High Dense Crowd Pattern and Anomaly Detection Using Statistical Model

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ABSTRACT: *Human crowd behavior analysis is a subject of great interest in research now days. Great advantage of investigating dense human crowds in places like mosques and temples to perform automatic surveillance for any unusual activity detection that might be a subject of interest and must be addressed on earliest to avoid accident. We present robust statistical skeleton for modeling a dense crowded scene and then find anomaly in it. Our main intuition is to utilize the true dense motion of the scene to model main motion pattern by using temporal statistical behaviors. After removing the noise we genuinely find anomalies in the scene by using the model. We used Matlab for designing algorithm of motion pattern and anomaly detection. Our test reflect that temporal motion pattern modeling presents hopeful results in actual world scene with dense structured crowded motion.*

Key Words: Dense Optical flow, Motion Features, Statistical Model, Structured motion.

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1. Introduction

Hajj pilgrimage is one of the ”pillars of islam” an obligation for able muslims.Every year 2 million pilgrims are expected in Macca, Saudi Arabia, 70 percent of them from abroad. Pilgrims perform rituals for 5 days. One of the most critical ritual is stoning the pillars (Jamaraat) representing Satan that are stoned by pilgrims. Last year deadly incident happened despite massive precaution taken and billion of dollars spent on improving infrastructure. That was the worst tragedy to hit the Hajj in last 25 years.Some of the worst incident in Hajj include In 1990 1,426 pilgrim killed in tunnel stampede In 2006 more than 360 pilgrim killed in stampede at Mina those earlier incidents prompt to government to spent billion of dollars on improving safety and scurity for the two millon pilgrims who perform Hajj every year. Around hundred thousands security officer were deployed last year along with helicopters hundred of ambulances and arrays of surveillance cameras and still it seems fail to prevent disaster. Thus it becomes very important to move towards intelligent vision system that could analyze the live video contents of the areas under inspection and find regularity and anomaly. This system could be use for other places of dense crowd motion like Makka as 1 shows dense crowded motion.

Figure 1. Motion of superabundant number of people moving in regular directions make highly dense crowded scenes, as shown in the figure, it is very difficult to investigate in a computational system

One of the most important benefits of investigating human crowds in busy places is to perform automatic surveillance for any unusual activity detection that might be a subject of interest and must be addressed on earliest to avoid accident. This cannot be perfectly done using all manual observations of crowds through so many cameras and visual aids. The superabundant number of people and objects which format crowded scenes shows a totally unrelated number of challenges. Walker within the scene move in totally non-uniform motion patterns and non-rigid body of the walker make the scene complex. The superabundant number of people within the video makes investigation of each individual motion a challenging task plus a video is composed by number of frame and frame is composed by number of pixels and processing of each pixel is computationally expensive. A scene composes of two things a dynamic part and a stationary part and of-course the dynamic is our subject of interest. As such, an algorithm must be able to avoid extra computations and processed only dynamic part with parallel processing to achieve real time results.

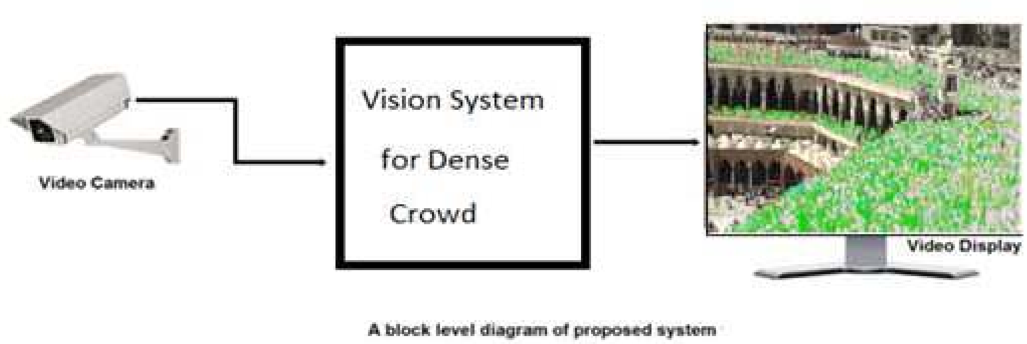


Figure 2. Crowd Motion Analysis System

The main stages of research in context of making A high dense Crowd Pattern and Anomaly Detection system are as under:

• Developing and evaluating an algorithm for high dense crowd pattern model using very high level language Matlab.

• Developing and evaluating an algorithm for Anomaly and regularity Detection by using the model in Matlab.

