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Rotation and Scale Invariant Intrusion Detection for Security Systems

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Abstract: ***There are some areas where a very tight security is needed. These areas include Line of Control, Airports, etc. Also, in some areas, it is not possible to appoint human soldiers due to the worst environmental conditions and high risk of attack by enemies. In such cases, a complete independent system is necessary which will automatically detect the intruding objects and destroy them. Thus, such a system will ensure tight security without endangering the precious life of human soldiers. The system proposed here is a complete independent system in which camera, image processing software, supplementary hardware takes care of destroying intruding objects automatically. The system is kept simple from implementation point of view. Total 20 objects of different sizes and shape are tested. From experimental results it is found that system gives good performance for various shapes and sizes. Thus the system is scale invariant as well as rotation invariant. Overall recognition accuracy is 93%.***

Keywords: Feature extraction, MATLAB, object recognition, rotation invariant, scale invariant.

1. Introduction

The system is proposed for detecting, tracking and destroying intruding objects. System is provided with a camera which is mounted at suitable place from where a complete view of area under interest can be obtained. In order to have better results, it should me made sure that the camera does not move at all from its initial position. Otherwise it will affect the detection accuracy. Images obtained from camera are given to image processing software. This software processes the images to detect the features of the detected object. Features of database object are stored prior to that of detected moving object. Then, features of database object and detected object are compared to decide whether the detected object is intruding one. If so, x-y position of this object is sent to microcontroller which provides PWM pulses to servo motor.

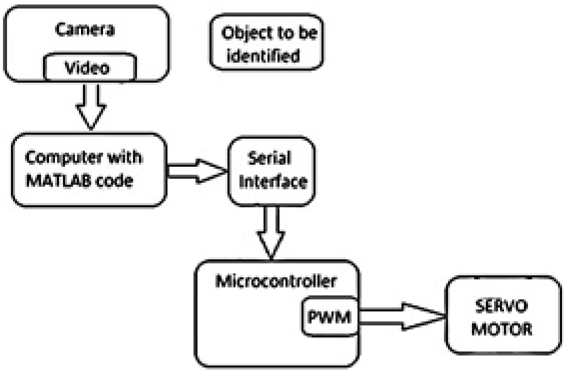


Figure 1: Block diagram of a complete system

Depending on the width of PWM pulses, angle of rotation of servo motor is controlled. On servo motor, cannon is placed which gets fired if intrusion is detected. The system tracks the object until it gets completely destroyed. Figure 1 shows block diagram of complete system

2. Related Work

This section of paper describes the work that has been done in the area of video surveillance systems, different approaches followed for better results in object recognition and tracking.

Researchers have attempted to develop a complete independent system for detecting an intrusion and tracking it until it gets destroyed using image processing algorithm, microcontroller, servo motors and other supplementary hardware [1], [2]. Shape and color of an object is extracted and compared with database object to decide whether it is intruding one. Canny edge detection algorithm has been used and PWM pulses are used to adjust rotation of servo motor. Satisfactory results are obtained in experimentation.

Qi Zang and Reinhard Kletteg [3] have reviewed previous research on moving object tracking techniques, analyzed some experimental results, and finally provided conclusions for improved performances of traffic surveillance systems. One stationary camera has been used. Many applications have been developed for monitoring public areas such as offices, shopping malls or traffic highways. Tracking of pedestrians and vehicles play the key role in video surveillance systems. Dimensions of bounding box are used to distinguish between pedestrians and vehicles.

Yigithan Dedeoglu [4] has presented a smart visual surveillance system which is capable of moving object detection in real-time, classification and tracking. The system has a stationary camera; system is capable of operating on color as well as gray scale video. An adaptive background subtraction scheme is used for moving object detection which is found to work reliably in indoor as well as outdoor environments. Temporal differencing and adaptive background mixture models are the two other object detection schemes, proposed for detection and performance quality comparison. The proposed system is able to perform functions like distinguishing transitory and stopped foreground removed objects; classifying detected objects into various groups such as vehicle, human and human group; tracking objects and generating trajectory information in multi-occlusion cases and detecting fire in video imagery. This system is assumed to work in real time. And for real time performance, the computational complexity and the constant factors of the algorithms used are important. Use of this system is restricted to stationary cameras and video inputs obtained from Pan/Tilt/Zoom cameras. The initial input to this system is fed from video imagery from a static camera which is monitoring a required site. Most of the methods are able to work on both color and monochrome video imagery.

