An Intelligent Offsite Object Identification and Recognition Video Surveillance System

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ABSTRACT

The need for an automated surveillance system in some aspects of our daily life cannot be overemphasized. Existing monitoring video cameras are very cheap, but the human resource to manage them is very expensive and prone to errors. Most surveillance cameras are currently used after an incidence, to run through a set of recorded data to identify a culprit. The need for a continuous monitoring system that can alert users or security officers of an incident in progress is therefore important in today's risky environment. The methodology uses a combination of temporal differencing and background subtraction method for object detection. It is then followed by a template-matching classification algorithm which uses the object silhouette followed by the contour tracing algorithm. After object detection and classification, we use PCA and feature based technique to identify the human detected. We also carried out performance analysis based on run time, time performance and detection quality of algorithms. The results show that our algorithms give a better performance than existing ones. The system works under existing infrastructures and ISPs without any modification, so that no new popular application on a mobile phone is created.

Keywords: Video Surveillance, Face Recognition, Silhouette, Feature Extraction, Principal Component Analysis

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1. INTRODUCTION

The increase in the number of cameras in ordinary surveillance systems overloaded both the human operators and the storage devices with high volumes of data making it infeasible to ensure proper monitoring of sensitive areas for long periods of time. In order to filter out redundant information generated by an array of cameras, and increase the response time to forensic events, assisting the human operators with identification of important events in video by the use of "intelligent" video surveillance systems has become a critical requirement. The making of video surveillance systems "intelligent" requires fast, reliable and robust algorithms for moving object detection, classification, tracking and Object recognition (Dedeoglu 2004).

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The aim of this research is to develop an automated robust surveillance system with authentication features. The real time video surveillance will be designed with robustness as the major design goal. The system aims at increasing the efficiency of security guards performing surveillance.

This paper presents a system which distinguishes transitory and stopped foreground objects from static background objects in dynamic scenes; detect and distinguish left and removed objects; classify detected objects into different groups such as human, human group and non-human; detect faces in human video imagery; authenticate the object identified and sends an MMS to the system user.

The system alerts the user of exempted object and is flexible enough to incorporate other functionality with relative ease. It logs the activities for future references and operates in real-time. The final decision, whether the object is a threat or not is still up to the user.

2. RELATED WORKS

Moving object detection is the basic step for further analysis of videos. It handles segmentation of moving objects from stationary background objects. This not only creates a focus of attention for higher level processing but also decreases computation time considerably. Commonly used techniques for object detection are background subtraction, statistical models, temporal differencing and optical flow. Due to dynamic environmental conditions such as illumination changes, shadows and waving tree branches in the wind object segmentation is a difficult and significant problem that needs to be handled well for a robust visual surveillance system.

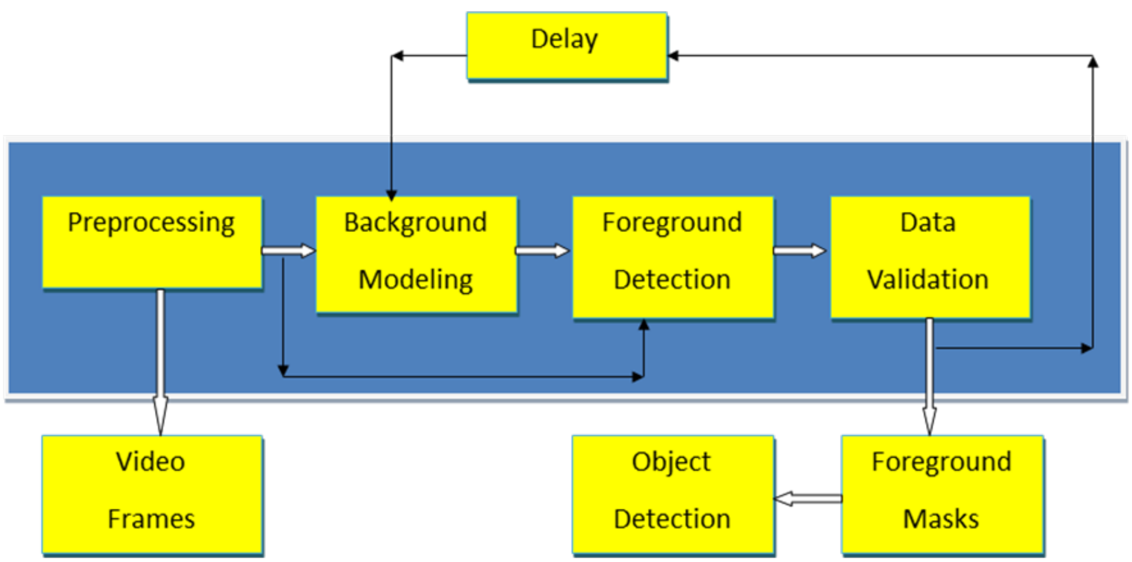

Fig.1: Generic object detection system

2.1 Phases of the Generic Object Detection System

1. Pre-processing consists of a collection of simple image processing tasks that change the raw input video into a format that can be processed by subsequent steps.
2. Background modelling uses the new video frame to calculate and update a background model. This background model provides a statistical description of the entire background scene.
3. Foreground detection then identifies pixels in the video frame that cannot be adequately explained by the background model and outputs them as a binary candidate foreground mask.