Since the overall vision system for Dense crowd pattern and anomaly detection is based on two parts, being algorithm design for Computer Vision in Matlab and conversion to C++, so there were two different kinds of challenges, which are:

• Designing an algorithm by using Matlab for Dense crowd motion pattern and anomaly detection that could deal with particularly verity of scenes, being independent of camera properties, pretty much invariant to illumination changes, contrast and noise.

• A scene composes of two things a dynamic part and a stationary part and of-course the dynamic is our subject of interest. As such, a algorithm must be able to avoid extra computations and processed only dynamic part.

• To achieve this robustness it requires consistency in motion detection and computation of motion vectors, being robust to image artifacts mostly observed in real world imagery, and mentioned earlier.

• The second important challenge deals with converting Matlab code to C++ with parallel processing to achieve real time results.

2. Previous Work

A particular algorithm for analysis of human crowd motion mostly consists of the several staged including Image data Acquisition, Extracting Motion features, finding statistical properties of the Motion over the time, and eventually find anomaly in Motion by using different Mathematical models. Every step whichis mentioned above can be executed in many different implemented in several different methods and procedures as shown 3.

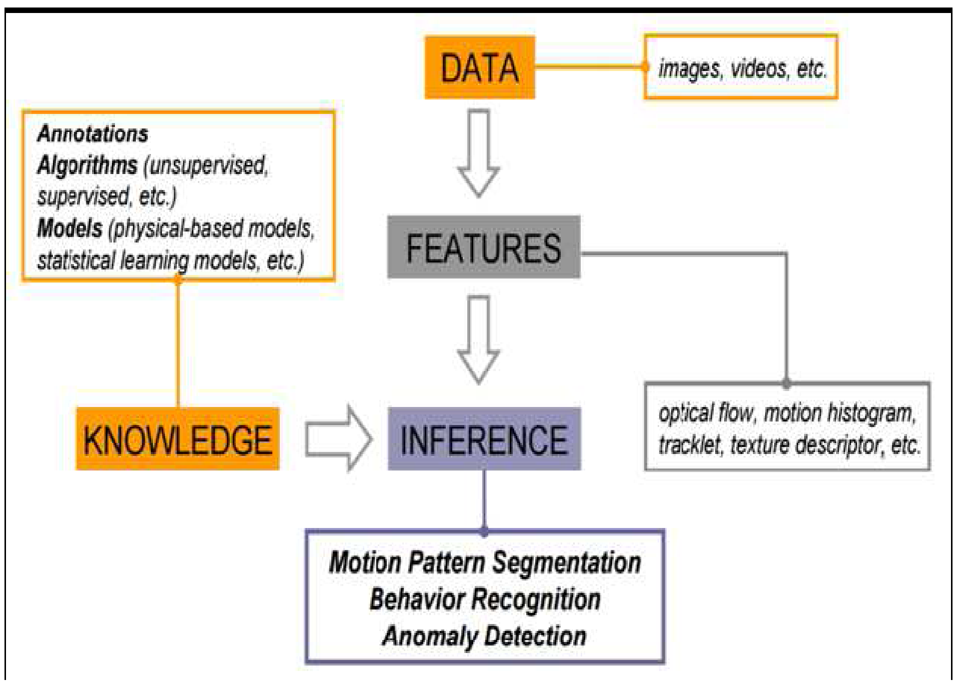


Figure 3. [1] Crowd Motion Analysis System

In order to better elaboration of this topic, we can divide it into two subtopics according to the purposes of task

1) Extracting motion feature
2) Regularity and anomaly detection

2.1 Crowd Motion Representation

Motion feature representation is a very important stage of crowd analysis because all next stages depend on it. According to literature there are mainly two types of motion representation of a crowded scene. Which are optical flow and background subtraction

1) Optical Flow: Optical flow method[2][3][4][5][6][7] widely used to estimate motion in a scene .it provides pixel level motion. Vehicle motion estimation was done by [8] which develops a optical flow of motion together with image processing technique to track vehicles. They also use filtering to remove noises. In order to avoid unwanted tracking of objects in roads they adopt a thresh holding in morphological operations. They utilize the blob analysis to track the object.

2) Background Modeling: There are many method for zero global motion use Background modeling Detecting [**?**]. Frequently statistical model used for Back ground subtraction. In this approach Intensity of a pixel is calculated as the massed sum of N Gaussian distributions. Temporal probability of intensity of a pixel depends on each Gaussian. Class of the pixel depend on contribution of Gaussian.

