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Automatic Detection of Falls and Fainting

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Abstract: Healthcare environments have always been considered an important scenario in which to apply new technologies to improve residents and employees conditions, solve problems and facilitate the performance of tasks. In this way, the use of sensors based on user movement interaction allows solving complicated situations that should be immediately addressed, such as controlling falls and fainting spells in residential care homes. However, ensuring that all the residents are always visually controlled by at least one employee is quite complicated. In this paper, we present a ubiquitous and context-aware system focused on geriatrics and residential care homes, but it could be applied to any other healthcare centre. This system has been designed to automatically detect falls and fainting spells, alerting the most appropriate employees to address the emergency. To that end, the system is based on movement interaction through a set of Kinect devices that allows the identification of the position of a person. These devices imply some development problems that authors have had to deal with, including camera location, the detection of head movements and people in horizontal position. The proposed system allows controlling each resident posture through a notification and warning procedure. When an anomalous situation is detected, the system analyses the resident posture and, if necessary, the most adequate employee will be warned to react urgently. Ubiquity and context-awareness are essential features since the proposed system has to be able to know where any employee is and what they are doing at any time. Finally, we present the outcomes of an evaluation based on the ISO 9126-4 about the usability of the system.

Keywords: Collaboration, Ubiquity, Context-awareness, Healthcare, Movement, Interaction, Kinect
Categories: D.5.3

1 Introduction

Healthcare environments contain many conditions and situations which create a complicated work atmosphere ([Arnrich, 2010], [Bardram, 2004], [Madeira, 2010], [Shrewsbury, 2011] and [Sneha, 2009]). Employees have usually to attend to more than one task at the same time and also they have to control the end of related processes (e.g. the reception of blood analysis results that are required to apply a specific treatment). Residential care homes are a good scenario within healthcare environments in which to apply efforts to study and analyze possible improvements. Firstly, the results could spur new developments of employees' tasks through new technology [Garrido, 2012]; and consequently, the residents´ daily lives will be improved.

Current technology allows the development of systems with several interactive modes to satisfy the needs of each implied user. In this sense, the needs of a user who is constantly in motion within the environment are not the same than the needs of someone who is statically placed in the reception area. However, an important problem exists in residential care homes, which creates the need to use new technology. Healthcare employees have to immediately address unexpected situations that may appear suddenly such as falls and fainting spells [Xinguo, 2008]. These situations can be a significant oversight in healthcare, mainly when they occur out of the employees' line of vision due to the difficulty of ensuring that every resident can be seen at least by one employee at any time.

Movement interaction devices help position and movement detection through a continuous interaction with users who are in their vision area. They offer the possibility of analyzing each situation and reacting appropriately. Actually, a wide range of movement interaction devices has appeared; among them we can highlight Kinect[1], Asus Xtion Pro/Pro Live[2,3] and SoftKinect DepthSense[4]. Authors have selected Kinect as the appropriate device when resolving the previously described problem of falls and fainting spells in residential care homes. The first reason is the quality-price relationship with regard to the other devices. Despite having a lower price (up to a third less), its features and capabilities are not very different. The initial application for which Kinect was developed composes the second reason: to be an Xbox 360[5] peripheral. Being included in an important commercial field like videogames is a compelling reason because it presents well-defined developments within complex interactions. The main consequence is the possibility of transferring virtual solutions to real environments due to the similarities that videogames have with the real world in many cases; or at least, these developments can be used as the basis to develop more specific solutions for daily life problems.

In this paper we present a solution to detect falls and fainting spells in residential care homes, which is applicable to the majority of healthcare centers. The system is based on employees and residents movement interaction with Kinect. The main

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[1] Kinect, Microsoft, 2012:
http://www.xbox.com/es-es/kinect

[2] ASUS Xtion Pro, ASUS, 2012:
http://www.asus.com/Multimedia/Motion_Sensor/Xtion_PRO/

[3] ASUS Xtion Pro Live, ASUS, 2012:
http://www.asus.com/Multimedia/Motion_Sensor/Xtion_PRO_LIVE/

[4] SoftKinetic DepthSense, SoftKinectic, 2012:
http://www.softkinetic.com/Solutions/iisuSDK.aspx

[5] Xbox, Microsoft, 2012. http://www.xbox.com/es-ES/

objective is to alert when these situations, in which no employee can see the fall or fainting spell, occurs. As a consequence, the system allows these situations to be solved automatically by alerting the appropriate staff as soon as this situation is detected. To that end, the system studies the staff distribution ([Anagnostopoulos, 2006], [Bardram, 2010], [Handte, 2010]) in order to select the person who is in the best condition to attend the emergency, taking into account two considerations: the person who is closest to the area and performing tasks of low importance at that time.