4. Finally, data validation examines the candidate mask, eliminates those pixels that do not correspond to actual moving objects, and outputs the final foreground mask. Domain knowledge and computationally-intensive vision algorithms are often used in data validation.

2.2 Object Classification

Object classification categorizes detected objects into predefined classes such as human, vehicle, animal, clutter, etc. It is necessary to distinguish objects from each other in order to track and analyze their actions reliably. Currently, there are two major approaches towards moving object classification, which are shape-based and motion-based methods (Wang et al. 2003). Shape-based methods make use of the objects' 2D spatial information whereas motion-based methods use temporal tracked features of objects for the classification solution. Detecting natural phenomenon such as fire and smoke may be incorporated into object classification components of the visual surveillance systems.

2.3 Human Identification

The next important step is to understand the identity of persons entering the scene. Latest studies on person identification demonstrate the popularity of architectures based on biometrics (distinctive personal features). Face and gait are the main biometric features that can be observed within passive surveillance context (Hu et al. 2004). Research on face recognition has a longer history and there are several studies on face detection, face tracking, extraction of facial features and face recognition (Rowley et al.1998; Turk and Pentland 1991; Hjelmas and Low 2001).

Gait-based recognition has gained more attention in recent years. These studies can be classified into three main categories: model-based methods, statistical methods and physical feature-based methods. Model based methods use anatomical models to analyze gait of a person. Parameters like joint trajectories or angular speeds are used to build the models (Yam et al.2001; Tanawongsuwan and Bobick 2001). In statistical methods, moment features of object regions are utilized for identifying individuals (Shutler et al. 2000; Lee 2001). Finally, physical feature based models make use of the geometric structural properties of human body to identify the motion pattern of an individual. Among these properties are the height, stride length and cadence (Abdelkader et al. 2002). A more detailed discussion on gait-based recognition studies can be found in (Hu et al. 2004).

3. METHODOLOGY

The objective of this work was to develop a surveillance system which detects motion in a live video feed and if motion is detected, then to verify the captured object, if is a strange object or a known one and to store the video feed for future reference and processing purposes. The activation of an MMS alert would help in nullifying a threat of security and storing of video provides a proof of such malicious activity. Keeping the work objective in mind, a basic system architecture as shown below in the Figure 2 was developed.

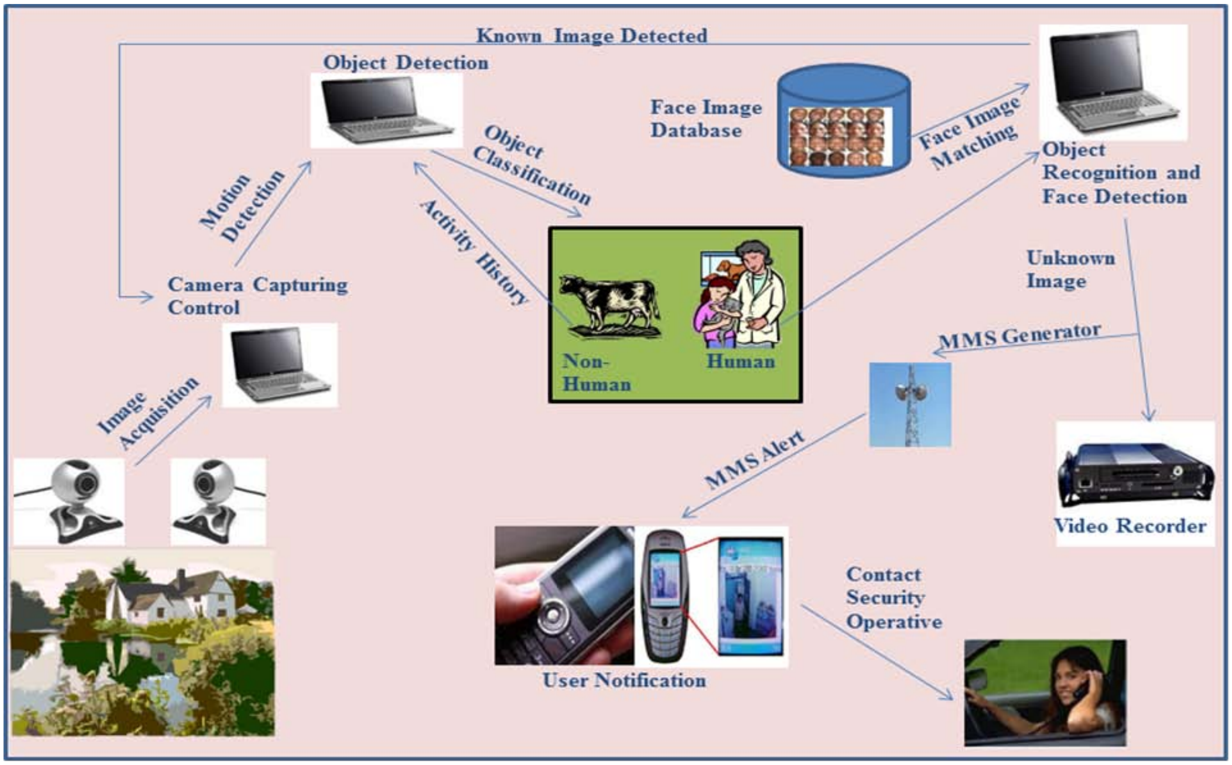

Fig 2: Overall system architecture

The system architecture describes how the system component interact and work together to achieve the overall system goals. It describes the system operation, how each component functions, and what information is exchanged. The architecture provides an idea of how the actual system works and operates.