Aristeidis Diplaros [5] discussed various methods for object detection, computational models and techniques are studied to merge color and shape invariant information to recognize objects in 3D space. Sanket Rege, Rajendra Memane, Mihir Phatak and Parag Agarwal [6] have presented an approach which involves digital image processing and geometric logic to recognize two dimensional shapes of objects, e.g. squares, circles, rectangles and triangles and the color of the object.

In object recognition, whenever feature extraction is performed, it should be taken into consideration that feature matching should be rotation and scale invariant. Swati Nigam, Kaushik Deb and Ashish Khare [14] proposed a new approach for shape based recognition which uses moment invariants for shape feature identification. Object and non-object data are classified using Support Vector Machine (SVM). Here moment invariants are used which are functions of central moments and are invariant against rotation, scaling and translation. This approach gave better result compared to other shape descriptor based recognition methods.

System can be made more efficient if it is made illumination invariant. A popular method used for appearance and illumination invariant human detection is Histogram of Oriented Gradients (HOG) detector [17]. To recognize the objects on different scales Scale invariant feature transform (SIFT) [18] based method is used. S. Nigam, M. Khare, R.K. Srivastava, and A. Khare proposed a hybrid of HOG and SIFT methods [19] for human object detection.

3. Methodology

Working of the system is explained below:

A. Camera

Camera used for experimentation is Zebion web camera with 1.3 Mega Pixel interpolated resolution, high quality 5G wide angle lens, 6 auto lighting LEDs for night vision, snapshot button for still image capture, compliance with USB 2.0, video resolution of 800 x 600 pixels and image resolution of 640x480, 800x600, 1280x1024 pixels. It is mounted at suitable place from where a complete view of area under interest can be obtained. It is very much necessary that camera should not move from its initial position. Otherwise it will adversely affect the detection accuracy since every frame of video is subtracted from background. Thus due to change in background results will also change. Video frames are given to the computer with MATLAB code. A Night-Vision Camera and camera with different resolution and colour depth can be used depending upon requirement of application.

B. Computer with MATLAB code

A computer with Intel 1.6 GHz processor and 512MB RAM was used as Image Processing hardware. Camera is connected to this PC via USB port. MATLAB 2012a is used as image processing software. Image frames captured by camera are given to this software. It processes these images for feature extraction. Image processing includes two main parts:

1) Pre-processing
2) Feature Extraction

Pre-processing:

The procedure of pre-processing is explained in following figure Fig. 2.

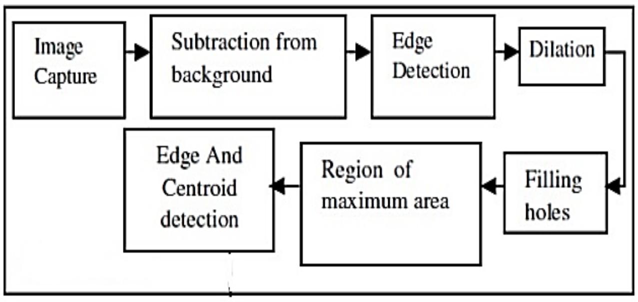


Figure 2: Pre-processing of captured image

When an object is observed from a far distance, its colour and shape distinguish it from other objects and background. Therefore it is necessary to first separate the object from background and other objects. To do this, background subtraction method is used.

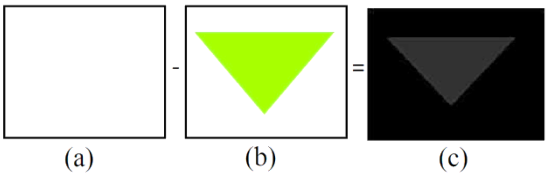


Figure 3: Result of subtraction

In Fig. 3, (a) is background image, (b) is test image and (c) is result of subtraction. It is clear from this figure that, we can separate the object from background using subtraction. Once the result of subtraction is available, edge of an object is detected using canny edge detection algorithm. Result of this step is shown in Fig. 4. From figure we can see that edges of the object are unclear and broken. To overcome this problem, image is dilated with some suitable mask. Result of dilation is shown in Fig. 5. Holes in binary images are black portion of image surrounded by white boundary. These holes are filled with filling operation to get number of different unconnected white areas. These white areas are related to different objects in image. Result of filling holes is shown in Fig. 6.

