Monitoring Healthcare Activities toward Automatic Recognition using Accelerometers

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Abstract

Intelligent homes should be able to recognize human activities in order to assist people in their daily life. In particular, this is important for healthcare related activities, where people can be reminded of taking some medicine or checking their blood pressure. Not only that, an intelligent system should also be able to verify the correct performance of that activity. Nevertheless, human activity recognition is not trivial and much work still needs to be done. This paper presents a study that show how the activity of measuring blood pressure is performed by professional nurses. This, with the purpose of developing an intelligent system that takes into account the way that the activities are performed by people. A video recording of the activity along with accelerometers attached to manometers allow us to obtain 29 patterns that will help us to code this activity in computer readable form for posterior use by a recognition system.

Keywords: Activity recognition, accelerometers, intelligent homes.

1. Introduction

The idea behind building intelligent homes or buildings is to assist people in their daily life activities in order to make those activities more efficient. To do so one of the basic tasks of an intelligent home should be that of recognizing activities performed by the people living there (e.g. cooking, reading, sleeping, etc.). Healthcare activities are particularly important, so that people can be reminded of taking their medicine, checking their blood pressure, etc. Nevertheless, the recognition of human activities is not a trivial task. In order to recognize certain activity it is required to first analyze that activity to have a better understanding of it.

The goal of this paper is to analyze how a healthcare activity is performed, namely the measuring of blood pressure. The origin of non-transmissible diseases is associated with risk factors related to harmful life styles. For example, high blood pressure is an important risk factor for predicting several disease. In order to know if a person has this factor, her blood pressure needs to be measured often [1]. Moreover, this risk factor might produce other disorders such as heart attack, cardiac insufficiency and so on. Therefore, measuring blood pressure is an extremely important activity to human being health.

Knowledge about how people perform daily activities has inspired research related to the monitoring of interactions with domestic objects associated with the completion of each activity. For example a simple state-change sensor can be used to detect any change of state of an object which can subsequently be used to reflect the interactions of a human being with the object. In this sense, sensors transform a physical signal into an electrical signal that can be manipulated symbolically on a computer [2]. In addition, the goal of an intelligent system for human activity recognition consists of automatically analyzing and classifying activities with information gathered from different capture sources like video cameras or other sensors such as accelerometers.

In this work, we are concerned with monitoring healthcare activities, in particular the blood pressure measurement activity. This paper describes a case study in order to understand the details in a real scenario where this activity is performed by professional nurses. Therefore, we used cameras with the purpose to gain insights into the activities that people perform and to complement our investigation. We considered that this understanding is a main phase in the monitoring healthcare activities toward automatic recognition.

One of our purposes is to understand as much as possible about the users, the activities they perform, and the context of those activities [3] so that we can develop a system that can support users in achieving their goals based on real evidence such as shown in [4, 5]. An example is shown in [6] where they present a study focused on a wearable system with the purpose to monitor systolic blood pressure (SBP) overnight, especially to measure the average SBP over a long period. In their study ten healthy young subjects were recruited with the goal to investigate whether pulse transit time can be a surrogate of 24-h blood pressure in an unattended environment.

One interesting approach is shown in [7]. The authors shown a study which blood pressure (BP) was monitored over a period of about 1 year in 61 subjects. In that study the authors evaluated the participation in a continuous health care monitoring using several physiological parameters and they concluded that, ”The long-term repeated use of home blood pressure testing may be a good self-care strategy for monitoring daily health”. Therefore, it is very important to know what is the correct way to perform the blood pressure activity, so in our research we take into account the bahavior performed by professional nurses.
Other authors have been worked on using the data with the aim to segment data such as shown in [8], they proposed three segmentation algorithms to separate time series sensor data into segments to be further processed by an activity recognition algorithm. In this direction, we are using accelerometer data to segment the blood pressure activity based on human being movements. In [9, 10, 11] the authors focused on using several sensors, but they do not highlight any previous work related to understanding the scenario as we propose.

This paper is organized as follows. Section 2 introduces the methodology followed for this study. Section 3 shows the results by means of a particular example. Finally, Section 4 provides our conclusions and directions of future work.