Regarding the features of the system, it has to incorporate two features which are fundamental to complete the objective: ubiquity ([Bick, 2008], [Henricksen, 2006], [Madeira, 2010], [Weiser, 1991] and [Zhou, 2010]) and context-awareness ([Ahn, 2010], [Anagnostopoulos, 2006], [Bardram, 2006] and [Bardram, 2010]). These features are essential to determine the most appropriate employee to handle an emergency at any time. Ubiquity allows the system to offer connectivity to employees at all times and in any circumstance. The system will always be able to determine where each employee is and what tasks s/he is performing. With that information, the system will know in an emergency situation (i.e. the detection of falls and fainting spells) who is the most appropriate employee to attend to the problem. In other words, the system will be context-aware because it can determine the employee's location with respect to the fall or fainting location, which will allow alerting the employee in best conditions to respond.

The rest of the paper is organized as follows: Section 2 describes the foundations of Kinect, as well as its different current uses, development tools and related works. The ubiquitous and context-aware system which will automatically react in response to falls and fainting using the Kinect device is presented in Section 3. In addition, this section includes an introduction to the development problems that became an important turning point. Section 4 describes the system evaluation based on the ISO 9126-4 focusing on effectiveness and satisfaction. Finally, Section 5 presents conclusions and future work.

2 Kinect as a Movement based Interactive Device

Kinect is a device created by Microsoft whose main objective is to give users the capacity to interact through movements with the console Xbox 360. In this way, Kinect can be considered a device that allows natural interactions.

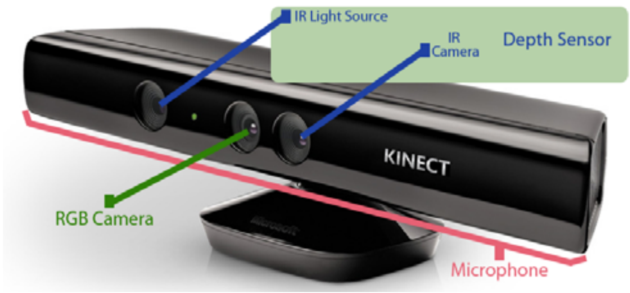

Figure 1: Hardware components of Kinect

This device implies important advances due to the fact that users have the capacity to interact with computer systems through natural and common gestures. Kinect has turned out to be an adequate tool to experiment with in order to reach solutions and improvements in fields such as augmented reality [Vera, 2011] or medicine in which a wide range of aspects have been threaten, from medical images [Gallo, 2011], haptic problems [Shrewsbury, 2011] and the rehabilitation of chronic diseases [Schonauer, 2011]. Regarding falls and fainting detection, which is the main topic of this paper, there are some remarkable related works that are described below.

[Nait-Charif, 2004]) presents a method able to detect inactivity and, in combination with body pose and motion information, offers a useful cue for falls detection. To that end, this work uses ceiling-mounted, wide-angle cameras with vertically oriented optical axes. The proposed method represents a great novelty preceding the appearance of Kinect. [Mastorakis, 2012] proposes a real-time fall detection system based on Kinect through velocity and inactivity calculations being able to decide whether the detection has occurred. [Kawatsu, 2012] presents a system with two algorithms for detecting falls. One of them uses a single frame to determine if a fall has occurred, and the second one calculates times. Additionally, the system contains a mechanism for falls reporting using emails and mobile messages.

All the previous works analyzed have several points in common. The main one is that all of them detect at least falls, and some of them also fainting. . In this paper we present a system whose main advantages are that it is a 24-hour monitoring system working on real time. It considers a complete alert system, it studies hundreds of possible cases in which the residents can be, and the proposal is also integrated within a complete advice note system through mobile devices and a switchboard. The interaction based on movement interaction is an emerging technique and since the appearance of systems such as Kinect, it has sparked a revolution in which non-invasive devices has been used for the human-computer interaction, so the patients feel more comfortable. Kinect is currently used in some healthcare applications and we have used it to improve the quality of life of patients who might suffer falls and fainting, integrating such detection in a whole system which interact with the user synchronously and that manages several warning levels to monitor people and to assist them properly. These points, which make our proposal different from the related works mentioned before, will be described throughout the paper.

From the hardware point of view (see Figure 1), three main elements compose Kinect: *RGB camera*, *depth sensor* and *a set of four microphones*. The first element detects the color components, red, green and blue, as well as the different users' bodies and facial gestures.

These capabilities allow the RGB camera to help in the facial and corporal recognition process. The depth sensor generates 3D images of anything into its vision making measurements of the distance from the device to different user body points. Finally, the set of microphones allows the system to detect voices without noise.

