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A Vision based Fall Detection System for Elderly People

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Abstract

Among the elderly people, falls have become a common health problem. With a growing population of elderly people, health systems are needed to meet the necessities of elderly people. A Microsoft Kinect sensor monitors the usual activities of people and the acquired image frames are processed in Raspberry pi. The context aware feature extraction technique identify the shape of a person and a mean based classification distinguish the fall from usual activities, if it encounters the unusual activity then the alert is sent to the particular person's caregivers through SIM800 GSM modem. Using the low cost Kinect sensor with Raspberry pi, action dataset is built that consist of three types of actions such as sitting, standing and falling for three different persons. The proposed computer vision approach accomplished the static background model which is resistant to the variations in illumination and provides better results.

Keywords: Canny Algorithm, Contour Approximation Method, Depth Image, Fall Detection Computer Vision

1. Introduction

In India, the population of people who are more than sixty years of age has increased from 8.4% to 22.6%. Among them, people more than eighty years increased from 0.8% to 3%. In 2042, the ratio of aging people more than sixty will exceed people who are 0-14 years of age. According to the survey, nearly 50% of elderly people in India suffer from Chronic diseases and 5% of elderly people have immobility[1]. The population of elderly people living alone is 2.4%[2]. Nowadays, elderly people are affected by bone fragility, low mobility, poor sight, Parkinson disease and chronic disease. Therefore, they are at the risk of unexpected fall, which may cause heavy Nowadays, elderly people are affected by bone fragility, low mobility, poor sight, Parkinson disease and chronic disease. Therefore, they are at the risk of unexpected fall, which may cause heavy injuries. Many elderly people fear about falling because it is the leading cause of accidental death. People have started worrying about their daily activities which also reduces their self-confidence. In this project, to safeguard the elderly people and to make the people surrounding, flexible and adaptive, Ambient Intelligence environment is developed. Ambient Intelligence is a flourishing field of Information system which makes an environment sensitive to users by creating intelligence to their everyday environment. In this paper, the work summarizes the contribution of computer vision in the ambient intelligence application. The major concern for using computer vision technique for these applications is to ensure privacy. The proposed computer vision based fall detection system includes a Microsoft Kinect sensor which is for analyzing the daily activities of elderly people. It provides both the color and depth image. Therefore, if there is a need for protecting privacy, instead of color data, the depth data can be used to analyze the fall because it does not contain visual information. A single board computer Raspberry pi is used to process the frames of

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captured videos from Kinect sensor which provides 30 frames per second and then the SIM800 GSM module is used to send the message alert to the particular person's caretaker in order to provide the immediate assistance which is required for falling person after the accident. The paper is summarized as follows: Section 2 details the survey on the related work; Section 3 proposes the illustrated fall detection technology; Section 4 and 5 describes the hardware and software specifications required respectively; Section 6 analyzes the hardware result; Section 7 concludes with future work.

2. Related Work

The fall detection system uses various techniques and technologies. These techniques and technologies are characterized as vision and non-vision based groups.

2.1 Non Vision System

The fall detections of elderly people are based on the techniques such as use of accelerometers[3–5], gyroscopes[6] and with the help of buttons[7]. The major problem of the techniques are that it makes the elderly person wear the above devices often and the usage of buttons is ineffective when the person lay senseless on the floor. In addition to that, batteries are required for the earlier devices. To attain the adequate functioning, the batteries must be recharged regularly. Another promising technique is the Floor vibration detectors which are based on floor dynamics, and it is in the earliest of development[8]. Acoustic sensor systems use sound loudness from microphone to analyze the fall[9]. Due to the restrictive use of range the above systems are confined to indoor environments. An another unobtrusive technique is the development of Smartphone based fall detection system because Smartphone has GPS, accelerometers, microphone, camera, digital compass and gyroscope[10]. In the Smartphone based fall detection system, the waist of humans is considered to detect the fall regarding the Smartphone position[11]. The limitation of Smartphone based fall detection systems are low battery life which is not a minor problem and less technical skilled person does not know to handle the Smartphone[12].

2.2 Vision System

The computer vision systems have a major advantage that the elderly people do not need to wear any devices. It requires one or more cameras to track people.

