Tele-Operation of Web Enabled Wireless Robot for Old Age Surveillance

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Abstract. This paper discusses the system design and implementation of web-enabled wireless robotic system for old age surveillance. In societies, surveillance holds valuable importance for aging population. The system presented is meant for surveillance of elder citizens, who might face physical problems and could be potential site of criminal activities. As a solution to this problem, a prototype of a wireless robot mounted with a wireless camera and microphone is developed, which proved to be quiet effective to test various abnormal events occurring with elder ones. The system works using audio-video information that triggers message to remote client if any abnormality is detected. The remote client can receive live feed of the place where elder people are present using media streaming over and the same can also control the motion of the wireless robot over internet. This helps in restraining the felicity of elder citizens.

Keywords: Wireless communication, Web-enabled robot, Video streaming, Old Age surveillance, Embedded system, Image processing, Audio processing.

1 Introduction

Robots are intelligent machines that can be used to serve several purposes. Presently, wirelesses robotic have sufficient effective area of operation and if a system is built in such a manner so as to control these machines over the internet, then they can perform various tasks in the absence of user. There are many global issues which can be eased by the correct usage of the video and audio surveillance, most of which occurs in public places. Usage of surveillance also lies in the home to check the occurrences of abnormal events.

This paper focuses on the design and development of old age surveillance robotic system with the integration of both the video and audio feed for the detection of abnormal events. The prototype is a surveillance robotic system consisting of mounted wireless camera, a microphone and two CC2500 modules for wireless communication. The Wireless camera and the microphone are employed to track the target and send audio and video information to the server where data processing is performed to detect any abnormal behaviour. In case of any abnormality, an SMS is automatically generated by the system and is sent to the remote client. Access is given

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to the client to control the motion of robotic system through the web and examine the situation in real time.

This paper is the consolidation of various technical domains such as multimedia transfer over the internet, motion detection using image processing and message sending via SMS gateway. These technologies are fused in order to serve the purpose for the design and implementation of wireless tele-operation of web enabled robotic system which is unstructured and dynamic environment.

One of the important parts of this paper is to stream live video from the camera mounted on the robot to the client. The camera should give input wirelessly to the server to send video over network. Bluetooth technology is used to send video from camera to sever. With the recent advances in the field of computing technology, compression, high speed networks and bandwidth have made it easier to provide real-time multimedia services over internet, as explained in [4]. The paper gives an idea about the streaming of a media file over the internet and also discusses the techniques to improve its quality. The Increasing popularity of Motion control of mobile robots, both in scientific research and practical applications have made it an important research field topic these days. An important work in this field [2] that deals with the wireless sensor based remote control motion of mobile robots in an unknown environment with obstacles is using the Bluetooth wireless transmission and Sun SPOT technology. In this paper, CC2500 wireless module is used to send the wireless control signals between the robot and the server which enables user to interact with the real mobile web-based robots, and processes their motion through the Internet via the control interface of their web page. Obstacle avoidance strategy is implemented when the sensors detect an obstacle while making a move towards the target in an unknown environment.

Tracking of human body, modelling and activity analysis in surveillance [5] are one of the tedious tasks of this paper. Tracking refers to identifying the feature points of a human in the video frame and predicting its position in the next frame. The aim of tracking is to find the movement of objects between the two consecutive frame sequences in real time by monitoring of people and analyzing their abnormal activities in both indoor and outdoor environments. Background subtraction algorithm is also used here, in constant background video sequences. It is used to detect the moving regions by subtracting the current image pixels from background image pixels.

Mel Frequency Cepstral Coefficient [7] method is used, for identifying the speaker and differentiating it from one another. In order to increase the area of surveillance, the other concern is audio processing. Suppose there is a gunshot or someone fell down, there will be a screaming which is an abnormal case and to detect this, audio processing is used. There are many such cases when video processing performed does not give you enough information, in such cases audio processing plays an important role. Audio processing processes the audio signals either in analog or digital format in time or frequency domain. It covers diverse fields like Human Hearing, Speech Recognition, High fidelity music etc. The main purpose of the module is to store the sound coming from the remote location and to detect whether it is abnormal or not, using the algorithm used in [7] with several modifications to serve the purpose.