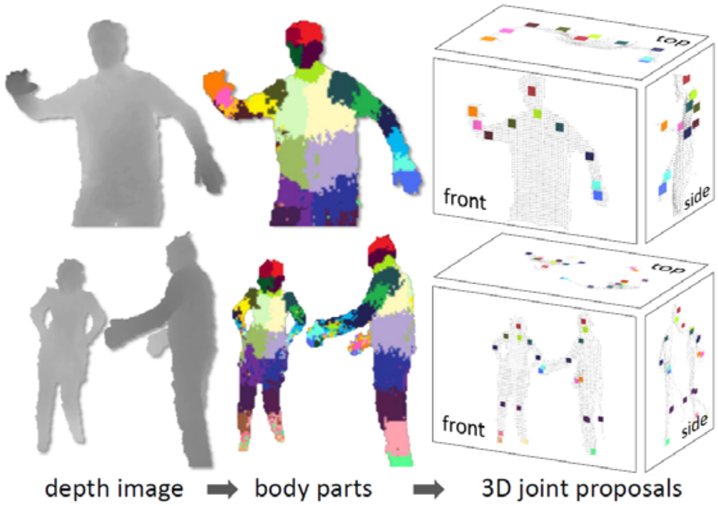

Figure 2: Kinect process to recognize user skeleton parts ([Shotton, 2011])

Together with hardware elements, Kinect has specific software that is used to detect a set of points in each user's skeleton which represents the users' joints. Systems based on Kinect work with these points in order to work with the users' interactions. The process followed to obtain the points is the result of a study performed by Microsoft researchers in Cambridge [Shotton, 2011]. Basically, the process (see Figure 2) consists in obtaining an image in which each user appears in a segmented way, so each user is separated from the background. The identification of body parts is the next step; it is done through a machine-learning which trains using millons of images ensuring that Kinect is able to work with any type of bodies, sizes and postures of people. Next, the system obtains a set of points of the body of each user, which represents joints. Kinect performs the whole process two hundred times per second, so it ensures that the tracking of the users is reliable. Additionally, the algorithm works separately for each frame, so the system does not lose the track of the users.

Kinect toolkits (SDKs) and libraries are essential in order to take advantage of the device adequately. They have allowed creating the application which makes use of the interaction capabilities of the Microsoft device. These SDKs can be classified depending on if they are for general purpose or they are focused on natural interactions (see Figure 3). The first group has one of the oldest libraries, *libfreenect*[6], as well as *OpenCV*[7] *and PCL*[8] *(Point Cloud* Library). Regarding the SDKs or libraries

[6] Libfreenect, 2012: https://github.com/OpenKinect/libfreenect/
[7] OpenCV, 2012: http://opencv.willowgarage.com/wiki/
[8] PCL, 2012: http://pointclouds.org

whose objective is the natural interaction, *OpenNI*[9] and the SDK elaborated by Microsoft[10] are the most remarkable. This last set is particularly interesting because of the topic to be solved in the next section, which requires working with corporal movements and then, with natural interactions.

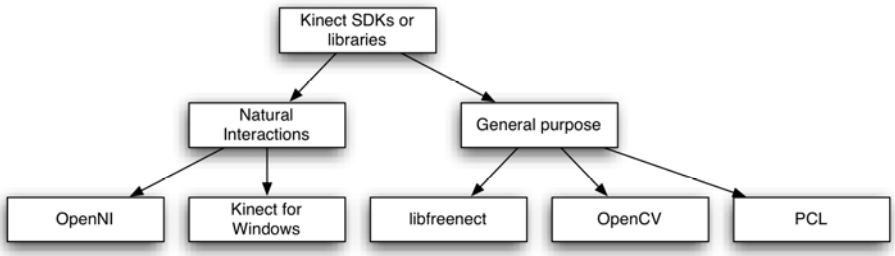

Figure 3: Classification of the main SDKs for Kinect

3 Movement Interaction in Healthcare Environments

Healthcare environments offer many possibilities when applying new technologies due to the huge amount of heterogeneous tasks to be performed and problems to be solved. The problem that residential care homes present is the lack of features to detect falls and fainting spells where no employee can visualize what is happening. This is an important aspect to take into account due to the impossibility of every resident being seen by at least one employee at anytime and anywhere. Knowing this problem and the authors' accessibility to a specific residential care home, the proposed system is focused in these centers.

Taking into account the aforementioned problem, the authors have developed a ubiquitous and context-aware system whose objective is the automatic detection of anomalous situations regarding the postures adopted by the residents in a residential care home. The system is based on the distribution of multiple Kinect devices in appropriate locations around the center. Each device, which is connected to a computer, is continuously interacting with people in its action area. The movement interaction used by Kinect allows the identification of different skeleton points of each identified person. The analysis process of the current posture starts when the identification is performed, as it is explained in the system workflow in Figure 7. The result will be to create an alert system with a specific urgency degree to verify the resident status; otherwise, it will continue with the search for anomalous situations.