The system architecture can be sub-divided into sub-sections which interact to achieve the overall objective. The successive sections discuss the various techniques used to achieve the objective. The sub-sections include:

1. Camera Capturing Control
2. Object Detection
3. Object Classification
4. Object Recognition
5. Video recording
6. User Notification
7. Activity History

3.1 Camera Capturing Control

To detect motion, the webcam captures the live video frames of the area to be monitored and kept under surveillance in real time. This is done by using a webcam which continuously provides a sequence of video frames in a particular speed of FPS (frames per second).

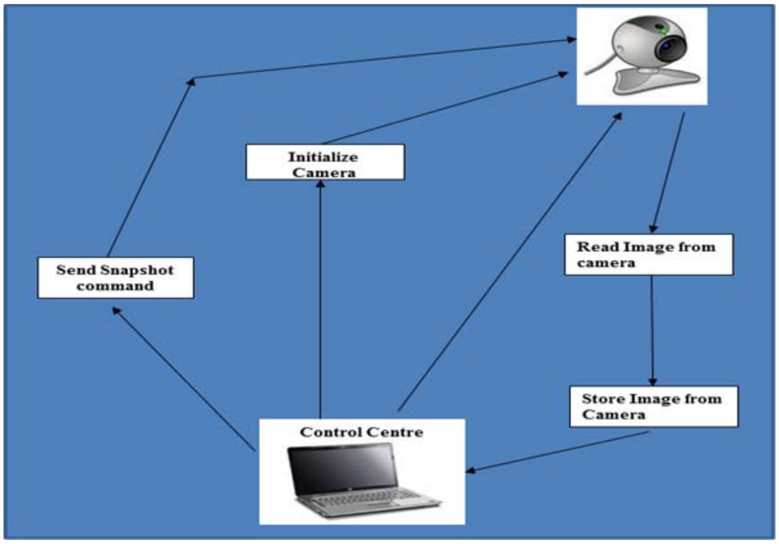

Fig 3: Camera control module

This control integrates all the functions needed to connect to multiple cameras together. It allows the user to add or delete cameras as well as edit all the camera settings. At the Surveillance Station, users can choose to add a camera by following the on-screen instructions to complete the camera setup and select video format. To remove cameras from list, users can simply click "Delete" to detach its camera service from the control panel.

3.2 Proposed Object Detection System

In this research, we employ temporal differencing and Background subtraction for the development of our algorithm.

1. **Temporal differencing:** Temporal differencing makes use of the pixel-wise difference between two or three consecutive frames in video imagery to extract moving regions**. It is a highly adaptive approach to dynamic scene changes**; however, it fails in extracting all relevant pixels of a foreground object especially when the object has uniform texture or moves slowly. When a foreground object stops moving, temporal differencing method fails in detecting a change between consecutive frames and loses the object. Special supportive algorithms are required to detect stopped objects.
2. **Background subtraction: Background subtraction provides the most complete feature data, but** is extremely sensitive to dynamic scene changes due to lighting and extraneous events. The aim is to get the advantage of the two techniques and thus a more efficient system. It is also very important to employ an algorithm whose run time is minimal since the system is expected to work in real time.