2. Methodology

As stated in the previous section, the aim is to analyze and understand how the activity of measuring blood pressure is performed. The data produced by this analisys will later be used by an intelligent system that should be able to recognize that particular activity. This can be done by keeping track of those objects used during the performance of such activity. For the activity concerned in this paper, the only object that needs to be tracked is the manometer. To track this object we attached an accelerometer which provides information about the movement of that object. Furthermore, in order to be certain that the activity is performed correctly we hired two professional nurses.

In summary, the goals of this study is to: (1) understand how the activity of measuring blood pressure is performed by a professional nurse; (2) identifying the way the nurse handles objects when performing that activity; (3) obtaining the patterns produced by accelerometers attached to the manometer. Video cameras were also used to record the whole study in order to link the data obtained from the accelormeters to the actions performed by the nurse.

2.1. Subjects

The study took place at our Usability Lab. A group of 31 volunteers (7 females and 24 males) were monitored and recorded while measuring their blood pressure. The average age for the whole group was 28 years. Additionally, the activity was performed by two professional nurses. Both nurses have four years of

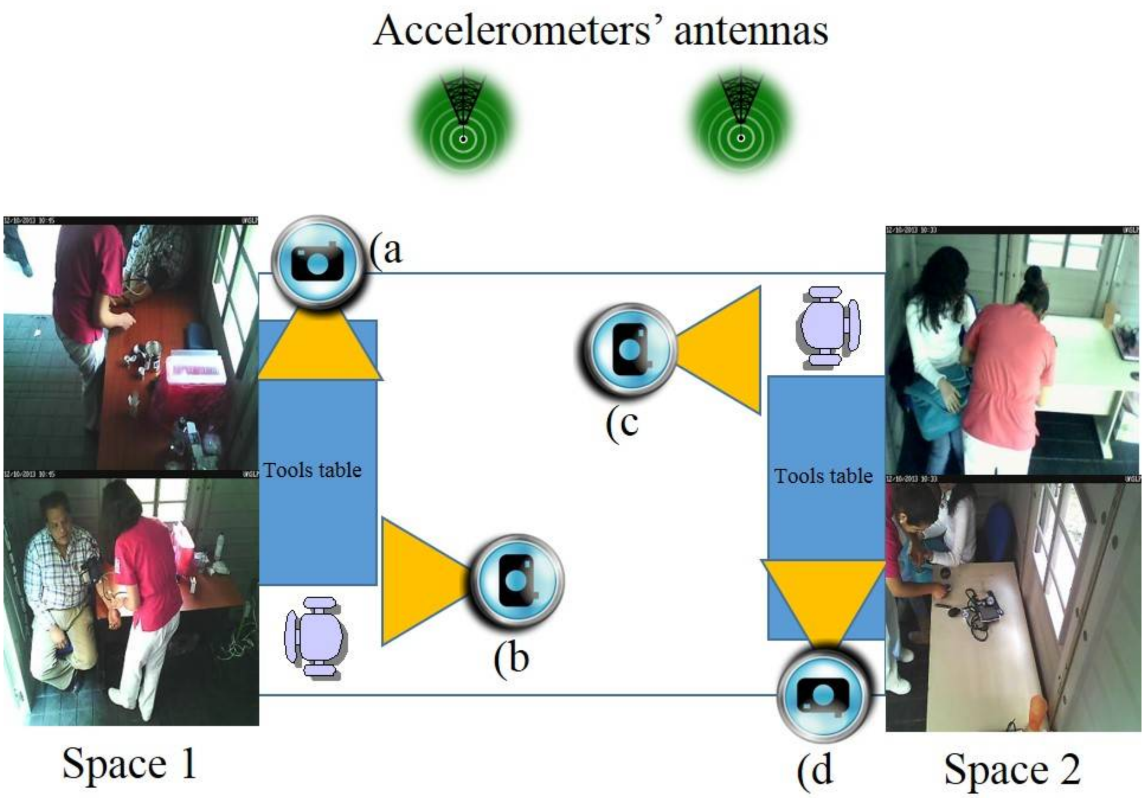

Figure 1. Scenario used, a-d)Position of the cameras in the usability lab.

experience. All participants were reported to be healthy.

