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Real-Time Security Based on Image Processing

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Abstract: ***The traditional CCTV Surveillance System can works 24 hours all days of a year with endless video recording with or without human activities and when getting sick after maintenance they keep on working. It has been experienced difficulties in producing video scene or image footages of an event happened, time-consuming in finding a scene out of non-stop recorded scenes, memory space wastage due to endless recording, human error due to human monitoring and cost of looking escaped criminal where studies show few are captured as a result Surveillances seems to have abysmal assistance in security contrary to the objectives of their introduction. The challenging issue with the traditional system is to sense automatically human activities in front of the Camera triggering video recording for future use and make notification which help to understand the time simplifying in producing scene or footage, place the event happened and make the Camera accessible remotely for quick view in real time what happening to help take quick and appropriate measures. This paper present the Real-Time Security System with the ability to detect human movement using the same IP Camera installed, trigger automatic video recording, make notification and the Camera being accessible with Android Application developed which have numbers of interactive features like remote photo shot, video recording, sharing capability, calling, messaging and others.***

Keywords: CCTV, SSIM, SAD, HMDS

1. Introduction

It has been observed introduction of sophisticated and very advanced technology to the market everything almost changing from being too manual to at least semi-automatic and mostly automatic and smart, deploying and marking the 21st-century technology which has changed the lifestyle and conduct. The developments of technology demand the advancement of the traditional Surveillance CCTV System to Real Time by taking the advantages of the available technique into practice in order to solve the challenges of the traditional systems.

In CCTV Surveillance Camera records video which is the combination of several frames [6] captured in places they are installed and the frames taken have features which when processed with appropriate algorithm can help to recognize and identify scene with human movement in each frame and with the first frame taken determining the frame's background which provide details of non-moving and unchanged objects [6]. This is done by using the IP Camera for it to be accessed remotely, movement detection and human detection algorithms using the frames captured.

The Real-Time Security System introduced and presented automatic video recording which is triggered only when human movement is detected which reduce the amount of data to be stored [5] and make the notification. When human movement is detected the system make notification to security personnel and this person use the Android application developed to access the camera to view what is happening and take further action like talking directly to the detected person, activating alarm, initiate call and SMS, take live photo, record live video and be able to share in real time. The proposed Real-Time Security System consists of Human Movement Detection System (HMDS) with automatic video recording capability, the IP Camera, Arduino Uno R3 Microcontroller, GSM module, Android Application, SD Card Module and others.

2. Proposed System Architecture and Algorithm

The proposed system is a Real-Time Security consisting of Human Movement Detection Subsystem (HMDS) which works by capturing frames from the surveillance IP Camera process them by detecting human from different objects captured and if there is a movement of the detected Human the system sends a notification to a security personnel and start recording the video of the movement detected. So with this system, there is no endless recording of which memory resources is saved and the recording made is kept for later use like in Court of law for criminal conduct as a proof, mark the time and where the event happened, saves time in producing the footages and reduce human error in surveillance monitoring.

The system consists of Android Application of which the security personnel can use to immediate access the IP Camera after received notification to check human movement notified where photo and video recording can be directly taken but also there are features that can enable to take action like sharing the photo or video recorded, make calls, send SMS, activate alarm to chase away and speak directly to detected person using the speakers integrated into the system and connected to the Android Application.

The system also consists of calling services to the security personnel as a direct notification since sometime message notification might not be heard by the security personnel.

The system consists of SD Card Module of which the sound

that is used as an alarm is stored and played when an alarm is activated by the Android Application.

The system also consists of IP Camera which is used to take frames from the place being secured, and through the frames, Human Movement Detection algorithm runs to detect object movement and identify human movement and get reported automatically.