As the problem is concerned, rescue robot [1] is developed in order to meet the demands of this surveillance system using microcontroller, camera, microphone and other basic units. This robot is controlled over internet and it is being compared with other surveillance systems and robots dedicated for such work [8], [9], [10].

Prototype of tele-operated mobile surveillance robot [6] talks about the design and fabrication and find its application in various fields like remote monitoring, urban surveillance and human motion detection etc. In paper [6], it helps to understand that how to proceed and draw framework for the surveillance system in order to meet the requirements.

Internet based robot where robot is controlled over the internet and also sends real time information of remote location to client is implemented in [3]. It explicates the mechanism to drive robot and associated problems which may arise during implementation.

Section 2 explains various systems, section 3 explains about the system design and consolidation of different components in one system. It also includes the comparison with other such systems. In section 4, the video and audio processing algorithms are discussed and in section 5, experimental results are presented. The conclusion is presented in section 6.

2 System Components

The project is the consolidation of various technologies which include wireless communication, multimedia networking, embedded system, abnormal motion detection and abnormal audio detection.

2.1 Robot

Robot comprises camera (Bluetooth enabled), microcontroller, motors, tyres and some set of wires for connection. The basic structure of the robot is taken from the paper [8], [9], [10] and has been modified to suit the purpose. Wireless camera is connected to system via Bluetooth, to send video to the receiver via server over network. Motors are connected with microcontroller, which is connected with the server wirelessly. Wireless modules CC2500, one is connected to microcontroller mounted on robot and another is with server system at remote location which communicates to send control signals. Microphone is attached to the server which takes input from the surrounding for audio processing. Attached to robot, temperature sensors are used to detect if there is any fire event in the house, which is also an abnormal situation.

2.2 Microcontroller and Wireless Communication

Microcontroller is an integrated circuit which is the combination of processor, memory and programmable input/output peripherals. The program for controlling the robot is written in Bascom software and burned in the rewritable memory of microcontroller. The program will guide the robot to move according for the given input control signals.

The input to move robot from one place to another and change its direction is given by client over internet which is transferred to robot via wireless communication module CC2500 attached at both the ends that is robot and server. It works at 2.4 GHz carrier frequency using RS232 UART interface with variable baud rate.

2.3 Media Streaming

Streaming video over the web network is substantial part of this system. To give opportunity to client to see video of the home after logging on webpage, is the motive of this module. Streaming video [4] over a network covers the areas like Video compression, Application-layer quality of Service Control, Streaming servers, Protocols for streaming media etc. Paper [4] helps to understand the way of implementing the media streaming which is an eminent part of the system.

It is important to consider network bandwidth, network traffic and other settings like proxy settings, firewall etc. for achieving successful video streaming. Sender's and receiver's web pages have been developed which are meant for sending and receiving video and control signals for robot over network. They both are connected with server which provides connection, authentication and other facilities. The web pages provide interface where client can login and connect to the server placed at location in concern. After login, client can have overview of the location and can control robot using instruction panel assigned in the web page of receiver.

2.4 Abnormal Motion Detection

The main idea is to detect the abnormality in the video information and trigger a message to the client. Bluetooth enabled camera is mounted on robot which sends real time video to the server which processes it to detect abnormalities. Abnormalities like somebody fell down (especially elder ones since they will be in field of vision of the robot), somebody suddenly running in case of criminal activity or natural calamity or any other abnormality.

Paper [5] explains the basic technique for tracking the motion of human beings. The method is Background subtraction which is used to detect the motion of the target object. After differentiating the motion, abnormality is detected by applying the stated algorithm in section 4.

2.5 Abnormal Audio Detection

Video processing in isolation is not sufficient to detect the abnormality at the remote location. Suppose there is a gunshot or someone scream (especially elder ones), which is an abnormal case and therefore audio processing needs to be implemented to detect it. There are many such cases when video processing is inefficient and audio processing plays a critical role.

This paper implements the algorithm based on Mel frequency [7] for identifying the human and non human activities (like gunshot) and detect the abnormality by using power (intensity) of the sound as one of the parameters. The flow chart for detecting audio abnormality is shown in Figure 1.

If the audio feed is identified as human sound, the system calculate the power of the sound to classify it as screaming or non screaming and send an alert SMS accordingly. Rather if it is perceived as a gunshot then surely it is an abnormal sound case and system triggers an alert message. The algorithm used is stated in section 4.