2.2 Regularity and anomaly detection

Social force model[9][10][11][12] is used to find behavior of crowd. One of the works in this area of crowd motion analysis was done by [9] which develops a social force model of crowd motion to detect and localize abnormal crowd behaviors. The social force model is developed based on how people interact with each other in a crowd. In order to avoid tracking of objects in dense crowds they adopt a particle advection technique and compute a force flow field. Based on this force field, they extract the interaction forces among the moving objects (people) in the scene. They utilize the change in interaction forces with respect to time as a classification parameter of crowd motion In [13] a modification to social force model based approach has been proposed by introducing an adjacency based, unfeasible, as the entire frame would be clustering technique. This technique performs clustering of human crowds in groups and then performs unusual activity detection based on how these crowd clusters interact with each other. They first compute the optical flow in the scene, and then perform unsupervised clustering methods to cluster human crowd into suitable clusters. Then they determine the statistical attributes of these crowd clusters by finding their direction of motion, speed, size etc. Finally they bring in a social force model to detect any anomaly by closely examining these attributes of crowd clusters In[14] a focus has been put in detecting blobs and tracking them considering human crowd. They first perform background subtraction to determine areas in the image where motion is happening, and then they are segmented and tagged, finally their tracking reveals if these blobs (i.e. human crowd groups) follow a normal pattern of motion, or some abnormal pattern. In [15] a feature tracking based method has been used for detecting moving objects in the scene. First interest points are detected in the scene using Harris corner detection approach. Then in subsequent images these corner points are tracked using KLT based tracking to detect motion vectors. After that some statistical properties of these motion vectors extracted, which analysis give a clue regarding underlying motion to be categorized as normal or abnormal motion.

In[16] existing optical flow method to compute flow vectors of the each frame then they combine them as a global motion called it flow field and reduced the flow field. They find closeness of flow vectors considering neighborhood graph and then cluster the flow field by using agglomerative clustering algorithm.

3. Local Spatio - Temporal Motion Patterns

The present design is managed to an algorithm for analyzing Human crowd in well dance places Mosques, Malls markets and other places like that. The overall Algorithm design was completed in two major phases.

1) Algorithm for formation of statistical Model of Human crowd pattern
2) Algorithm for Anomaly detection by using the Model

3.1 Crowd Motion Pattern Algorithm Design

As discussed earlier Crowd Motion pattern and Anomaly detection algorithm can be split into main two sections in broader term. In this part we will discuss Crowd Motion Pattern. We can further divide it into three major Parts which are given below.

1) Dense optical flow collection of 1000 values from 1000 frames against each pixel
2) Separate motion part from stationary part by thresh holding
3) Extracting statistical fetchers like mean μ and standard deviation σ of each pixel from the 1000 values

3.2 Computing Motion Vectors

Optical flow Idea was introduced by horn and Schunk. Image is two dimensional x and y while video is three dimensional x,y and t. By looking at two consecutive frames at time t and at time t+dt then the intensity at (x, y) and the intensity at $(x+dx, y+dy)$ will be very similar that is called brightness constancy assumption.

$$f(x, y, t) = (f_x + d_x, f_y + d_y, t + d_t); \quad (1)$$

By taking the Taylor series of right hand

$$f(x, y, t) = f(x, y, t) + (f_x d_x + f_y d_y + f_t d_t) \quad (2)$$

$$f_x d_x + f_y d_y + f_t d_t = 0 \quad (3)$$

by taking derivative of both side we come up the equation below

$$f_x.u + f_y.v + ft = 0 \quad (4)$$

This equation called optical flow equation where u is the velocity in x direction and v is the velocity in y direction. In order to compute the motion vectors across the image, We used dense optical flow because in dense crowded scene individual taking very less pixels, to make accurate model we need optical flow against each pixel.

