency signal to a caregiver or health care provider. Such a type of solution also yields a high level of privacy, since it does not collect any type of information about a user's activity. Two examples of devices belonging to the emergency call category are commercial products Alert1 [16] and Philips HomeSafe [17]. One problem associated with these solutions is their poor acceptance by elderly people [19]. The Philips Lifeline medical alert systems, which include the aforementioned HomeSafe, also provide a smartphone application that explores the idea of a one-touch call button. When compared with the method proposed herein, these solutions may be deemed more cumbersome, since our proposed method, which corresponds to an instinctive movement (knocking), can be executed without the need of a direct and explicit interaction between a user and the smartphone application.

The purpose of this paper is to describe a novel emergency signal detection algorithm, herein designated by the knock to panic (KTP) algorithm, as well as the evaluation of its performance using collected data. The KTP algorithm is designed to identify a knock to panic movement. The latter involves the user hitting the device, with his/her hand, three or more times, quickly, along the face parallel to the screen (on the front or back of the device that should be stationary and located in the trouser front pocket or in a belt worn around the hip of the user). When the application identifies a KTP movement it emits a sound to the user and sends an alarm signal to an emergency service.

We remark that the action of knocking is somewhat instinctive for human beings when they want to draw someone's attention to something or someone (for example in the case of danger or help). This human behavior was the main motivation for devising

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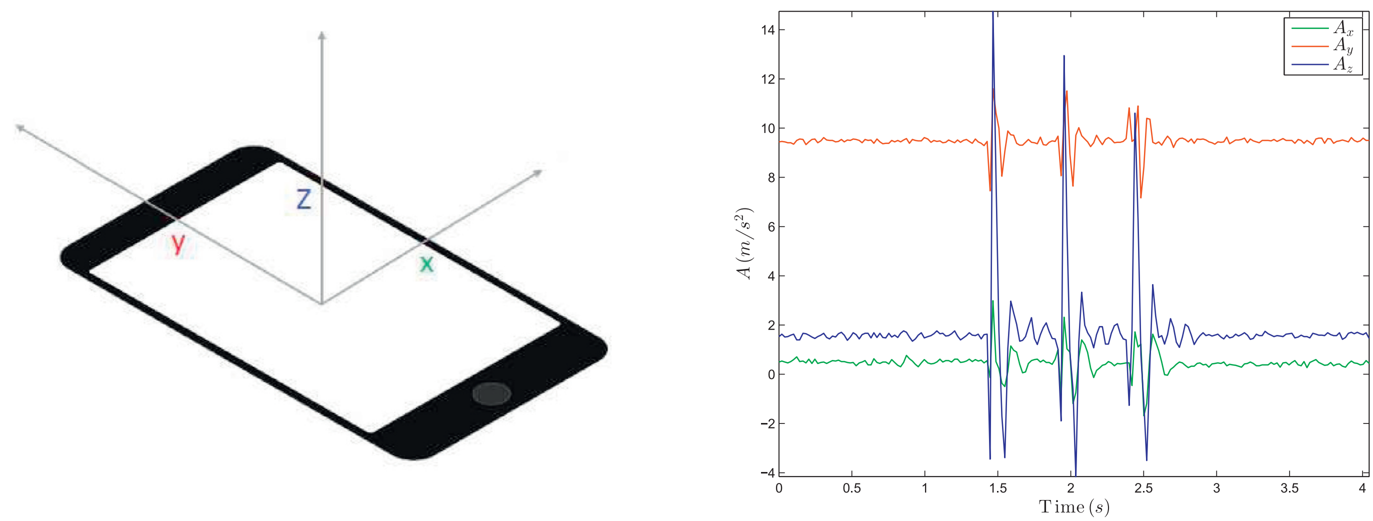

Fig. 1. The smartphone reference frame (on the left), and the KTP pattern represented by the accelerometer data (on the right).

this smartphone-based emergency application. On the other hand, the choice of the word "panic" for this application is related to the definition of panic itself, which is a sudden uncontrollable fear or anxiety, that usually prevents people from acting or thinking normally. Therefore, an automatic movement like knocking is expected from people that experience some sort of panic. A sensation similar to panic is also felt by people in an emergency situation.