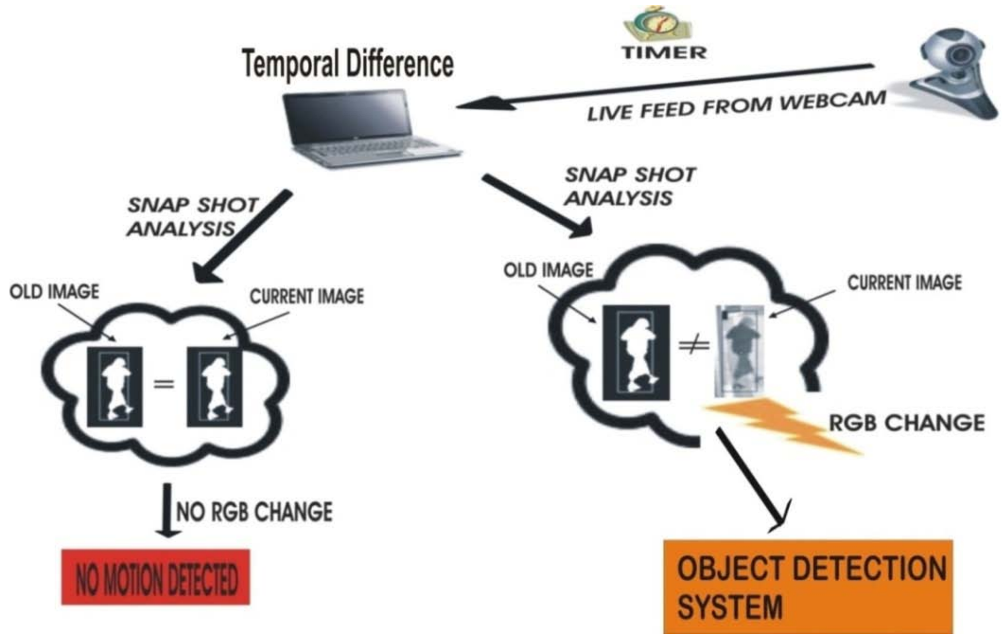

Fig: 4: Proposed temporal difference model

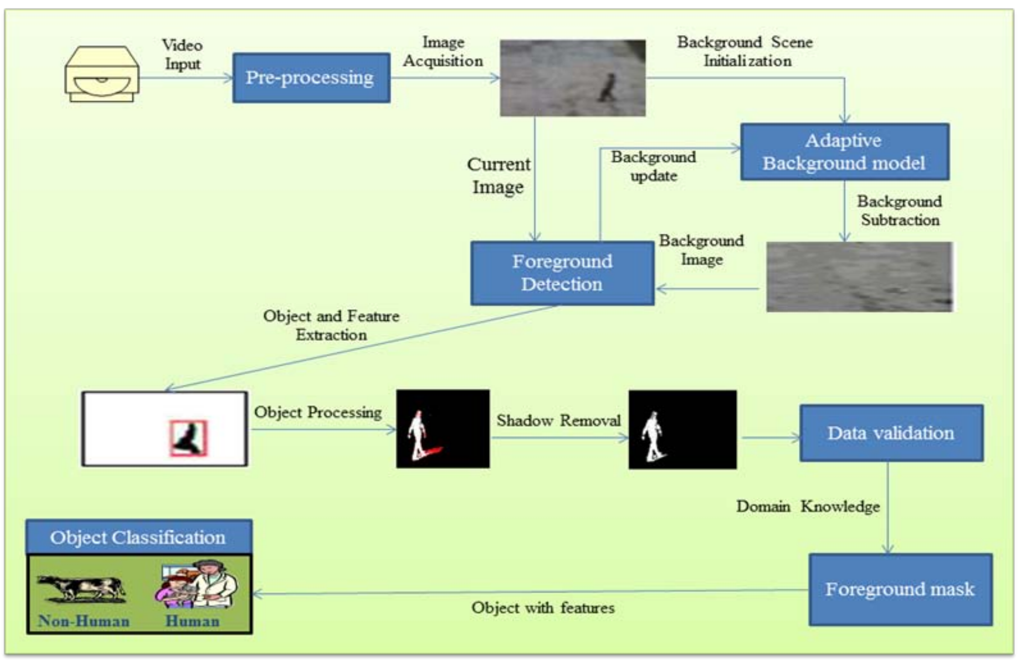

Fig 5: Proposed adaptive background subtraction model

3.3 Object Classification

The classification metric used in our method measures objects similarity based on the comparison of silhouettes of the detected object regions extracted from the foreground pixel map with manually classified template object silhouettes stored in a database. The whole process of object classification method consists of two steps:

1. **Offline step**: Creating a template database of sample object silhouettes by manually labeling object types.
2. **Online step:** Extracting the silhouette of each detected object in each frame and recognizing its type by comparing its silhouette based feature with the ones in the template

3.4 Face Recognition

The problem of face recognition in a real world situation can be said to be in three categories:

1. Face detection
2. Face segmentation, feature extraction and normalization
3. Face recognition

3.4.1 Face detection. This is the entry point of the face recognition process. The face detection system architecture is based on three main modules using a client-server approach as solution for the distribution. The three modules are sensor control, data fusion and image processing. The sensor control module is a dedicated unit to control directly the two cameras and the information that flows between them.

The data fusion module controls the position of the remote control camera depending on the inputs received from the image processing and sensor control module. The information obtained from the static camera (the position of the recognised object) is used to feed the other camera. Therefore, the remote control camera can zoom to the recognised human to detect the face.

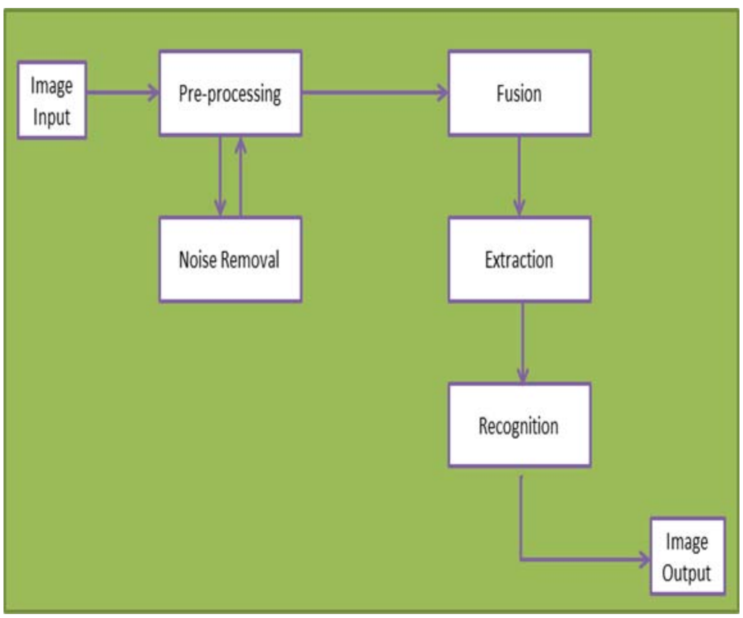

Fig 6: Proposed image processing steps

3.4.2 Face segmentation, feature extraction and normalization. Here, face images are normalized or enhanced to improve the recognition performance of the system. If we avoid pre-processing, there is a chance of getting a low performance by the system, thus the need to apply histogram equalization, automatic rescaling and manual face cropping. After this has been done, the chosen features are extracted and appropriately ranked.