A camera gives an immense amount of information about the people such as location, actions, and motion. Thermal target is located through the thermal cameras which detect the falls and inactivity of a person by analyzing its motion[13]. The people fall is identified by the velocity of falling in biomechanics[14]. In[15], by tracking of head's velocity, the fall events are detected. This approach is not robust because there is a difference between the fall like event and an actual fall. Other computer vision techniques focuses on posture based events as in[16]. The estimation of human poses has produced a huge literature which is surveyed in[17,18]. The enhancement of computer vision has urged the progress of development in depth cameras[19,20]. Grest et al[19] used the known size of the skeleton to track by Iterated Closest Point. This skeleton based event is more robust and it can differentiate the falling and non falling events. The limitation of the approach is that the raw data which is captured from side view is only used for analysis.

3. Proposed Methodology

3.1 General Architecture

The General Architecture consist of 3 Modules 1) Image Capturing Module 2) Image Analysing Module 3) Alarm Module

3.1.1 Image Capturing Module

In Image Capturing Module, the widely acknowledged tool OpenNI VS2010 is used for Kinect sensor. The image generator in OpenNI VS2010 is used to obtain the colour image and depth image from the Kinect sensor, both the images have the little difference. Therefore, the depth camera needs some correction[21] to modify the differences in the images. To obtain the coincidence between the images, the depth sensor is to be controlled by Open CV. Hence, the OpenCV 1.0 is configured with OpenNI vs. 2010.

3.1.2 Image Analysing Module

The Raspberry pi Model B is used as an image processing module. The OpenCV 1.0, an open source library for computer vision is used for processing an image. The following are the steps taken to analyze the frames from the capturing module.

3.1.2.1 Image Segmentation

In computer vision, image segmentation refers to the process of labelling the image pixels, therefore, the same labelled pixels have the similar characteristics. Thresholding, Edge detection and morphological process are done to locate boundaries and object in an image. The threshold value is used to classify the pixel and is applied to the received image to convert it to the binary image. If the pixel value exceeds the given threshold, it is assigned either white or black. Edge detection is needed to adjust the intensity because the edges and region boundaries are closely related. Hence, the canny algorithm is used to perform the edge detection. The Canny algorithm satisfies the three main standards such as good localization, minimal response and low error rate. The Canny does the following three steps for edge detection. First step is using Gaussian filter to obtain an image by removing noise. The equation for Gaussian filter kernel with the size of 2k+1*2k+1 is given as follows

$$H_{ij} = \frac{1}{2\pi\sigma^2} \times \exp\left(-\frac{(i-k-1)^2 + (j-k-1)^2}{2\sigma^2}\right) \quad (1)$$

Where, H refers filter impulse response, [i,j] refers each pixel in an image, k refers the Kernel size, and σ represents the standard deviation of Gaussian distribution. The size of the Gaussian kernel selection will reduce the detector performance. The size of the kernel is directly proportional to the localization error and inversely proportional to the sensitivity to noise. Here, the Gaussian filter kernel size is chosen as 3. Therefore, 7*7 Gaussian filter is used to create an image. Second step is finding an intensity gradient (G) of an image (x,y) by edge detection operator. It is defined as

$$G = \sqrt{G_x^2} + \sqrt{G_y^2} \quad (2)$$

Where, Gx and Gy are the gradient of an image (x, y). Finally, Non-maximum suppression and hysteresis is applied, based on the derived gradient magnitude to remove the pixels that are not considered as edge. A morphological process is to find the holes or intensity bumps in an image. Morphological operations provide an output image by applying structuring element to an input image. In this project, erosion is used which is one of the morphological processes. Erosion is to estimate a local minimal value over the kernel area. The structuring element B scans over an image A, then the minimum pixel value convergence by B is calculated and replace the pixels of an image with minimal value under anchor point. The erosion of an image is defined as

$$A \ominus B = \bigcap_{b \in B} A_{-b} \quad (3)$$

As a result, the background of the image getting thinner, whereas the dark area gets thicker.

3.1.2.2 Object Detection and Recognition

The object detection refers the object localizing in an image. In this work, the contours are used to analyze the shape. Contours can be described as a curve joining all the continuous points along the boundary, having same intensity or colour. Each contour in an image is stored as a vector of points. Contour retrieval mode finds the utmost outer contours by retrieving the contours which have no next or nested contours and setting its corresponding hierarchy element as negative. Contour approximation method allows only end points by compressing diagonal, horizontal and vertical segments. It removes all redundant points in the contour and compress it to save memory. Outlines are drawn in the contour of an image if thickness ≥ 0. The area of each contour is calculated by the moments (M), where the moments describe the average weight of image pixel's intensity I (x, y). It is defined as,

$$\mathbf{M}_{i\,j} = \sum_x x^i \sum_y y^i\, I(x,y) \quad (4)$$

The contours which do not match the criteria are discarded. The Rectangular bounding box is created around the contour which satisfies the criteria. It is drawn by two points that are placed in the opposite corners which are referred as pt1 and pt2. The height of the bounding box is considered to analyze the shapes (i.e. sitting, standing and falling) of the person. Figure 1 shows the result of pattern detection and recognition of falling person.