2.2. Technical Information

The case study was recorded with four cameras: two cameras were located in the ceiling of the laboratory (Figure ??b and ??c), and the rest were located close to the tools tables (Figure ??a and ??d). The whole study was recorded and lasted for around 1.5 hours. The cameras used are a wvc53gca Linksys model. The video was captured using MPGe-4 format having a resolution of 320 X 240 pixels, the frame rate was 10 frames per second.

Additionally, two accelerometers were attached to two manometers used to measure blood pressure. The accelerometers provided close to 51,000 data samples for the duration of the case study (i.e. one hour and half). The accelerometer used in our study was a Freescale D3172MMA7455L model. It has a high sensitivity (64 LSB/g at 2 g and 64 LSB/g at 8g in 10-bit mode); a 1-pole low pass filter; the receiver supports 16 sensors per one USB stick allowing the identification of multiple objects, and the power consumption is low voltage operation (2.2-3.6 V). We used the default configuration for their implementation. The information produced by the accelerometers is the acceleration measurement related to the three coordinate axes (x,y,z). Also, it is possible to use the concentrate of these values as the absolute value expressed in terms of g-force (g). Thus, this absolute value was used to show how objects are handled. This kind of technology is very sensitive to movements, so the variations begin to be recorded when the accelerometer starts to move. An important thing to note is the effective area of the receiving antenna, which is large enough to recognize several objects that could be used in a given setting. Also, because of this sensitivity it is necessary to establish a threshold to interpret the input signal. With a threshold, even if the signal is very variable, we can infer that the accelerometer is being used, otherwise we assume that it is immobile.

2.3. Description

Everytime a menometer is handled by a nurse, a pattern of movements is produced, where these movements are given by the accelerometer. These patterns provide a possible representation of the activity for blood pressure measuring.

Two accelerometers and two antennas were used, where each accelerometer sent signals every time it was moved around, and each antenna received the accelerometer's signal.
We created a system with the purpose to acquire the accelerometer's signals. This system is able to link the accelerometer signal to the video sequence. Two cameras were synchronized to one of the accelerometers. Hence, two video sequences were produced for each accelerometer.

The implemented process in the study was as follow. Two antennas were installed and connected to two computers at the back of our Usability Lab. Each antenna received the data related to its corresponding accelerometer, where each accelerometer was attached to a blood pressure device. The data were stored and processed in a database on each computer.

It is important to determine whether an accelerometer is moving or not. When an accelerometer remains immobile, the received value is approximately 1.0, therefore we established two values as thresholds (1.5 and 0.5). If the accelerometer remains in the range this means that the object is immobile on a base location (tools table), otherwise it means that the object has been handled. The manometer had to be placed in the tools table whenever it was immobile.

Each nurse attended a subject one by one. However both nurses were working simultaneously.

3. Results

We analyzed the data gathered from the two accelerometers and their corresponding video sequences manually. This resulted in 29 patterns produced by the accelerometer when the activity was performed. Two patterns were not used due to the fact that the signal was lost during the task. This happened because the antennas were installed near to a window metal, so the signal was lost while the antenna was on that place.

As mentioned above, 51,000 samples were obtained and stored in a database. 28,000 samples were obtained by one antenna, and 23,000 by the another antenna. The data consists of an ID related to each signal produced by accelerometer, and the information produced by the accelerometers. The absolute value of the accelerometer was used to show how the objects are handled. Also the date and time were stored in a database. Finally, the number of each frame and the name of the video file were stored. The latter was linked to each signal produced by one accelerometer. So each time a change from 0 to 1 (or viceversa) happened a sample was recorded in the database.

3.1. Understanding the activity of measuring blood pressure

On average, the whole activity of measuring blood pressure used 1,200 samples (i.e. two minutes approximately). This happened each time the nurse performed the activity. Figure 2 shows an example of one pattern for the duration of a single activity. This is described as follows:

1. The nurse grabs the manometer from the table (Figure 2b).
2. The manometer is placed around the arm of patient (Figure 2c).
3. The nurse starts to pump rapidly with her hand and let the air out slowly (Figure 2d).
4. The nurse starts to remove the manometer from the patient's arm (Figure 2e).
5. The nurse removes the manometer, which produces a stronger movement of the device (Figure 2f).
6. The manometer is placed on the table (Figure 2g).