3.4.3 The Proposed Face Recognition System. This work extends the existing systems by combining the PCA with a feature based technique thus giving us the advantage of the two techniques and a more efficient system which is robust to light variation and also robust to scale and rotation.

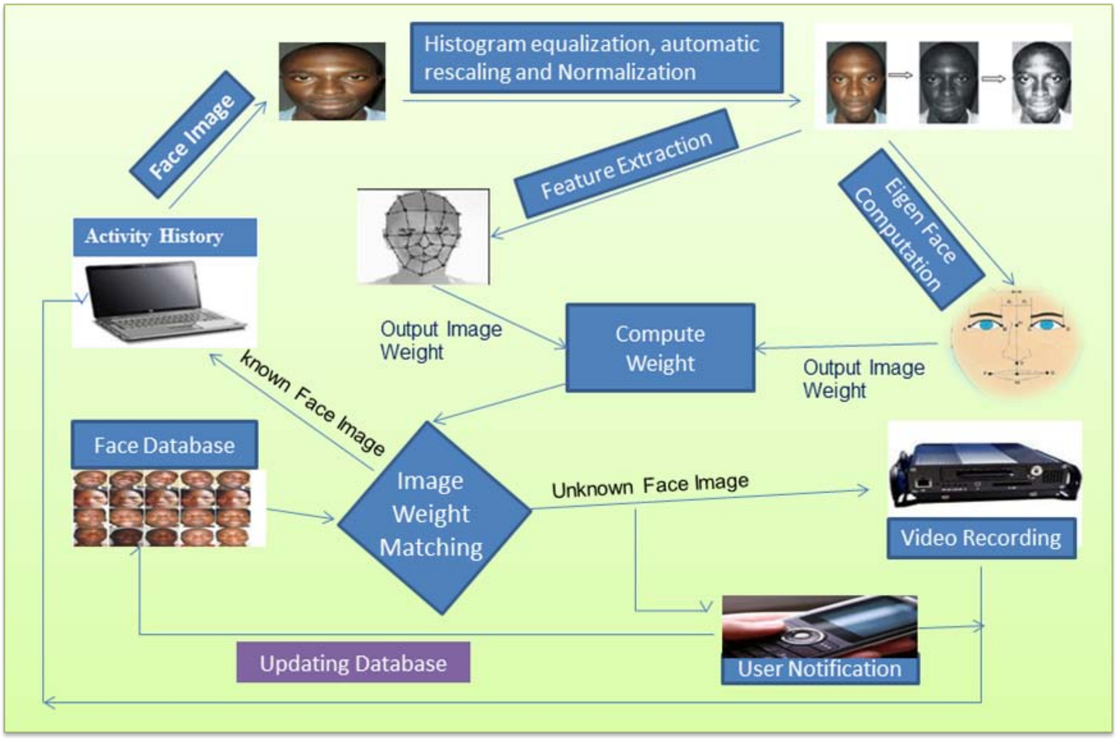

Fig 7: The face recognition system

The proposed system though primarily based on the PCA technique, is enhanced by being combined with a feature based technique. This is aimed at attaining the advantage of the two techniques and thus a more efficient system. The system passes through different stages after acquisition and before recognition, the first being the extractions of some facial features which are very important.

Some featuresare selected and used as distinct fingerprints for each individual image in the database. The weight for each fingerprint and total the aggregate weight for each image in the database is computed, and the score is labelled for each image. After extraction of the needed features, the PCA is applied to the same image set in the database, this gives some weight descriptors for each image after the eigenface has been computed and thus giving the possibility of adding the total score for each image from their fingerprints to the new score computed based on their weight from the eigenface.

Any probe image being recognized is also analsyed according to the above steps, such that the important features are also extracted and scored and the eigenface computed. The two weight scores are added i.e. from the eigenface computation and the features extracted and then compare the score with the aggregate scores in the database, if it matches the score of any image in the database, it is recognized as known.

3.5 Proposed User Notification System

The final step of the intelligent video surveillance systems is to alert the user of exempted objects. It will be achieved by an image processing module which converts raw image to its JPEG format for the MMS image. The software then sends an MMS to the concerned person.

Once the face image of the exempted object is identified, the user notification modules calls the method *getSnapshot()* and returns an array of bytes, which is the image data in the format you requested. The default image format is JPEG (Joint Picture Emission Group). The proposed model of the notification system is shown in fig 8.

3.5.1 Creating a Message Connection. To create a client Message Connection, simply call a method passing a URL that specifies a valid WMA messaging protocol.