3.1.2.3 Object Classification

The classification task aims to classify the object in an image into the particular class. Object-oriented classification is performed to analyse an image which is based on a set of similar pixel's information. In object-oriented classification, the mean matching technique is used to classify the image. Figure 2 shows the object classes used to categorize the fall.

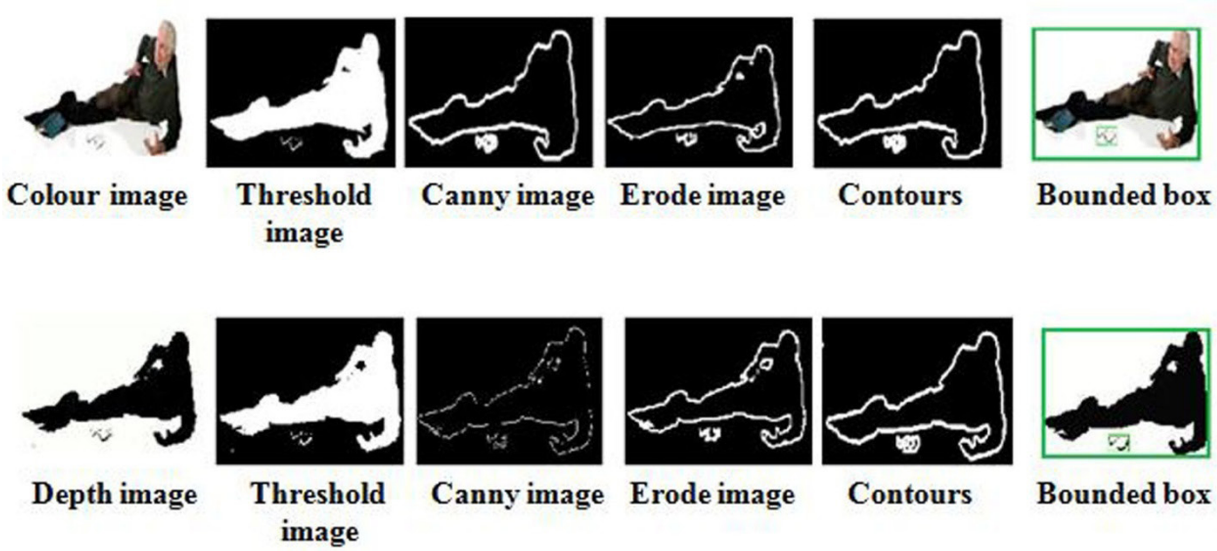

Figure 1. Colour and corresponding Depth image processing.