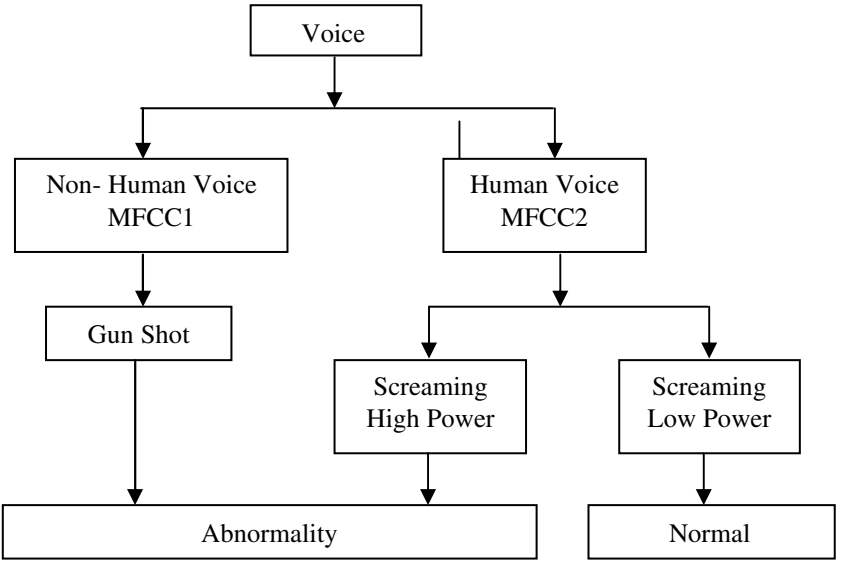

Fig. 1. The flow chart of detecting the abnormality in Audio information collected from the location. Voice is differentiated into non human and human on the basis of MFCC [7] and then power of the sound is computed to check whether it is abnormal or not.

3 System Design and Comparison with Other Systems

3.1 System Design

The Figure 2 presents the design of the developed household surveillance system which detects video and audio abnormal events. Activities at home are observed under surveillance where video feed is provided to server from the wireless camera and audio feed from a microphone. The camera is mounted on robot to stream video to the server and audio information is collected using microphone connected to server. Data processing is performed upon the received audio and video feed at the server and in case of any abnormality being detected; an alert SMS is triggered to the remote client via handset attached to the server using SMS Gateway application.

After getting alert SMS, client makes login on the receiver webpage and ask server to stream video of remote location. Now remote client can have overview of location and can give instructions to the mobile robot to navigate by sending desired control signals through the receiver webpage. These control signals on reaching the server is passed to the mobile robot wirelessly via the CC2500 modules and accordingly the robot is tele-operated over the internet. Robot can also move from one location to another in the house automatically if the blueprint map of the house is customized on receiver page.

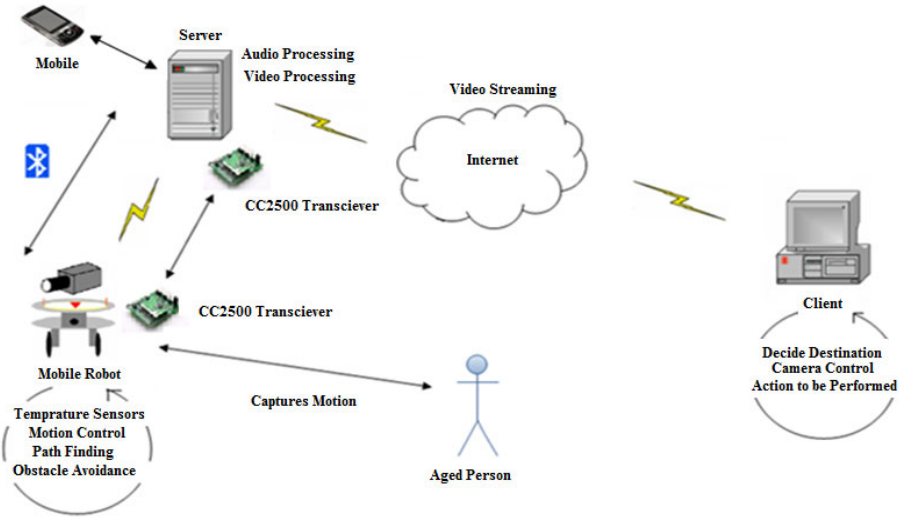

Fig. 2. System Design: Consolidation of various technologies which includes audio and video processing, video streaming, CC2500 transceivers, embedded system, SMS gateway etc.