This list shows specific and important events related to the way in which a professional nurse performs the activity. As mentioned above, the accelerometers are very sensitive to movements, so the variations begin to be recorded when the accelerometer starts to move, as can be seen in Figure 2a). Firstly, at sample number 27, the accelerometer signal was a little high. It was produced by the patient when she hit the table. Therefore, the activity started at that point.

As mentioned above, two cameras were synchronized to an accelerometer's signal. This allowed us to create a visual story based on movements or events as shown in Figure 2, and also a meaning was produced by each event when the object was handled within the activity.

Another important event is related when the activity was performed, it was included in Figure 2d-e. It is important to note that, the total time of the activity was 96 seconds but only 33 seconds were used for the

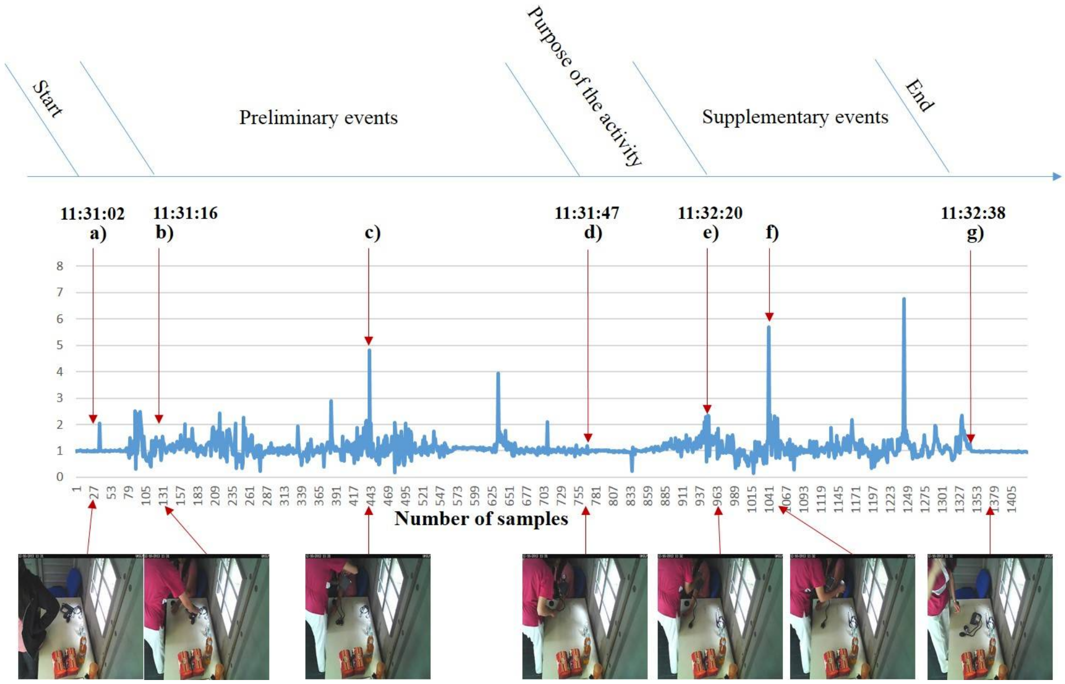

Figure 2. Raw data related to absolute values of an accelerometer.

actual measuring of the blood pressure. The rest of the time was used for preliminary or supplementary events.

As a result of this analysis, we identified the way in which measuring the blood pressure is performed by a professional nurse. Moreover, we obtained the data of the accelerometers used when performing such activity based on human behavior.

4. Conclusions

We conclude that activity recognition is a complicated process, so it is necessary to take into account several details related to human activities such as we have shown in this paper.

The accelerometers are very sensitive to movements, so the variations are an important cue when it is attached to object. It is because each movement is an event produced by the object while an activity is performed. Each event provides a meaning of the activity based on how objects are handled, as well as human behavior. Therefore, the understanding was obtained and we believe that our study is necessary to get important insights such as needs, requirements, capabilities, current tasks and goals, the conditions under which the object will be used and constraints on the object's performance within activities that human being performs.

The results obtained in this work will be used to develop an intelligent system. As a future work, we wish to apply data mining and artificial intelligence techniques in order to infer new activities based on the behavior of humans.

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