The identification of postures is made by using the development kit provided by Microsoft. This process is a key element to understand the functionality of the system, so next we explain how the system performs the identification of postures. The SDK allows the recognition of all the body joints that Kinect is able to identify, concretely

[9] OpenNI, 2012: http://openni.org
[10] Kinect for Windows SDK, 2012: http://www.microsoft.com/en-us/kinectforwindows/

20 points. These points are provided to the system through a class that represents the skeleton and offers an accessible way to them. Once the system obtains this class, the next step is to search for those points that are necessary to identify postures, by collecting their position in the obtained parameters. Each position is stored in a specific class composing a set of three values referring the exact position of the point in the space (x, y and z axes). Once the positions get this representation, the detection of residents' postures starts. To this end, defining algorithmically each known posture is necessary, whether it is classified as dangerous or not. In this way, all known postures will be stored algorithmically as if it were a pattern. The next step in the postures identification is to check if each detected posture matches up with a defined pattern. In this way, each posture must be analyzed by the algorithm that represents each defined posture. Therefore, a concrete posture will be identified when the matching with respect to a pattern is within an adequate range of error. Figure 4 shows some examples of correctly identified postures.

Figure 4: Falls and fainting detection system deployment

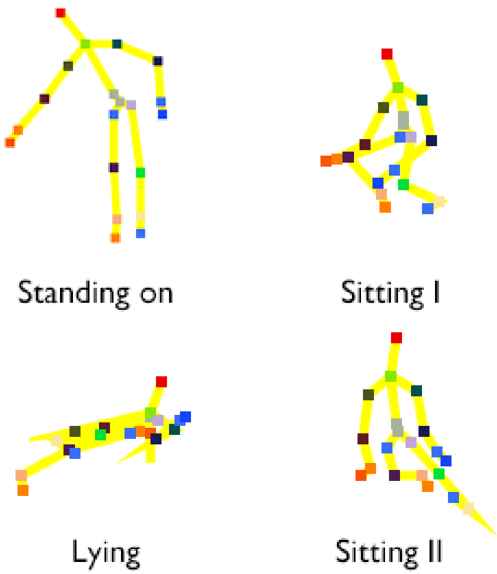

Figure 5: Example of correct postures identified in the proposed system

The system deployment in the residential care home is composed of four main elements in order to execute a correct operation (see Figure 5): *vigilance area*, *personal computers*, *Web Server* and *the database*. The first one refers to the vigilance of any zone of the center where falls and fainting spells could occur and where there are no employees, i.e., common areas such as corridors, elevators, etc. A Kinect device is placed within these areas in order to detect the residents' postures. Personal computers, to which each Kinect device is connected, are the next necessary element for the implementation of this system. These computers contain the part of the system which is in charge of using the Microsoft SDK for Kinect whose main objective is the identification of each resident's posture. Next, the system uses the Web Server to communicate with employees, to create alerts and to locate concrete employees based on specific conditions. The server accesses the fourth component, the database, which holds the current state of the system. This state allows the classification of the system as context-aware because it gives updated information about the location of each employee and the task s/he is performing. This information gives the system the capacity to know at any time who is the most appropriate employee to be warned when a fall or fainting spell occurs. Whenever the system detects these situations, the computer requests to the server a list of the people in best conditions to solve the problem.. To that end, the server composes the list based on the location of the related Kinect device, the location of each employee and his/her current task.

Another aspect of the system regarding its context aware behavior is the constant collection of data concerning all employees´ statuses. The system collects the information through the devices that each employee uses. Information on the tasks that each employee performs is gathered by the server itself (which indicates the next task to be performed) and the information about locations is gathered by the interconnection network. The network is composed of a set of access points that are associated with a specific zone of the center. In this way, when a user is connected to a new access point (due to a better WiFi signal intensity), the device communicates the new connection to the server which reflects it on the database. Therefore, the system offers ubiquity through the interconnection network, which allows employees to be connected at any time and under any circumstance.

3.1 Falls and Fainting Detection and Actuation Process

The involved process (see Figure 7) starts when a person is in the range of motion of each Kinect device located around the residential care home. Then, the system captures the person's posture that is subsequently analyzed. The analysis consists in comparing the detected posture with a pattern of postures that are previously known and defined. Each pattern has a degree of danger associated to it which indicates with what level of urgency to act, or not to act at all.

The system works following four possible states from which it is possible to guide its behavior: *normal, pre-alert, alert* and *urgency*. These states imply different degrees of action allowing the system to work from a "relaxed" mode to an urgency mode. The system status is taken into account in most of the situations because the system acts in different ways depending on its state. Figure 6 shows two examples of the system states in which it is possible to see the detection of a resident who is in two different postures: sitting and sitting and fainting.

Initially, the system is in the normal state continuously evaluating the users' posture. If the system detects a normal posture which does not imply danger (it is not a fall or fainting spell) the system continues to seek anomalous postures.. However, if the system detects a fall, a fainting or an unknown posture that does not match with any known pattern, it enters into pre-alert state. This situation indicates that the resident is likely to be in a dangerous situation.

The pre-alert state consists in waiting for a certain period of time before alerting. This pre-alert state allows the system to confirm that the detected situation is really a fall or fainting spell, instead of a momentary posture that a resident has briefly adopted. To differentiate both situations, the system uses a procedure that detects an explicit movement of the user by requiring him/her to modify the anomalous posture. If the user does not respond to this request and does not change his/her posture, then the system enters into an alert state.