3.5.2 Creating and Sending a Multimedia Message. The connection is a client, the destination address will already be set by the implementation (the address is taken from the URL that was passed when the client connection was created). Before sending the MMS message, the method populates the outgoing message by calling.
It is imperative that an MMS functionality enabled SIM card is integrated in the system and the destination MMS ID supplied by the administrator must work correctly.

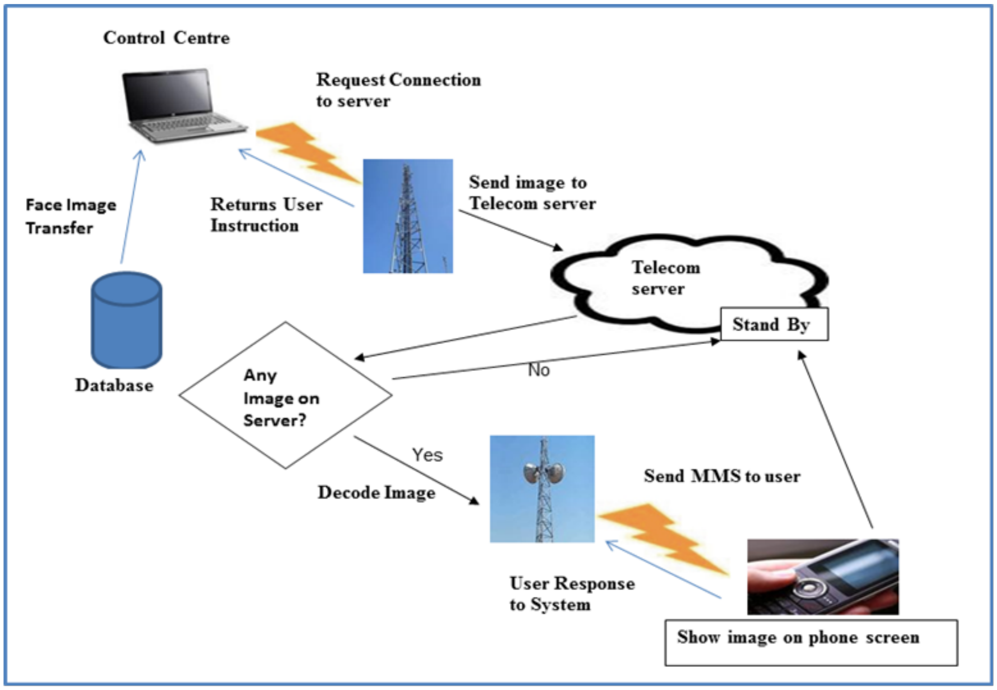

Fig. 8: Proposed user notification system

The users decides whether the threat is worth investigating or not. The system then logs that alert to the system.

3.6 Video Recording and Activity History

Video surveillance systems require recording facilities which helps the user to feel more secured. He/She would also feel more secure if the user can be guaranteed that the surveillance system will not only help in stopping the crime been committed but also provide evidence against the perpetrators.

The system commences recording as soon as an exempted object is detected with the aid of an integrated video recorder. The user still has the privilege of terminating the recording if the object is not considered as a threat to security. Fig 9 below illustrates the integrated video recording module.