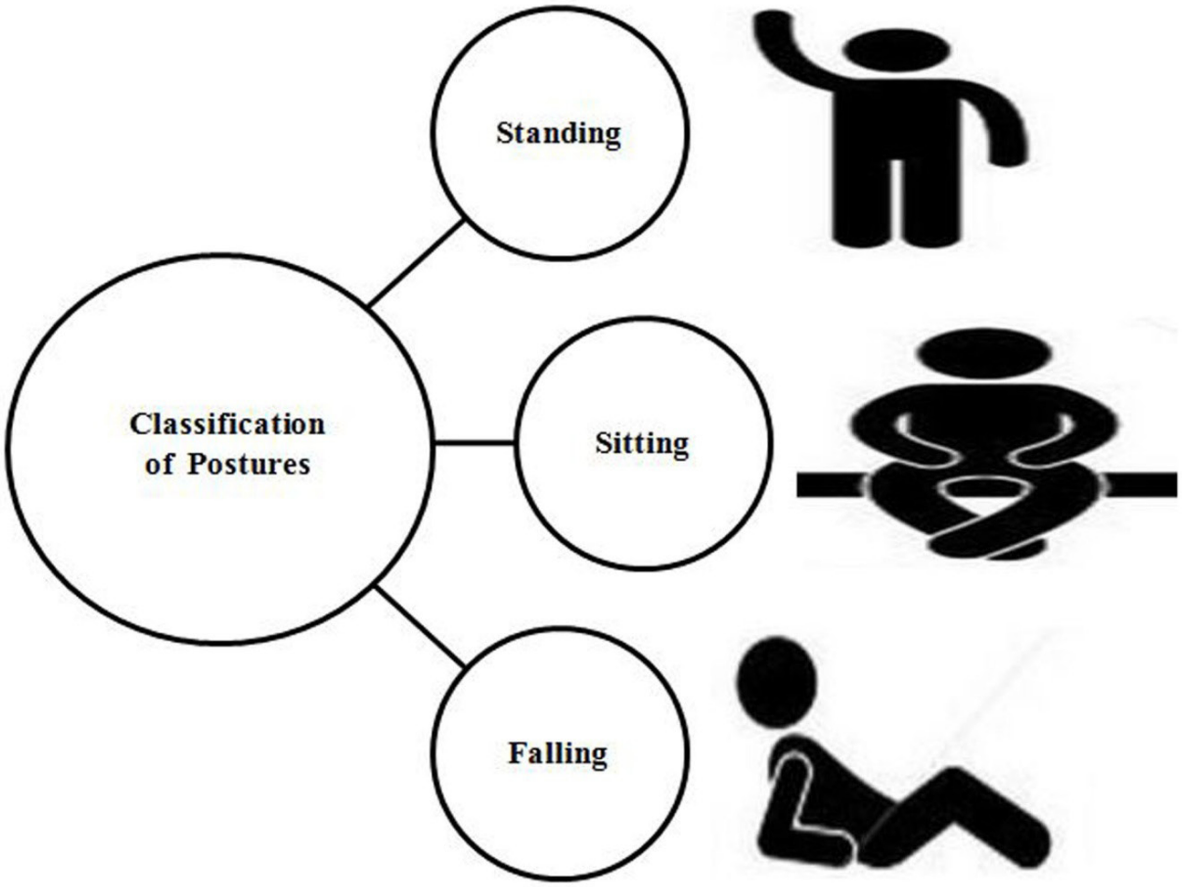

Figure 2. Postures Classification.

The difference between the database image and the captured image is computed. Then, the mean value is calculated from the obtained image pixel values. The equation to calculate a mean of array elements from each channel is given as follows

$$Mean_c = \frac{\sum_{I:\, MASK(I)\neq 0} src(I)_c}{N} \quad (5)$$ Where

$$N = \sum_{I,MASK\,(I)\neq 0} 1$$

In the above equation, src defines an input array of channels. A channel is the number of components used to specify a pixel value and then the MASK defines the optional operation mask. By calculating a mean of different patterns, the mean range is obtained for each pattern. The resultant mean range is given as predefined value for sitting, standing and falling patterns in the algorithm. Therefore, the real-time image frames are classified according to the predefined mean of classes. In Figure 3, Thresholdst and Thresholdsi represents the mean range for standing and sitting respectively.

3.1.3 Alarm Module

SIM800 GSM modem is controlled by the AT (ATtention) commands. The modem is set to the SMS text mode in order to send an SMS message to a GSM phone. Therefore, SMS would be sent to pre-set person when the fall is identified in the image analyzing module. Figure 3 shows the design flow of fall detection system.