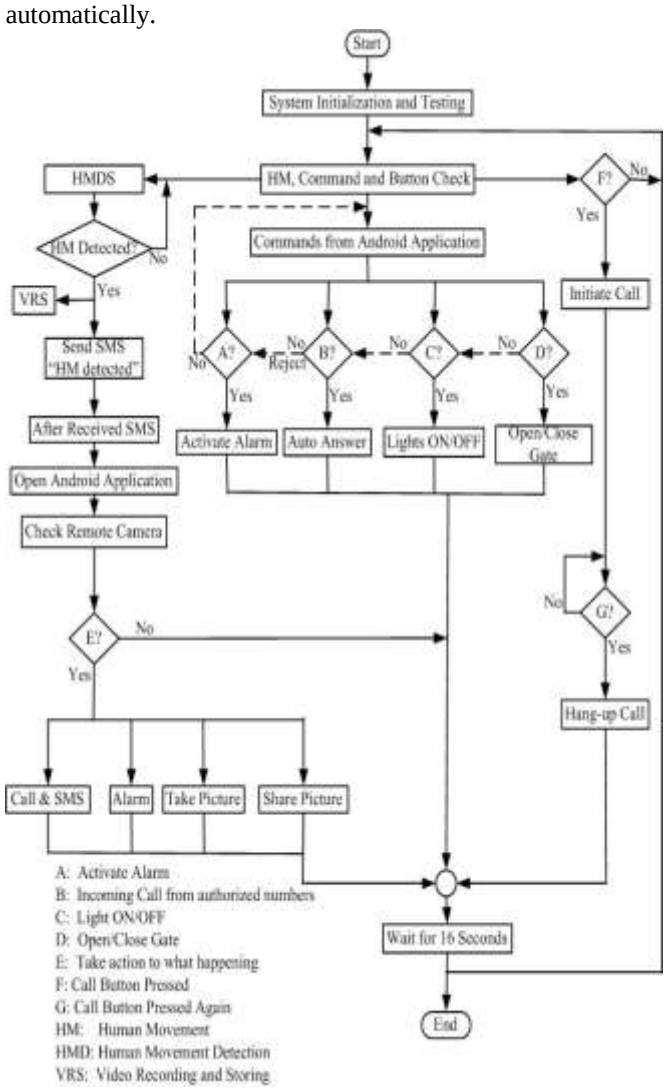

Figure 1: The System Architecture

(a) Human Movement Detection (HMD)

There two algorithms that are performed consecutively to detect human movement;

(i) Movement Detection

The System run Sum of Absolute Difference (SAD) algorithm to recognize if there is movement.

Sum of Absolute Difference (SAD) is a method used to measure image block similarity in a Digital Image Processing where the absolute difference of each pixel in the image block of two images one being the referenced is calculated. A metric block is formed by summing the absolute differences to obtain the Sum of Absolute Difference which has various applications and one of them used in this work is Motion Estimation.

SAD is mathematically represented as follows for both current block and referenced block with similar dimensions [2];

$$SAD=\sum_{i}\sum_{j}|I_k(i,j)-I_{k-1}(i,j)| \quad (1)$$

Where;

$I_k(i,j)$: The current frame;

$I_{k-1}(i,j)$: The referenced frame;

Image Motion estimation involves motion vector determination from one image to another and for video sequences, vector determination is from adjacent frames in a video. The motion vectors can be of image or frame or specific image/frame rectangular blocks or even per pixel. The motion vectors can be estimated by direct using pixels or indirect using features based method.

Through SAD computations and comparisons, the blocks matching between two frames for current and the previous (referenced) one is determined which help in estimating block displacement (movement or motion) and hence motion estimation.

(ii) Human Detection

After the system detects Object movement in front of the Camera, the system run algorithm that recognizes human among the Objects movement detected. The algorithm used based on Structural Similarity Index (SSIM).

Structural Similarity Index (SSIM) is an improved traditional Peak Signal-to-Noise Ratio (PSNR) and Mean Squared Error (MSE) method for measuring the image similarity. SSIM is based on a reference image with luminance, contrast, and structure as key comparison measurements carrying the image structural information in the visual scene. The information helps to recognize as to whether the image taken from the camera is a human or not and the decision help further system processing.