At this point, the system acts differently depending on two temporal situations given in the residential care home: silent hours (at night) and operating hours (during the day). The first situation represents a period of time in which residents should not be disturbed with any signal that may create a sharp change in their state. Generally, residents are resting during this period of time. During the day, residents are usually awake and will be able to receive signals requesting some interaction. In this way, when the posture detection is performed during the day or evening, the system sends a sound signal, requesting the resident to move an arm. If the resident responds to the request and the system detects the new expected movement, it eliminates the alert because it discards any danger, returning to the normal state. If the resident does not move his/her arm, the established procedure for both day and night starts. Concretely, this procedure consists in sending an alert to the employee who is responsible for warnings and alerts. Then the employee may see the state of the resident through the video that the Kinect device offers. If the employee does not see any fall or fainting spell, he returns the system to the normal state; otherwise, he changes the system to the urgency state. This state implies that the system may send an urgent message to the most appropriate employee, the closest one who is not attending another emergency. In this way, the affected resident will be attended as quickly as possible.

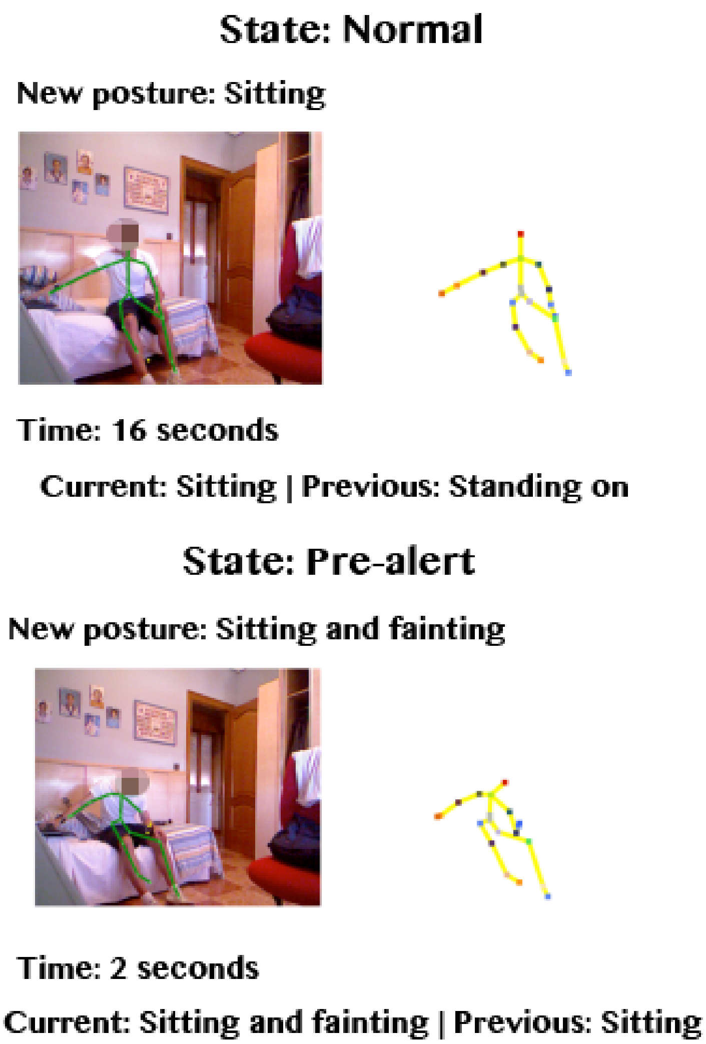

Figure 6: Examples of system states

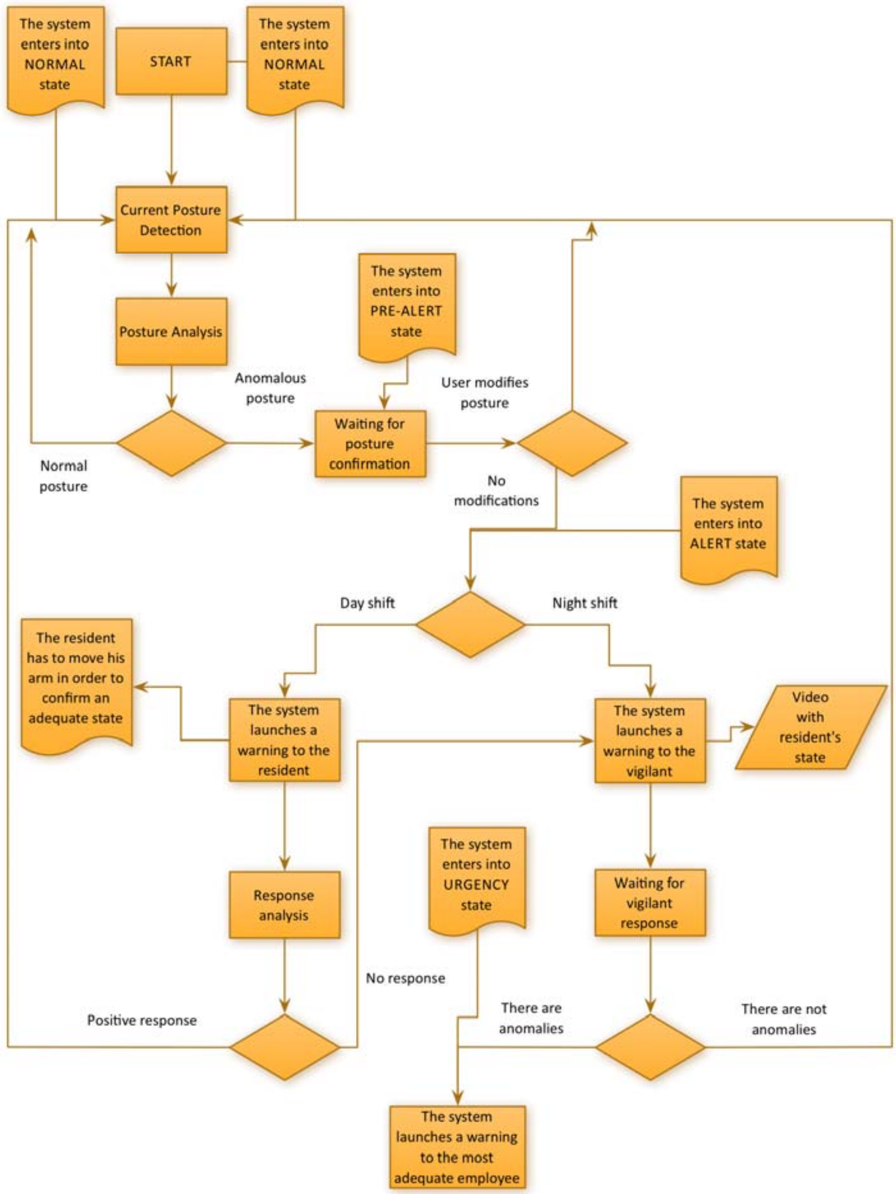

Figure 7: System workflow

3.2 Development Barriers

A set of problems has appeared during the development of the system and the testing phase. Finding solutions has been necessary in order to complete the development without penalizing any of the system's features. The problems basically have their origin in the use of Kinect. Concretely, the three main problems we have had to tackle are the following: (1) the location of the camera, (2) the detection of head movements, and (3) the detection of residents in a horizontal position.

The camera location is an important aspect to take into account. The main reason is the high degree of influence that the location of the resident has when detecting and calculating the skeleton points. Initially, the system had cameras located at a common height for computer users, that is, at the height of the monitor. However, that location did not allow a correct identification of movements because for example, detecting a person who was standing up was not always possible. In this case, the problem appeared when the person was totally in front of the camera and changed his position by ninety degrees. In that moment the movement could not be identified.