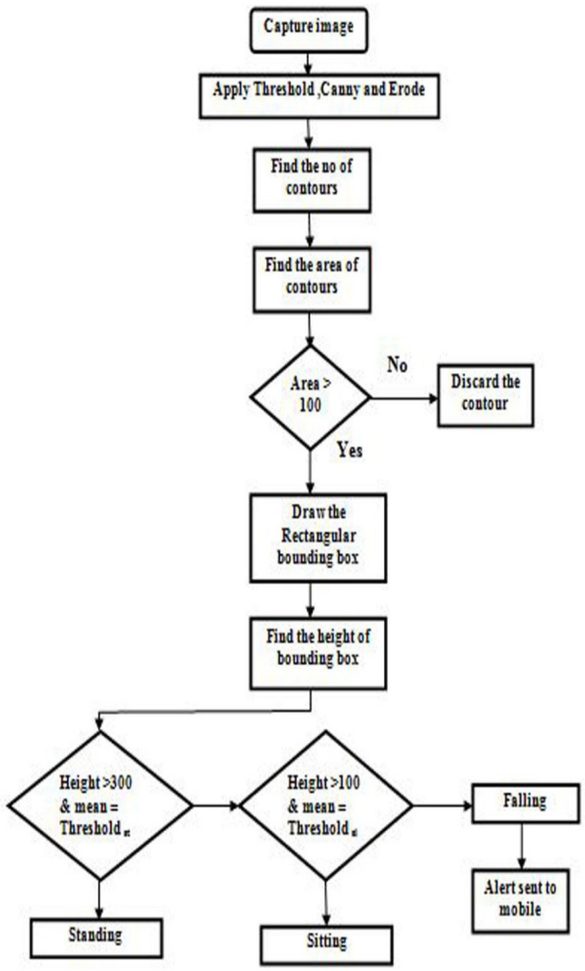

Figure 3. Design flow.

4. Hardware Description

4.1 Microsoft Kinect Sensor

The Microsoft Kinect sensor consists of a microphone array (four microphones), a motorized tilt, an accelerometer, an RGB sensor and a depth sensor with 640 X 480 pixels standard resolution. RGB-D sensor possesses in combination of colour information with per pixel depth information. Motorized tilt allows to control camera by 30 degrees up or down. Three axis accelerometers can be used to measure the position of the sensor. It comes under the technology of Affecting computing. It is cheaper when compared to the other depth sensors. It is the first sensor add together colour information with depth information in order to recognize the object significantly and works under any ambient light conditions.

4.2 Raspberry pi Board

Raspberry pi is a cheaper credit card sized computer designed based on ARM architecture and running on a Linux Operating System (OS). This computer runs entirely on open-source software. It has a 512Mb RAM, 10/100 Ethernet port, HDMI, GPIO, and 2 USB port. The SOC BROADCOM BCM2835 includes an ARM1176JZF-S 700 MHz processor, SD card and Video Core IV GPU. The GPU has been capable of access, fast 3D core. Several SD Card images have been released for loading into the SD card to create an operating system. The image based on the Linux version of Debian OS, which is called "Raspbian wheezy"[22] is used for this project.

4.3 SIM800 GSM Modem

SIM800 GSM has 68 Surface Mount Technology (SMT)

pads and provides interfaces between the module and all user's hardware. It has GPRS multi-slot class 12/class 10, One PWM, Bluetooth function, Audio channels, one SIM card interface and operates on Quad-band 850/900/1800/1900 MHZ and transmit the SMS and Voice data with low power consumption.

5. Software Description

The Qt Creator Version 4 IDE (Integrated Debug Environment) is used. The Qt framework which is used to create the Qt creator provides cross platform development of GUI (Graphical User Interfaces) in C++. The Qt libraries are open source. It has the C++ compiler which is from the GCC (GNU compiler collection) on Linux. Generally, OpenCV libraries are written in C/C++. C++ OpenCV code is used in this project. It run faster and its library is being continuously updated and Its functions are implemented on GPU. The Figure 4 shows the Qt Creator simulation result.

6. Experimental Result

The fall detection system involves Microsoft Kinect sensor, Raspberry pi, SIM800 GSM modem and a laptop is used as a display. Figure 5 illustrates the fall detection system of elderly people. PUTTY software and VNC viewer software are needed to install in the laptop. SSH enabling is required for establishing communication between Raspberry pi and the Laptop. SSHing in Windows OS can be done using PUTTY software which is a terminal emulator it bridges the systems. VNC (Virtual Network Computing) uses RFB (Remote Frame Buffer Protocol) which sends an event messages from the client to server. It is used to remotely control the Raspberry pi through Laptop. The keyboard and mouse events of Laptop can be transferred to Raspberry pi by VNC which is a desktop sharing system and it has a dedicated server, client, and communication protocol.