3.2 Comparative Study

In this section, our robot has been compared to other existing robots of surveillance system. On the basis of parameters like Surveillance use, Tele-presence, Autonomous

Table 1. Comparative study of our system with others implemented so far

Parameters for comparison	Mercury	Xavier	Kaplan Car	Our Robot
Surveillance Use	**No**	**No**	**No**	**Yes**
Tele-presence	**Yes**	**No**	**Yes**	**Yes**
Supervisory Control	**No**	**Yes**	**No**	**Yes**
Autonomous Robot	**No**	**Yes**	**No**	**Yes**
Web Based Control	**Yes**	**Yes**	**No**	**Yes**
Direct Control	**Yes**	**No**	**Yes**	**No**

control, Web based Control etc robot distinction has been established among the candidates. Our robot has one competitive advantage over others as it is being controlled over internet and is also autonomous in nature. Non-availability of direct control is demand of our situation as it doesn't need to be operated by the elderly people.

4 Algorithm Description

4.1 Abnormal Motion Detection

The purpose of this module is to discover abnormalities in video feed and to trigger an alert message to the client present at the distant location. Background subtraction algorithm [5] is used to track the motion of the target. After differentiating the motion, abnormality is detected by applying the stated algorithm.

The first step is to detect foreground images through removal of background images, by applying suitable background subtraction techniques. The background subtraction algorithm should consider the illumination changes, motion changes and geometry of background changes. Second step is motion segmentation, is the process of partitioning of a digital image into different regions or objects and finds the objects and boundaries in the images. It can be used in detection, recognition and tracking purposes, Equation (1) is used for back ground subtraction where Frame_c – Current image, Frame_b – Background image, and T – Threshold value.

$$|\text{Frame\_c} - \text{Frame\_b}| > T \tag{1}$$

Last step is to implement motion tracking algorithm like particle filter algorithm to track the human body. Eventually sending the alert message to person concerning on surpassing the set threshold. The value of threshold is calculated by training the system repeatedly. Training is performed by considering all the respective cases and thus by calculating the number of pixels changed for each sample of images and considering their average value.

Pseudocode

```
Program VideoProcessing(Frames)
 Do
  Store frame in a variable of type Bitmap;
  Calculate the width and height of the Frame;
  Apply grey scale;
  Store upcoming frame in another variable of type Bitmap;
  Apply grey scale;
  Apply Background subtraction algorithm on two Frames;
  Store the value returned and display;
  Count number and frequency of changing pixels;
  Train the system;
  Compare with threshold and initiate alert message;
  While Frame! =NULL
```

4.2 Abnormal Audio Detection

This paper implements the algorithm used in paper [7] modified in such a way in order to serve the purpose and it proves to be an immense help. The main purpose of this module is to store the sound from the remote location and detect whether it is abnormal or not. To understand and classify various sound, different feature vectors are used like MFCC coefficients, Power, Frequency (spectrogram) etc. Here we have considered power of sound and its MFCC coefficients to detect abnormality.

The first step is to break the sound signal into frames of 25ms and desired part of the signal is emphasized using Signal Windowing and to implement this Hamming window (2) is used, where N is the number of samples any instant n. The second step is to calculate the FFT of the desired signal using (3) k = 0, 1, . . . ,N− 1, where k corresponds to the frequency f(k) = kfs/N, fs is the sampling frequency in Hertz and w(n) is a time-window.

$$w(n) = 0.54 - 0.46 \cos(2*pi*n/N) \tag{2}$$

$$X(k) = \sum_{n=0}^{N-1} w(n)x(n)e^{-j2\pi kn/N} \tag{3}$$

For each tone with an actual Frequency, f, measured in Hz, a subjective pitch is measured on the “Mel” scale. The mel-frequency scale is linear frequency spacing below 1000Hz and a logarithmic spacing above 1000Hz. Formula (4) to compute the mels (f Hz).