These circumstances created the necessity of performing different tests in order to identify positions from different perspectives. The tests results showed that height is a key factor because it allows the Kinect device to perform a better skeleton detection. This improvement comes from the fact that the number of body points detected in each resident is then used to detect the skeleton and in consequence, to identify his/her movements. The height allows Kinect to visualize most of the resident's body and then, to identify the points more clearly. Evidently, the height has a maximum value beyond which the camera loses too much reception. In short, and according to the tests results authors decided to place each Kinect device, at a height of two meters approximately, which is the recommendable height to visualize each resident from all the points of the room.

The second problem comes from the possibility that a resident may faint while s/he is sitting. Concretely, the problem has its origin in the difficulty of managing the point that Kinect uses to detect the position of the head of a person, which is at the center. This generates dilemmas when the system tries to detect if a resident has raised or dropped his head or has moved his head from the left to the right and vice versa. The simulations indicate that the coordinates (that Kinect calculates) of these movements do not change much in the detection of these different movements. Some attempts to solve these problems were carried out but without the expected results, such as the variation of the accuracy of the related movement points. Another option was the possibility of adding additional devices to be worn by residents such as a gyroscope [Vera, 2011]. Evidently, this type of solutions is not viable because residents have to move around with them everyday, implying moral consequences and higher costs. Finally, the solution we applied was to consider a reasonable waiting time before concluding that a resident has fallen down because s/he has spent too much time without moving. To that end, the system stores the last position for each resident so that if that position has not changed in the last five minutes, the system enters in pre-alert state, which starts the process previously described.

The third and last significant problem was the detection of people when they are lying down. The problem comes from a point cloud which is generated by all the points in the same position. Once the problem was located, two solutions were applied. The first one is directly related with the camera location. Given that the problem appeared when the camera was located at the height of the monitor, elevating the camera position improved the number of times in which the lying position was correctly detected. Even so, keeping in mind that the point cloud was generated only with lying people, the second solution was to consider this point cloud to be a pattern that indicated the lying down posture because it was the only possible position in this situation.