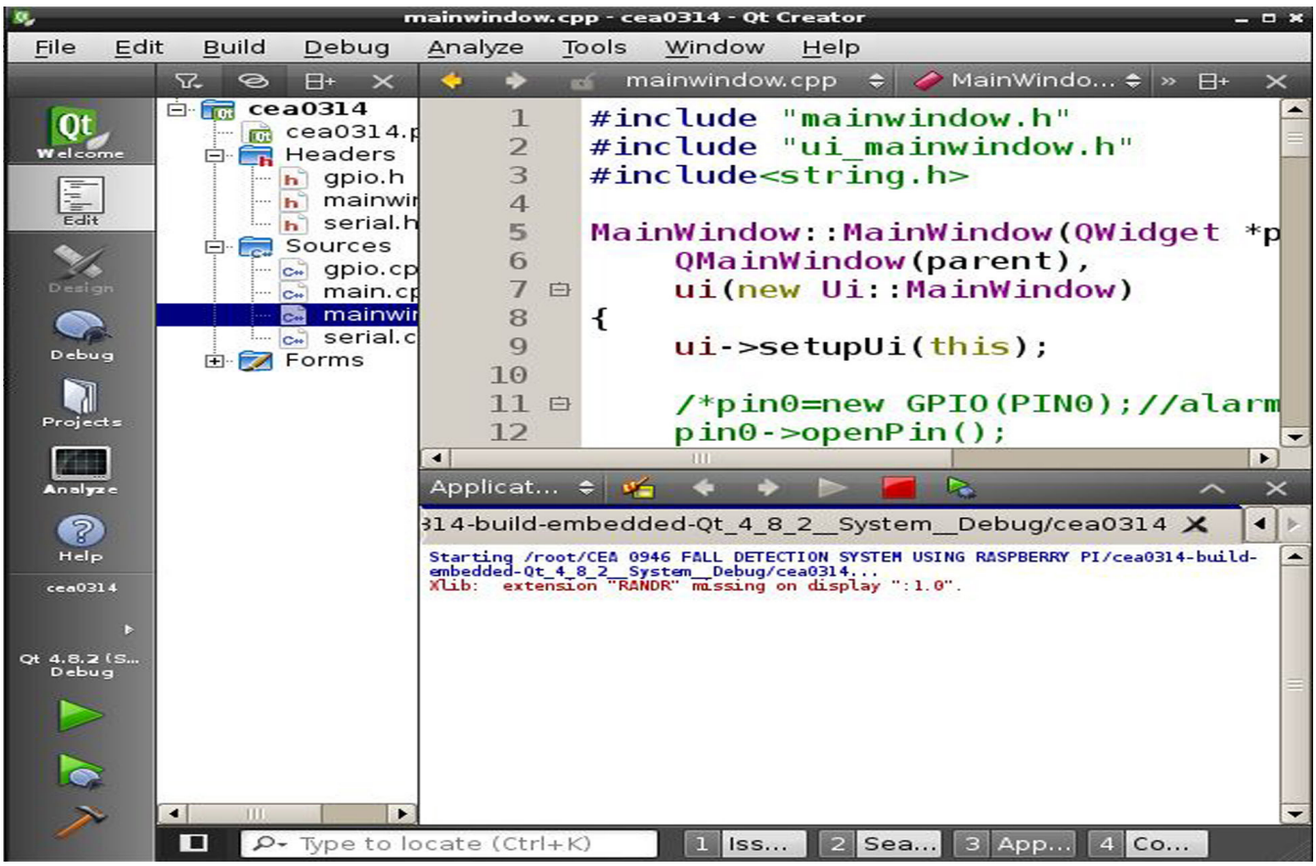

Figure 4. Simulation Result.