$$\text{Mel}(f) = 2595*\log10(1+f/700) \tag{4}$$

The third step is to calculate the filter bank which acts as a filter for each desired mel frequency component. First, the frequency is scaled logarithmically using the so-called Mel filter bank H (k,m) and then the logarithm is taken, giving equation (5) where m is the number of filter banks and M < N. The Mel filter bank is a collection of triangular filters defined by the centre frequencies fc(m), written as in equation (6).

$$X'(m) = \ln\{\sum_{n=0}^{N-1} |X(k)|.H(k,m)\} \tag{5}$$

$$\begin{aligned} H(k) &= \{f(k) - fc(m-1)\} \;/\; \{fc(m) - fc(m-1)\} \quad \text{when } fc(m-1) <= f(k) < gc(m) \\ &= \{f(k) - fc(m+1)\} \;/\; \{fc(m) - fc(m+1)\} \quad \text{when } fc(m) <= f(k) < gc(m+1) \\ &= 0 \quad \text{when } f(k) < fc(m-1) \quad \text{and } f(k) >= fc(m+1) \end{aligned} \tag{6}$$

In final step, the log mel spectrum has to be converted back to time and the result is called the mel frequency cepstrum coefficients (MFCCs). The MFCCs may be calculated using this equation (7) where n=1,2,…,K. The number of mel cepstrum coefficients, K, is typically chosen as 20.

$$C(n)=\Sigma(\log Sk)[n(k-1)\pi/2] \tag{7}$$

The VQ (Vector Quantization) [7] approach has been used to match the MFCC of input signal to detect abnormality. Once the sound captured (see Figure 2) from the microphone, if it is non human (gunshot) sound it is taken as abnormality. But if it is

human sound, power of the sound is calculated and compared with the threshold (which is maintained by calculating the power of sounds like screaming from various samples).

5 Experimental Results

The robotic system discussed in this paper has been implemented successfully. Webpage for remote client control and server applications for processing of crude audio and video data was developed using the algorithms and approaches described in the paper.

Being capable of detecting all dealt cases of abnormality and communicating the same to the remote client via SMS and also enabling the wireless tele-operation of robot over internet the system performed all the operations to suit the purpose of old age surveillance efficiently. The Figure 3 shows the developed robot prototype.

Fig. 3. Robot prototype consisting of microcontroller, CC2500 module and Bluetooth enabled camera

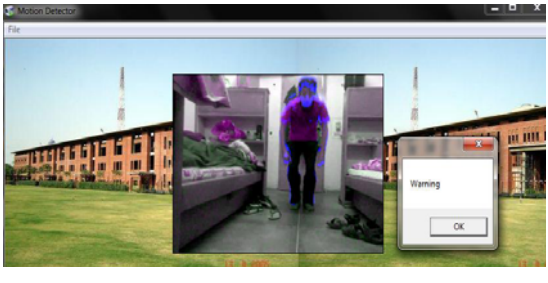

Fig. 4. Window is showing abnormality detection using algorithm in section 4.1, where warning is incited when a person fell down

Image processing is performed in order to detect the abnormality in video feed using algorithm discussed in section 4.1. Image with the message warning is shown in Figure 4 and testing of same testing when performed with elder person is shown in Figure 5.

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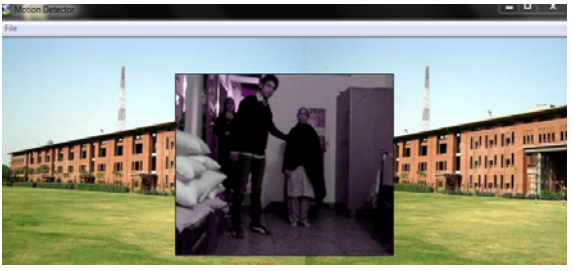

Fig. 5. Testing with aged person

6 Conclusion

This system elucidates an efficient method for surveillance and is aimed to be highly beneficial for any person or organization apart from elderly monitoring. This system is the consolidation of different technologies which includes audio-video processing, multimedia networking and embedded systems. This work could be further extended by application of the same in a multi robot environment whereby multiple audio-video feeds are processed at the server to detect the abnormality with precision. Also motion of the multiple robots could be synchronized to have a better coverage of the surveillance area.

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