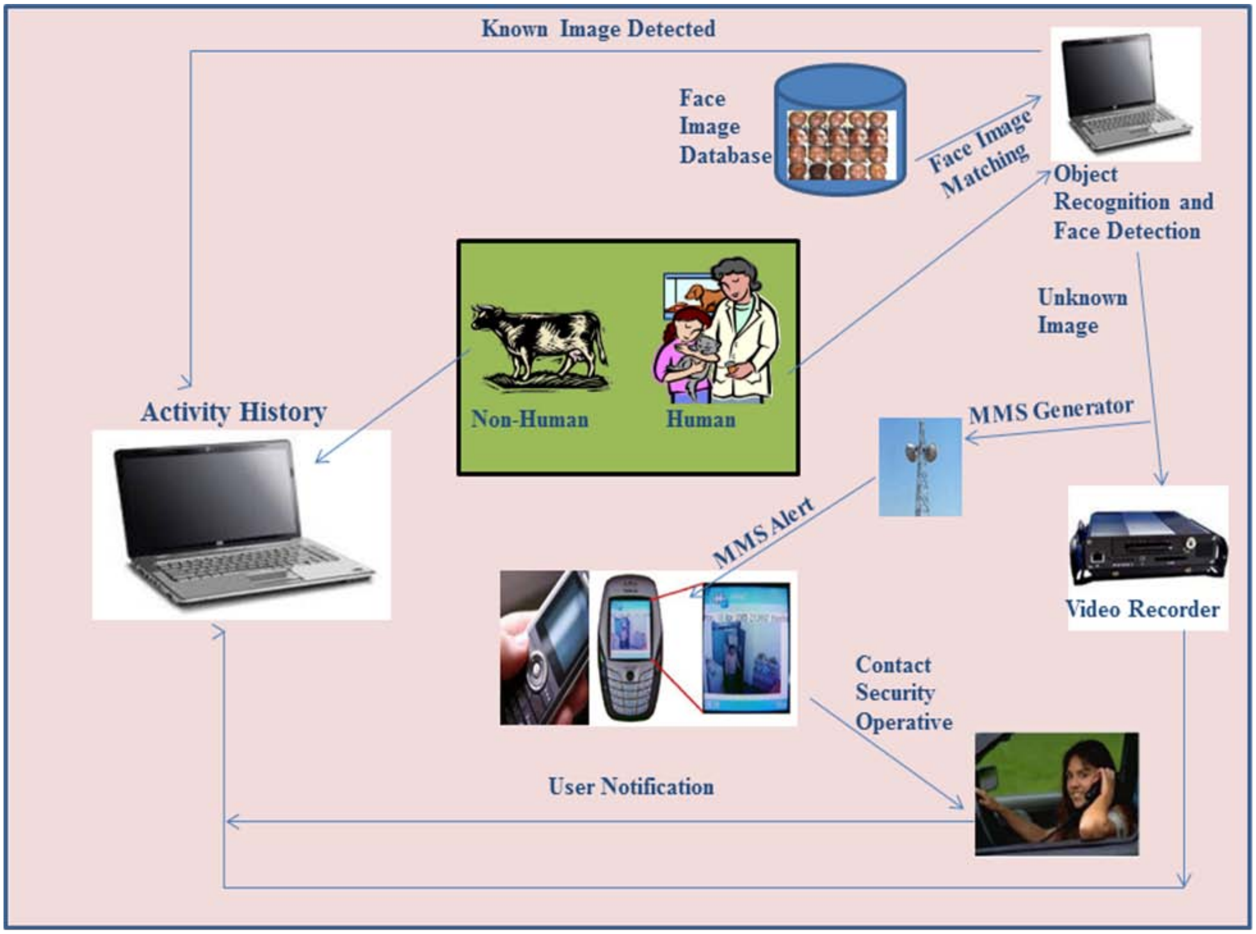

Fig 9: Video recording and activity history

4. RESULTS AND EVALUATION

This section presents the test environment and the experimental results of our algorithms. It also presents the various experiments conducted to verify the claims on the proposed system. The model comparison is also highlighted.

4.1 Results for Object Detection Algorithm

The computational performance of the three different object detection algorithms approach - adaptive background subtraction, temporal differencing and adaptive background mixture models was tested. The runtime analysis of the algorithms is shown in Table II while the time performance analysis, which is the per-frame processing time of these algorithms for an image size of is shown in Table III

The time performance analysis was carried out by first executing each of the algorithms using a limited number of video frames. For example; this was achieved by applying the conditional statement below for the temporal differencing algorithm.

```
While (vid.FramesAcquired<=50) % Stop after 50 frames
   data = getdata(vid,2);
   diff_im = imabsdiff(data(:,:,:,1),data(:,:,:,2));
   imshow(diff_im);
end
```

Our method enabled us to measure the time taken to process a specified number of frames.

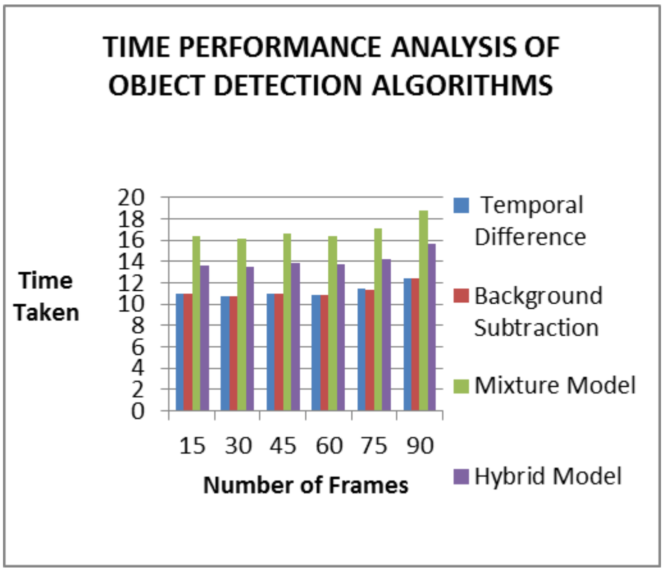

Fig 10: Time performance analysis of object detection algorithms

The Fig 10 above shows the compaison of the time performance for the various algorithms modelled in our work. The average time to process a frame is given below in Table I.

Table I: Time Performance Analysis of Object Detection Algorithm

OBJECT DETECTION ALGORITHM	AVERAGE TIME TO PROCESS A FRAME
Temporal Difference	11.25033333
Background Subtraction	11.19818333
Mixture Model	16.87103333
Hybrid Model	14.06873333

The result shows that our hybrid model gives a better time performance than the Gaussian mixture model. It was observed that our hybrid model proves to be better algorithm than each of the other models – temporal difference and background subtraction model since it combined both of their advantages.

4.2 Resultw of Performance Evaluation of Object Classification Algorithm

In order to test the object classification algorithm we first created a sample object template database by using an application to extract and label object silhouettes. We used four sample video clips that contain humans and non-humans such as vehicle, animals etc. The number of objects of different types extracted from each movie clip is shown in Table V. The sample object database was used to classify object in several movie clips containing human and non human. The resultant performance of our object classification algorithm is shown in Table V.