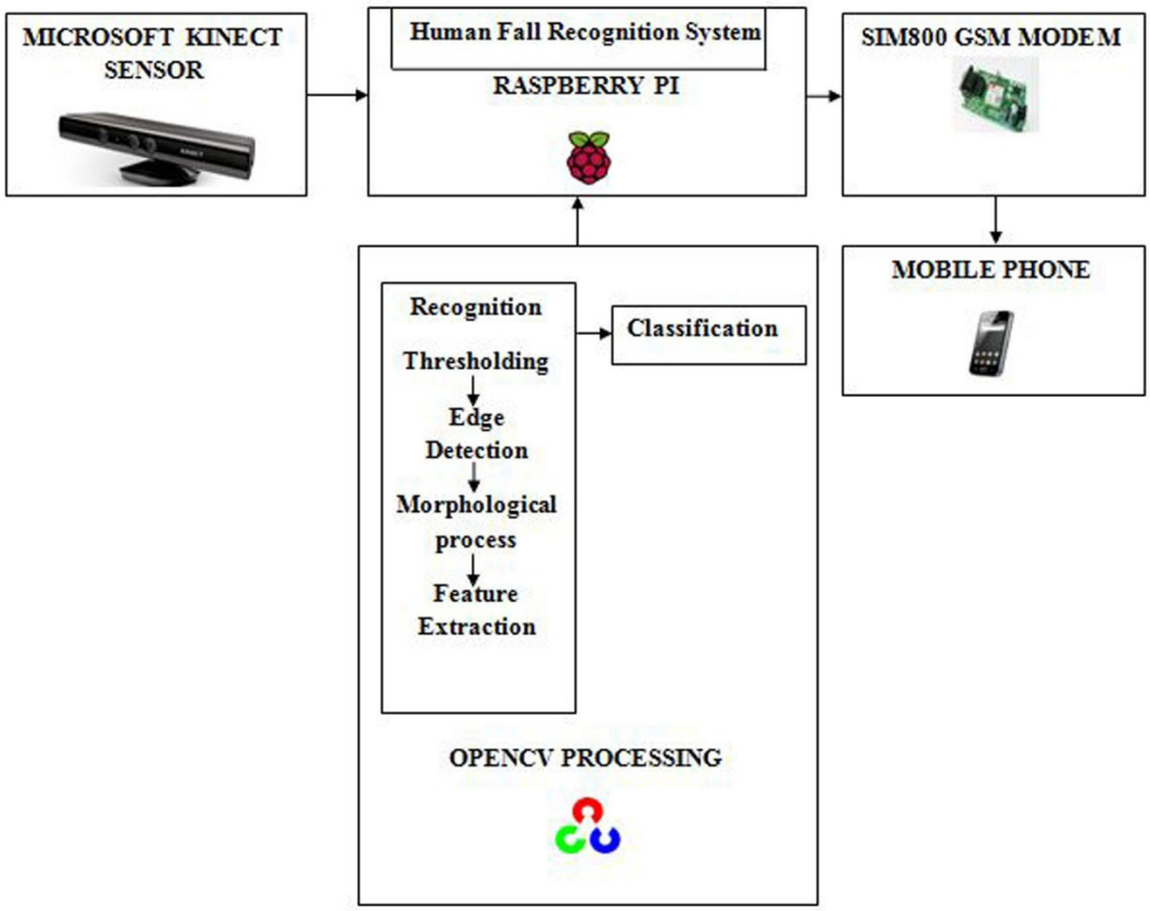

Figure 5. System Overview.

The proposed system has been implemented and verified using OpenCV. The OpenNI VS2010 is used in Qt creator to obtain image frames from the kinect camera in Raspberry pi. Each image frames are analysed in Raspberry pi by contour based feature extraction. In this method, the contours in a frame are extracted after the segmentation of an image in a frame. The contour area is computed to identify the person in a frame and contour lines are drawn as rectangular bounding box around an each action of a person to identify the shape of a person in addition to that the mean based classification is carried out. The database is created with three different person's sitting, standing and falling actions. The mean value is computed by comparing captured image with database image. According to the predefined mean value, the images are classified into a particular class (i.e. sitting, standing and falling). As shown in Figure 6, when the elderly people encounter the fall and then the alert message is sent to the mobile phone of person's caretaker through GSM module which is shown in Figure 7.

7. Conclusion and Future Work

Experimental results show that the proposed methodology of elderly people falls detection system is efficient. The proposed system supports the independent living elderly people. The system monitors user's behaviour by analyzing the information obtained from Kinect sensor. Afterwards, the system will make decisions and send the notification if it is necessary. Some approaches for fall detection consider a specific part of the body, such as the head to detect the fall. In this approach, the analysis of fall detection involves fitting a rectangular bounding box