At this stage, we get a number of white regions. These unwanted regions are due to illumination variation, camera imperfections and minor changes in the background while capturing images. Since we are interested in only intruding object, we need to select only the corresponding region. The area of unwanted white regions is smaller than the white region corresponding to intruding object. Thus, if we select only the white region with maximum area, we get intended object. Edge of this image is detected using canny edge detection method. After this step, we get a clear edge of an object as shown in Fig. 7.

Feature Extraction:

The process of feature extraction is shown in Fig. 9. In this system, shape and colour of an object are extracted.

a) Shape:
In order to save shape descriptor of an object, we need to calculate distance of all points on its edge from some arbitrary point; this point is taken as centroid of an object. In this case, distances of points on the edge are taken at the angles with interval of 10 degrees from centroid. Fig. 8 shows centroid of an object. Thus 36 different distances are stored in shape descriptor of an object. To increase the accuracy, we can increase the number of distances by decreasing the interval of angle, but this will increase the computation time.

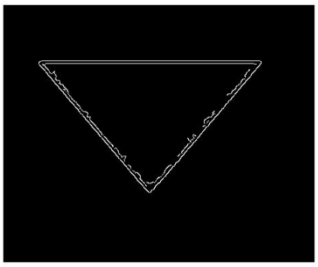


Figure 4: Edge detected by canny edge detection algorithm

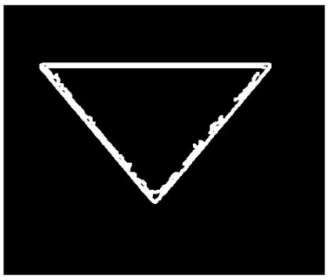


Figure 5: Result of dilation

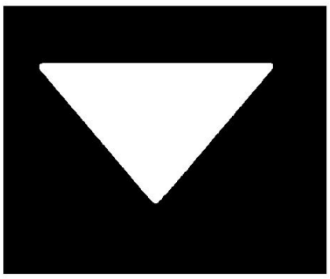


Figure 6: Result of filling holes

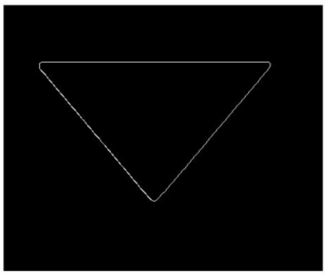


Figure 7: Clear edge of an object

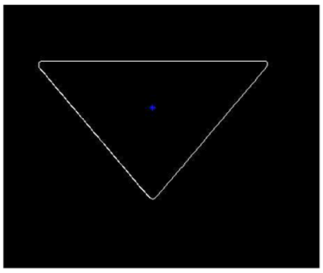


Figure 8: Centroid of an object

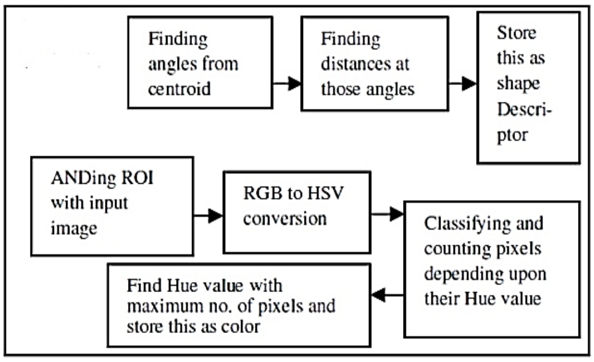


Figure 9: Feature Extraction

It is not necessary that the object will be at same distance from camera in every captured frame. The object size may very though its shape is same. The system should work properly for different sizes of an object. This is known as scale invariance. To make the system scale invariant, the distances stored in shape descriptor are normalized. Normalization means dividing each distance from the maximum distance available in the descriptor. This brings all readings of shape descriptor in the range of 0-1. 1 corresponds to the maximum distance. Thus, scale invariance is achieved. If an object is rotated, it should be correctly identified by the software. To do this circular shifting of readings is done. Thus, rotation invariance is achieved.