- *Luminance:* Measures the image visibility under brightness where distorted one is less visible expressed by the equation below.

$$L(x,y)=\frac{(2\mu_x\mu_y+C_1)}{(\mu_x^2+\mu_y^2+C_1)} \quad (2)$$

- *Contrast:* Measures image visibility in significant activities or texture where distorted one is less visible under significant image activities or texture expressed in the equation below.

$$C(x,y)=\frac{(2\sigma_x\sigma_y+C_2)}{(\sigma_x^2+\sigma_y^2+C_2)} \quad (3)$$

- *Structure:* Measures the spatial closeness of the strong interdependence of the image pixels calculated with the equation below.

$$S(x,y)=\frac{(\sigma_{xy}+C_3)}{(\sigma_x\sigma_y+C_3)} \quad (4)$$

Where;

$$C_3 = \frac{C_2}{2} \quad (5)$$

The combination of comparative measures gives a mathematical representation of SSIM as below calculated on various windows of common size NxN for this case window x and y of the image [1];

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \quad (6)$$

Where;

x and y: sample windows
L(x,y): The luminance;
C(x,y): The contrast;
S(x,y): The structure;

μ_x : The average of x;

μ_y : The average of y;

μ_x^2 : The variance of x;

μ_y^2 : The variance of y;

σ_{xy} : The covariance of x and y;

$$C_1 = (K_1 L)^2 \quad (7)$$

$$c_2 = (k_2 L)^2 \quad (8)$$

C_1 and C_2 are two variables to stabilize the division with weak denominator;

$K_1 = = 0.01$ and $K_2 = 0.03$: The default constant;

L: The dynamic range of pixels-values which is $(2^{\#bits\ per\ pixel} - 1)$.

Through comparing the SSIM of two images after some preprocessing stages, their similarity can be realized as a result help to recognize human from other objects detected.

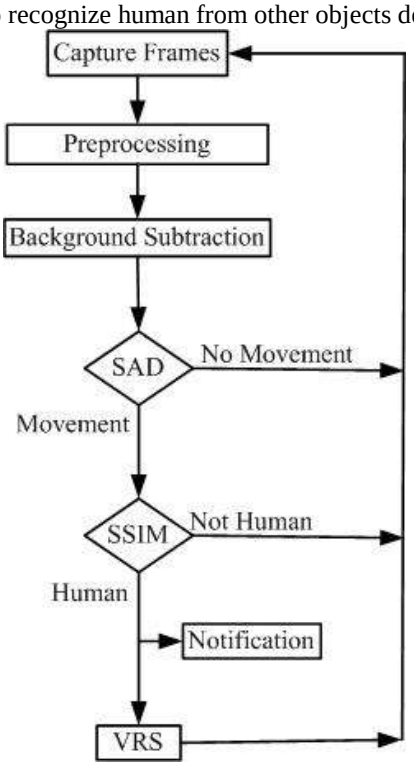

Figure 2: HMD with Video Recording and Storing (VRs) architecture

Figure 3: HMDS developed with Matlab

(b) Android Application

Android is the mobile devices Operating System such as Smartphones, smartwatch, and tablets based on the Linux kernel. There so many devices running Android Operating System of which any Android Mobile Applications developed can be installed and run on them. The mobile applications have an extremely changed lifestyle the way we interact and empowering development almost in every sector and hence play a great role in success chain [3].

The application developed to bring the security of our place to ourselves with the smartphone by accessing the Camera remotely after a notification of the human movement being detected at our place is received and help to take appropriate measures after live viewing through the Android Application installed on our smartphone. The application is not only used to access Camera but also we can take photos, record short video clip and be able to share, we can initiate call direct from it and others.

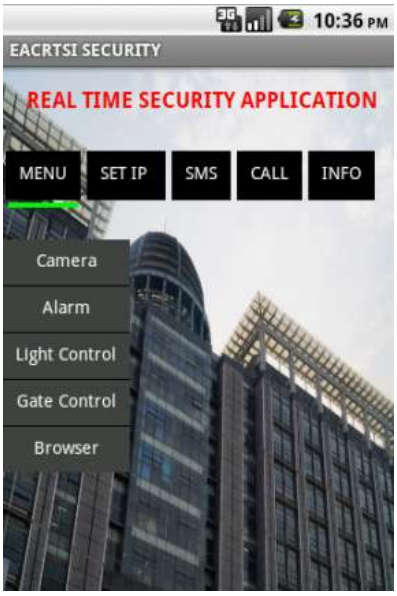

Figure 4: Android Application developed

(c) Microcontroller

The core part of the Embedded Systems is a processor which accepts different inputs, information or data and commands to process and store them by giving instructed output to the user. A Processor is an electronic circuit which changes the value in memory when performing an operation of data as instructed by the instructions that are stored in memory. The instructions are grouped as a program to instruct the processor to perform task [8]. The key processors for Embedded System are Microprocessor and Microcontroller.