The KTP algorithm is threshold-based and relies only on the data information provided by the smartphone's built-in accelerometer sensor. These two characteristics are of utmost importance since they help in reducing battery power consumption, a crucial issue for smartphone users. In addition, the tests conducted for evaluation purposes (and reported herein), as well as the currently ongoing tests in real environments (in senior care or senior monitoring contexts, both residential or domiciliary) carried out by our collaborative partner (http://oncaring.com/) confirm the good performance of the proposed application. Moreover, a modified KTP algorithm is also briefly described that further reduces the application's battery consumption. We emphasize that the KTP application is an accessible and practical tool that is instinctively activated. It can be extremely useful not only for the elderly but also for any smartphone user undergoing any emergency and difficult situation, for example, a panic situation, self-protection, or any situation requiring fast or immediate assistance.

2. Methods and materials

By definition, KTP involves hitting the device three or more times, with the user's hand, along the face parallel to the screen, on the front or back of the device. During this movement the smartphone must be stationary (just for 2.5 s (seconds)) and located in the trouser front pocket or in a belt worn around the hip of the user. If these conditions are fulfilled, a specific acceleration pattern is observed in the smartphone accelerometer response signals, as shown in Fig. 1. As can be observed, the three knocks, made by the user of the smartphone, are clearly visible in the A_z component of the acceleration along the z-axis, that is perpendicular to the screen plane, while the acceleration signals A_x, A_y along the x- and y-axis are almost constant.

The KTP algorithm involves the following sequential three steps: 1 – knock detection, 2 – verification of the stability conditions and 3 – verification of the oscillatory conditions. In Step 1, we look for the primary feature in the KTP pattern and in Steps 2 and 3 we attempt to detect the secondary features of the KTP pattern that are imposed in order to enforce KTP detection and to avoid misclassification with other movements. In addition, we present a simplified KTP algorithm that consumes less battery, and an extra module (that can be used independently or combined with the KTP algorithm), that allows us to identify knocks when the smartphone is placed over a hard surface.

2.1. Step 1 – knock detection

We denote by $|S|$ the number of elements of a set S and the acceleration vector, for time t^n, by $A^n = (A_x^n, A_y^n, A_z^n)$, with $n = 1, \ldots, N$ ($t^1 = 0$ is the initial time and $t^N = T$ is the final time). We define the sets I_t, I_m, and I_k, with time intervals of size 2.5 s, 0.5 s, and 2.0 s, respectively, as

$$I_t = [t^m,\, t^m + 0.5[\, \cup\, [t^m + 0.5,\, t^m + 2.5] = I_m \cup I_k, \quad \text{for } 0 \le t^m \le T - 2.5. \tag{1}$$

The KTP algorithm is devised to continuously analyze the KTP patterns in a rolling window I_t of size 2.5 s. Moreover, since the KTP is by definition a quick movement, we stipulate that it has to be executed in a time window of 2 s. The set I_k is the time interval where the knocks are expected to occur and I_m is the preceding short interval.

This first step of the algorithm involves the detection of the knocks, at least 3. As illustrated in Fig. 1, when KTP is executed at least three large peaks appear in the A_z component of the acceleration. The highest peaks are observed in the positive part of the z- axis, if the knocks are executed on the front of the device, otherwise if the knocks are applied on the back of the device the highest peaks appear in the negative part of the z- axis. In order to detect these peaks, we proceed as follows.

- Let C_z be a critical pre-defined threshold. First, we compute $\bar{A}_{z,I_m}$ (the mean value of A_z in I_m), and secondly, we look for values of A_z bigger than $\bar{A}_{z,I_m} + C_z$ (or smaller than $\bar{A}_{z,I_m} - C_z$), in the time interval I_k. Thus, we define the set of time knocks candidates, T^+_{knocks} (respectively, T^-_{knocks}) when the user hits the front (respectively, the back) of the smartphone, by

$$\begin{aligned} T^+_{knocks} &= \{t^n \in I_k :\ A_z^n \ge \bar{A}_{z,I_m} + C_z\} \\ T^-_{knocks} &= \{t^n \in I_k :\ A_z^n \le \bar{A}_{z,I_m} - C_z\}. \end{aligned} \tag{2}$$

These sets identify the times at which the component of the acceleration along the z- axis is above the line $\bar{A}_{z,I_m} + C_z$, for T^+_{knocks}, or below the line $\bar{A}_{z,I_m} - C_z$, for T^-_{knocks}.