b) Colour:
If the object is having different colours on its different parts then the colour which is occupying maximum area of that object is considered, and it is said that object that object is of that colour. e.g. if an object is having green colour covering most of its parts, and blue and black colours covering only some of its portion. So colour of that object is considered to be green only.
To find colour of the object, colour image obtained from camera is logically ANDed with pre-processed image. Now this resulting image is converted into HSV image. Hue plane of HSV image contains only colour information. All the

values of Hue plan lies between 0 and 1. Depending upon their values, colour is detected. E.g. red, green and blue colours can be distinguished as in HSV plane as:

Red pixels have values >0.8 and <0.15, Green pixels have values >0.15 but <0.48, Blue pixels have values >0.48 but <0.8. Thus second gross feature of the objects that is its colour is detected. Feature extraction is also performed on database object. Comparison of features of detected image and database object is done. If results match, the detected object is considered as an intruding object which needs to be destroyed.

C. Serial Interface

x-y position of the intruding object is sent to microcontroller. Microcontroller is interfaced with computer using serial cable. MAX232 IC is used to convert RS232 standard level signal to TTL logic level.

D. Microcontroller

Microcontroller is used to send PWM pulses to servo motor. Angle of rotation of servo motor is changed according to the width of PWM pulses applied to it. Microcontroller used is 89V51RD2 which has 80C51 Central Processing Unit, Operating frequency from 0 MHz to 40 MHz, 64 kB of on-chip Flash user code memory.

E. Servo Motor

Servo motor decides the angle of projection of cannon. The results obtained after Image Processing are fed to microcontroller which in turn controls firing angle and time for projectile launch.

4. Experimental Results

20 different objects were taken as database object. Out of total 80 trials, system correctly recognized, tracked and destroyed intruding objects in more than 74 trials. This brings 93% accuracy.

For shape description, total 36 distances corresponding to 36 angles were calculated. If total 32 distance readings of intruding object and database object are matched then object is said to be recognized.

If number of readings used for shape description is increased, then it drastically improves accuracy. More readings are taken, more accurately shape of the object can be described.

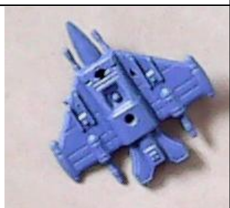
Thus by implementing this automatic system one can ensure complete intrusion free area under surveillance. This system has great application for military purpose. System eliminates need of human soldier to be appointed for this grave danger work, as this work is done by our system automatically.

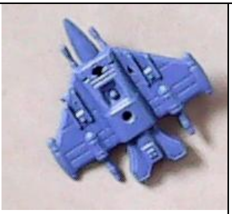
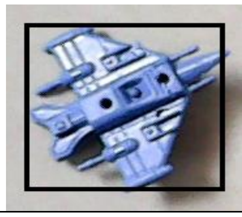
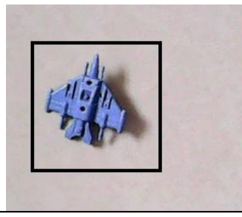
Algorithm is developed in such a way that whenever object is recognized, it is indicated by a rectangle around its centroid.
Experiments are carried out for different cases like:
a) Shape and colour is not matching
b) Shape is matching but colour is not Matching
c) Colour is matching but shape is not Matching
d) Both, shape and colour matching
e) By rotating object
f) Object with same shape but different size
Table 1 show that satisfactory results are obtained from experimentation. It is clear from the results that the system is scale as well as rotation invariant.

5. Conclusion

The system proposed in this paper is very useful for military applications where it is needed to detect and track the intruding object in the area under surveillance. A simple system is implemented which automatically detects and tracks the intruding object until it is destroyed completely. This system avoids need of appointing human soldiers in entry restricted area where a very tight security is needed. Thus, precious life of human soldiers is taken care of. The system is rotation as well as scale invariant.

Table 1: Result of Experimentation

Sr. No.	Background	Database Object	Test Object	Result	Comment
1					Shape matched, colour matched: **Object recognised**
2					Shape mismatched, colour matched: **Object not recognised**

3					Shape matched, colour matched, object rotated: **Object recognised**
4					Shape matched, colour matched, different size: **Object recognised**
5					Shape matched, colour mismatched: **Object not recognised**
6					Shape and colour mismatched: **Object not recognised**

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Author Profile

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