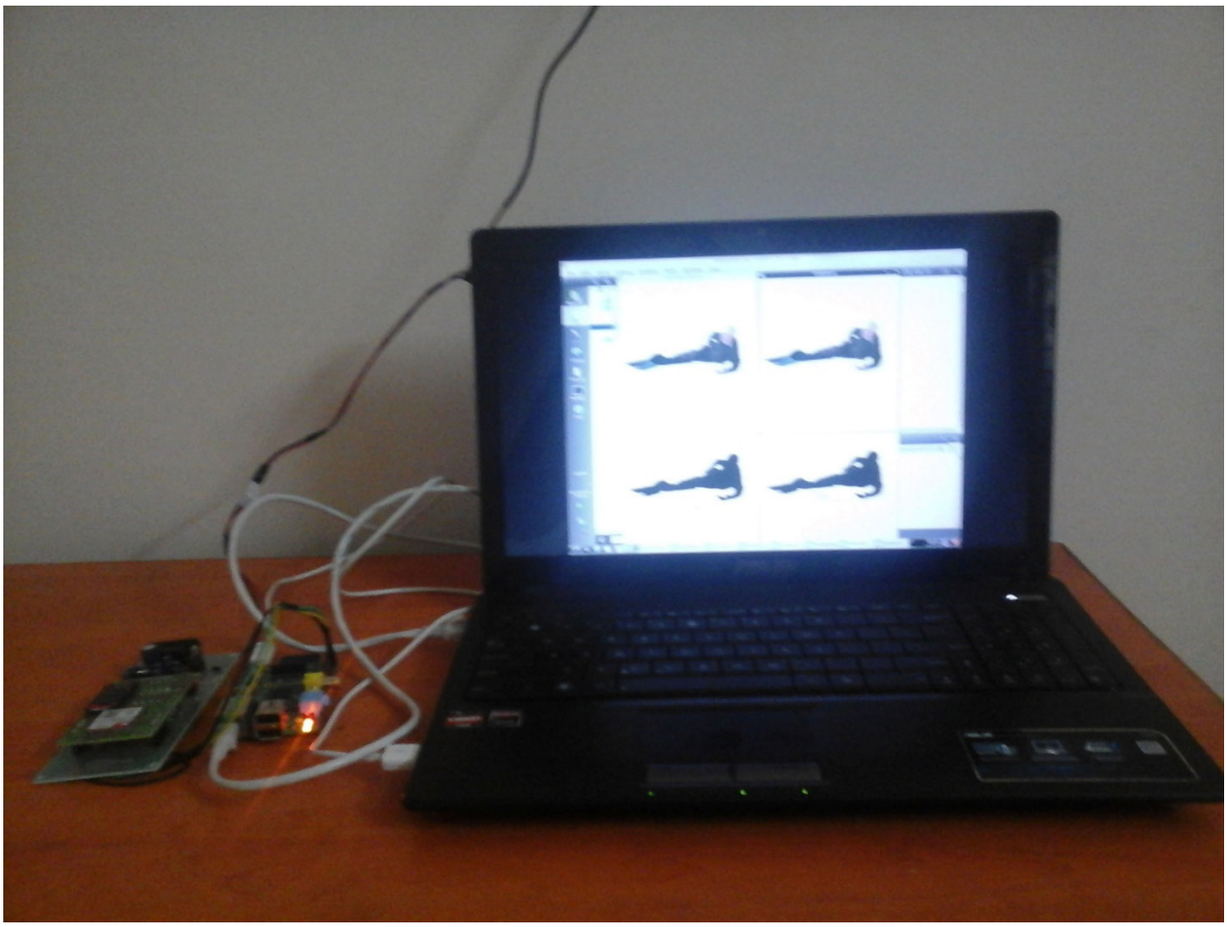

Figure 6. Hardware Setup.

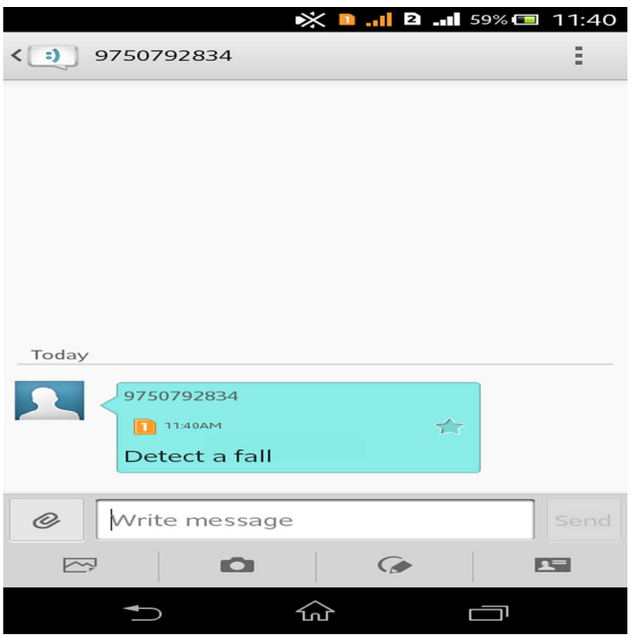

Figure 7. Alert received in mobile.

around the every action of a person by contour based feature extraction, therefore it considers the whole body to detect the fall. The proposed fall detection system is efficient, robust, fast, provides the safeguard in non-intrusive way and uses a low cost sensor with the cheapest computer. The simple algorithm has taken negligible time for computation is 0.2-0.3 ms, reduced complexity and ensures privacy. In future, the development is needed to improve the smaller movement tracking of elderly people and to build an IOT application in Raspberry pi.

8. Acknowledgement

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