4 Evaluation Results

The usability of the system was evaluated based on the ISO 9126-4 standard [ISO, 2002]. The evaluation was focused on the level of effectiveness and user satisfaction when using the system. Effectiveness was measured using objectives and tasks completion and error frequency. And satisfaction was measured using a questionnaire based on SUS (System Usability Scale) test [Broke, 1996].

The main focus of the performed evaluation was to test how the developed system detects each defined position. In this way, authors wanted to know if the system detects each position correctly, what the error rate is, and the system efficiency when performing the posture detections.

The evaluation was based on the performance of twenty tasks. This set of tasks, described below, represents some of the main postures (*standing on, lying, sitting* and *sitting and fainting*) and the transition between them. Concretely, each volunteer had to complete the following tasks:

- Standing on (Task 1).
- Lying down (Task 2).
- Sitting down (Task 3).
- Sitting and fainting (Task 4).
- Transitions between each of the previous postures, that is, sixteen transitions (Task 5-20).

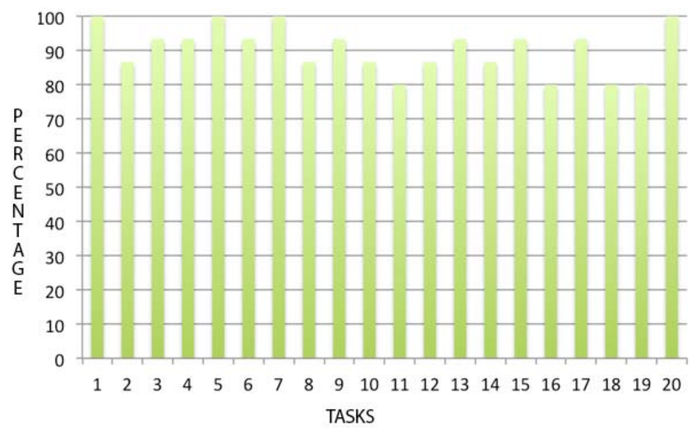

Figure 8: Percentage of effective attempts to perform each task

The group of users selected to perform the tasks had the following features:

- Fifteen users composed the group.
- Six users were female and the other nine were male.
- Participants were nearly 31 years old on average.
- The oldest and youngest user was 40 and 23 years old respectively.
- Only two participants had previously worked with Kinect.

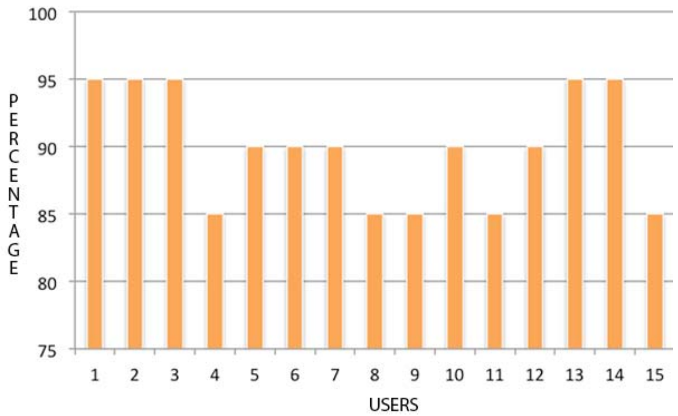

Figure 9: Percentage of effective attempts to perform each task for each user

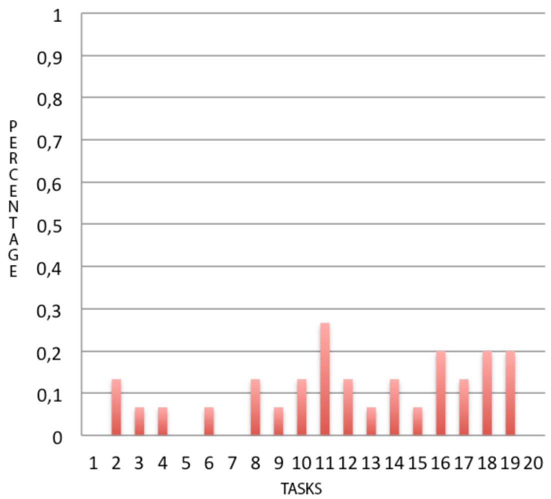

Figure 10: Error frequency for each task

Regarding the efficiency evaluation, we analysed it by measuring the task completion rate (see Figure 8 and Figure 9) and the error frequency for each task (see Figure 10) and for each user (see Figure 11). On the whole, users were able to do most of the tasks in hand. This means that the system successfully recognized the described postures and transitions. Any user performed less than 85% of tasks, as shown in Figure 9. Meanwhile, the minimum percentage of effective attempts to perform each task was 80%.