Table II: Number of Objects in sample object template database

VIDEO CLIP	HUMAN	NON HUMAN
Movie Clip 1	0	0
Movie Clip 1	1	1
Movie Clip 1	3	2
Movie Clip 1	4	3
TOTAL	**8**	**6**

Table III: Result of Object Classification Algorithm

VIDEO CLIP	HUMAN	NON HUMAN	CORRECT (%)
Movie Clip 1	**0**	**0**	**100**
Movie Clip 1	**1**	**1**	**100**
Movie Clip 1	**2**	**2**	**80**
Movie Clip 1	**4**	**3**	**100**

4.3 Result of Face Recognition Algorithm

This section shows the experimental results that were obtained from the conducted experiments on the proposed face recognition system. In testing the viability and efficiency of our approach, a sample set of face images (Colface database) were obtained under different variations of lighting, scale and orientation of ten subjects with seven images each per subject. Based on the different experiments conducted, some of the images are used as training images while others used as testing / probe images. Also, the ORL face database was used.

A normal experiment was conducted on all the subjects using five images each as training images and the remaining image as the testing image (for Colface face database) while for ORL, seven images is used as training and three used as probes. This experiment tests the algorithm on the two face database used with and without the application of histogram equalization. The result obtained is shown in the tables below.

Table IV: Face Recognition Algorithm without Histogram Equalization

Face Database	Total No of Images	Total No of Subject	No of Training Images per subject	No of Probe images per subject	Recognition accuracy
Colface	70	10	5	2	76.2%
ORL	400	40	7	3	81.9%

Table V: Face Recognition Algorithm with Histogram Equalization

Face Database	Total No of Images	Total No of Subject	No of Training Images per subject	No of Probe images per subject	Recognition accuracy
Colface	70	10	5	2	79.2%
ORL	400	40	7	3	86.9%

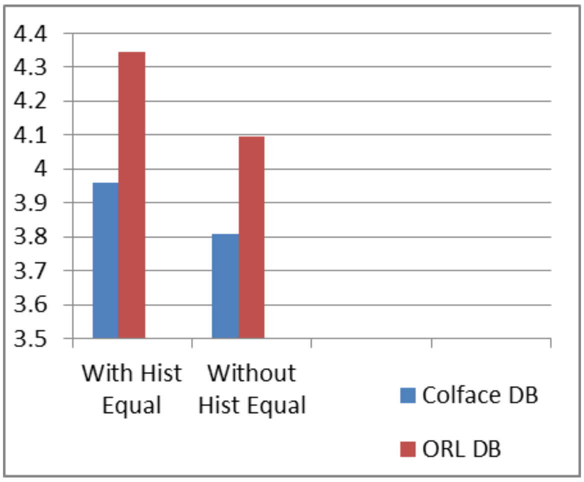

Fig.11: A chart showing the recognition rate for the two face databases

The results from proposed adaptive background subtraction and the temporal differencing models clearly present the fact that the recognition accuracy of the algorithm did not really deteriorate when working with compressed images. However, a slight difference can be noted from the recognition rate achieved when both the probe images and the training images are uncompressed compared with the recognition rate achieved in the experiments just conducted. This is however little compared to what one would have expected because of some information lost during compression. It is also acceptable bearing in mind the percentage of data discarded during compression. A critical look also shows that the algorithm performance was worst when both the probe and the training images were compressed but this is also acceptable.

Based on these results, it can favourably be concluded that compression, though affects performance, the effect is not that significant, in fact the effect cannot be compared to the effect that issues like pose (in varying degrees), background noise and illumination have on face recognition accuracies.

5. CONCLUSION

In this work, we implemented three different object detection techniques and compared their time-performance with the developed Hybrid model. The Fuzzy analysis helped to measure the degree of each technique's capabilities. Our Hybrid model's temporal differencing gives better runtime result for dynamic scene changes and detecting motion while the adaptive background subtraction scheme gives the most promising results in terms of detection quality and computational complexity to be used in a real-time surveillance system.

The feature based approach makes use of the individual properties of the organs that are found on a face such as eyes, mouth and nose as well as their relationships with each other. Principal component analysis on the hand is based on information theory concepts. The most relevant information that is contained in a face image is extracted. Eigenfaces method is a principal component analysis approach, where the eigenvectors of the covariance matrix of a small set of characteristic pictures are sought. These eigenvectors are called eigenfaces due to their resemblance of face images. Recognition is performed by assigning weight vectors to face images, according to their contributions to the face space spanned by the eigenfaces and then combining those weights with the weights computed from the extracted weights. Ultimately, our approach excels in its speed, simplicity and learning capability as applicable to real time surveillance systems.

Communication of the system with the user was based on the latest technology of sending MMS and remote controlling using Internet network cloud. The proposed system will work under existing telecom infrastructures and ISPs without any modification, so that no new popular application on a mobile phone is created.

The system developed does not carry out event and activity analysis which will likely be the future step of our research. Finding moving direction is not the target objective of this project and object tracking from one consecutive frame to the other can be a direction for future extension.

False alarm detection is not done and left for future work. A further step of research is to implement a tracking algorithm that can monitor transient objects from one frame of the video stream to another.

Future research may also extend the face recognition algorithm by implementing an automatic background removal algorithm. This will help minimize the effects of face background and head orientation on the recognition performance i.e. background of face images should be removed and heads should be normalized in some certain degrees based on the orientation.

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