Arduino Uno R3 which is 8bit ATmega328 AVR Microcontroller board where programs can be easily loaded to it from Computer running IDE characterized with faster transfer rates and more memory takes control of the system parts linking them together and makes the system to perform accordingly.

(d) GSM Module

A GSM Module is GSM Modem of which a SIM card is installed TTL output having pins with a microphone and speaker jack, power and ground connections used in the project mainly to perform the following operations:

- Receive, send or delete Command messages.
- Make, Receive, or reject a voice call.

The serial communication between GSM Module and Microcontroller is made successful through the AT commands [9]. These commands are sent by the Microcontroller and GSM Module reply with a result according to the command received. The Module used is SIM900 in project implementation.

3. Experiment, Result, and Discussion

The system was tested after all parts being assembled together, the camera connected to the network, the developed HMDS connected and the Android application installed on the smartphone and the communication between them established. Three experiments for each 10 tests were done: (a) For 4 different core functionalities when the system Camera connected to LAN network here indicated as Core1 in the table of results (b) For 4 different core functionalities when the system Camera connected to Mobile Network here indicated as Core2 in the table of results and (c) For 7 other system functionalities indicated as other in the table of result.

The core functionalities of the system which was tested are automatic human movement detection, automatic video recording when human movement detected, notification, accessing camera and alarm activation and the other functionalities are Sharing (Photo and video taken from the camera), Messaging, making calls, automatic receiving call from allowed contacts, rejecting all calls from non-allowed contacts, controlling gate and light.

The system tested around the Tianjin University of Technology and Education (TUTE) premises. When the system took more than 10 seconds to respond to any test as expected it was considered unsuccessful otherwise it was considered as successful.

Table: Results

Functionality	Tests	Successful	Unsuccessful
Core1	40	39	1
Core2	40	37	3
Other	70	70	0
Total	150	146	4

System Performance:

$$Performance = \frac{Successful}{Total} X\,100\%$$

$$Performance = \frac{146}{150} X\,100\%$$

$$performance = 97.3\%$$

System Error:

$$Error = \frac{Unsuccessful}{Total} X\,100\%$$

$$Error = \frac{4}{150} X\,100\%$$

$$Error = 2.7\%$$

During system testing especially when the Camera was connected to Mobile Network the system was unsuccessful for 3 tests which eventually contributed to 2.7% system error resulted from the system provided access to the Camera more than 10 seconds meaning that the system took more seconds to respond than as expected this is mainly due to a network availability which is not dedicated some received weak signal 2G and 3G where it became a little slow to retrieve a video or picture. So it is better to check the type of a Mobile Network available in case of using Mobile Network before installing the system, 4G networks gave better results and LAN network as well.

Figure 5: HMDS showing Detected Human Movement

Figure 6: HMDS showing no Human movement detected

Figure 7: Screenshot of Android Application streaming video live from a remote IP Camera

Figure 8: Playing automatically recorded video with VLC player

4. Conclusion and Recommendation

Security has been a major challenge and researchers are trying to find solution coming up with different suggestions but challenges still exist. This paper has suggested the use of Embedded System, Android Application and Camera Network based on Image Processing in particular SAD and SSIM algorithms posed another way of developing a Real-Time Security System.

The system developed when tested performed 97.3% which is a good result despite the use of low-performance level components which does not provide the system more robust. In future, the system can be further improved by adding features with Machine Learning technique, powerful Microcontroller and face recognition making real-time Security System more robust, reducing human error, use efficiently storage space available, get informed in real time of what happening and hence be able to take appropriate measures

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