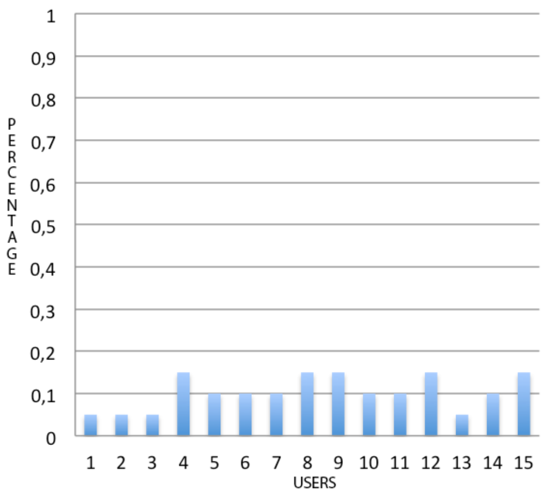

Figure 11: Error frequency for each user

The low error rate when performing the tasks shows the accuracy of the detection system. Concretely, the highest number of errors for one task was 0,26 what can be considered a minimal value, and 0,15 was the higher number of errors that users made. Additionally, the analysis contains the calculation of the standard deviation in order to know the difference among the obtained values. These deviations (0,076 for the average of errors in tasks and 0,039 for the average of user errors) indicate that there is hardly any difference among the values.

According to the outcomes of the efficiency evaluation we can state that the proposal offers an effective mechanism to detect postures and transitions. The detection is the first process of the system when analysing the state of the residents. This detection has to be effective in order to create correct and adequate warns to the employees. Taking into account the little number of errors, it is necessary to know that the system will be able to create correct warns when detecting unknown postures maintained during a specific period of time. When this happens, the system sends warnings to specific employees who can visualize what happens from a live video, being able to determine how to handle the situation.

Regarding users' satisfaction, the outcomes of the SUS test, compared with ideal values, shows that users satisfaction was really near to the maximum level. The outcomes of the SUS questionnaire are measured on a scale from 0 to100. A final value near 100 indicates a complete satisfaction. In our case, the final value was 98,175. This result confirms that users were very satisfied when using the developed system.

5 Conclusions and Future Work

In this paper, we have presented a ubiquitous and context-aware system that automatically detects and reacts to falls and fainting spells in a residential care home. The system is based on movement interaction through a set of Kinect devices. In this way, the system provides a support for conflictive situations by sending warnings to the most adequate employees in order to attend them as fast as possible.

The choice of Kinect devices to work with movement interaction has been determined due to its cost-features ratio. The capabilities of Kinect are adequate in comparison with other similar devices. The system deployment consists in locating multiple cameras around the residential care home, which are connected to a personal computer. The devices' location is determined considering these places where falls and fainting spells can take place and no employee is present to visualize what is happening (e.g. elevators).

Although we found several proposals in the literature, as briefly shown in Section 2, using Kinect to detect both falls and fainting is a quite novel approach. Moreover this project is integrated into a whole system which is able to manage different warnings to interact first with the resident, and then with the person in charge.

The system offers the capacity to analyze residents' postures within the area of action of each Kinect device. Concretely, the system automatically analyzes each posture testing if it is an anomalous one or not. To that end, the system compares each posture with a set of pre-defined patterns. If a fall, fainting or any other anomalous posture is detected, the system activates an actuation procedure that implies to follow a well-defined workflow which is based on a set of states that the system reaches: *normal* that indicate no falls and fainting; *pre-alert* to check the current situation and to avoid false alarms; *alert* to thoroughly analyze the current alert situation; and *emergency* to immediately take actions in the case of a fall or a fainting spell.

The automatic behavior of the system is possible thanks to the ubiquitous and context-aware features. Ubiquity offers connectivity around the environment at any time and anywhere. Therefore, the system is able to know the location of each user because it is stored each time the user changes his position. Regarding context-awareness, the system is able to identify the employees in best conditions to respond to an emergency situation, as it knows the location and current task of each user.

The system has been evaluated based on the ISO 9126-4 focusing on the effectiveness and user satisfaction. The evaluation is based on an experiment composed of twenty tasks and performed by a group of fifteen users. The tasks represent common postures (standing on, lying, sitting and sitting and fainting) and transitions between them that the system should detect. The evaluation outcomes indicate that all participants were able to complete all the tasks with a very low error rate. These outcomes show that the system performs adequately the first step of the workflow that consists in analyzing the residents' state. Regarding the validation of users' satisfaction, which was based on the SUS test, the results reflect that users were highly satisfied.

The proposal presents interesting future works. Authors intend to improve the resolution of the problem found when detecting head movements. In this way, the system will better detect those residents who had fainted while they were sitting. A new possible solution is the use of new movement interaction devices which offer a better skeleton points management. Concretely, an example is SoftKinetic DepthSense that allows working with a large number of intermediate points between head center and neck. Thus, the problem could be solved in a more efficient and precise way.

Additionally, an important future work is to extend the evaluation by using the system in a real residential care home setting. Once the presented evaluation has demonstrated that the system correctly detects common conflictive and normal postures and transitions, testing how the system creates warnings based on these detections is necessary.

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