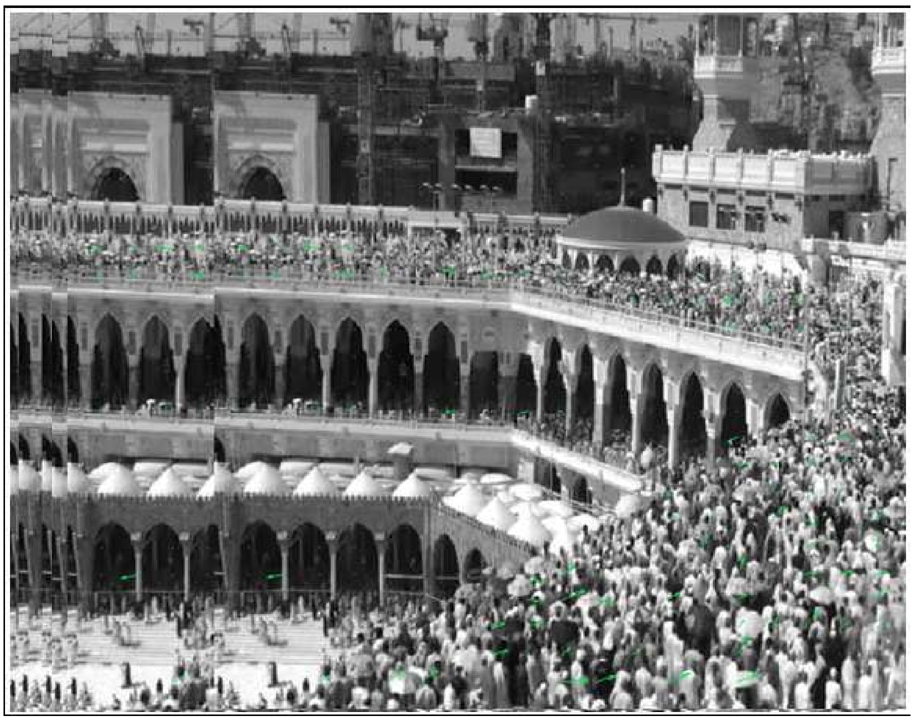


Figure 4. Motion vectors computed for each pixel by using dense optical flow

we computed dense optical flow of 1000 consecutive frames And stored the velocity information against each pixel In 4 we are representing optical flow in form of vectors against some pixels

3.3 Formation of statistical model

By using 4 we can extract motion feature against 1000 frams,its mean we have 1000 velocity values against each pixel $P_{xy}(U_n,V_n)$ where n varies 1 to 1000.

Where U_n is Horizontal velocity of nth frame of *xy* pixel

Where V_n is Vertical velocity of nth frame of *xy* pixel

These values we can use for modeling the motion pattern of a given scene. By finding the Normal distribution against each pixel we can model the behavior of each pixel.

$P_{xy}(U_n, V_n)$ Is the rectangular form of velocity

For more appropriate representation of velocity is its polar form

$$R_n = \sqrt[2]{U_n^2 + V_n^2} \tag{5}$$

$$\theta_n = \arctan \frac{V_n}{U_n} \tag{6}$$

$P_{xy}(U_n, V_n)$ Is the polar form of velocity

Where R_n is velocity magnitude of *nth* frame of *xy* pixel Where θ_n is velocity direction of *nth* frame of *xy* pixel

To Make statistical Model against each pixel we find the statistical values against each pixel data for this we find means $\mu_{xy}(R_n)$, $\mu_{xy}(\theta_n)$ and standar

deviations $\sigma_{xy}(R_n)$, $\sigma_{xy}(\theta_n)$

$$\mu_{xy}(R) = \frac{1}{1000} \sum_{n=1}^{1000} R_{xy}[n] \tag{7}$$

where $\mu_{xy}(R)$ is the mean velocity magnitude of *nth* frame of *xy* pixel

$$\mu_{xy}(\theta) = \frac{1}{1000} \sum_{n=1}^{1000} \theta_{xy}[n] \tag{8}$$

where $\mu_{xy}(\theta)$ is the mean velocity direction of nth frame of *xy* pixel

$$\sigma_{xy}(R) = \sqrt{\frac{1}{1000} \sum_{n=1}^{1000} (R_{xy}[n] - \mu_{xy}(R))^2} \tag{9}$$

where $\sigma_{xy}(R)$ is the standard deviation of velocity magnitude of *nth* frame of *xy* pixel

$$\sigma_{xy}(\theta) = \sqrt{\frac{1}{1000} \sum_{n=1}^{1000} (\theta_{xy}[n] - \mu_{xy}(\theta))^2} \tag{10}$$

where $\sigma_{xy}(\theta)$ is the standard deviation of velocity magnitude of *nth* frame of *xy* pixel

So we have statistical model $M(\mu_{xy}(R), \mu_{xy}(\theta), \sigma_{xy}(R), \sigma_{xy}(\theta))$ therefore we can modele the velocity against each pixel as shown in 5.

We separate background of the scene from the foreground to save the computations on the basis of thresh-holding as shown in 5. Where distance from the camera is long the motion perceived is negligible and from shorter distance motion perceived.

3.4 Regularity and Anomaly detection

This is very important part of designing phase of proposed system as we have find regularities and anomalies in the given scenes. This Phase of the algorithm we can further break into three parts broader term.

1) Calculation of dense optical flow of current frame.
2) Remove the noise .
3) Comparison the flow with the model we find anomaly

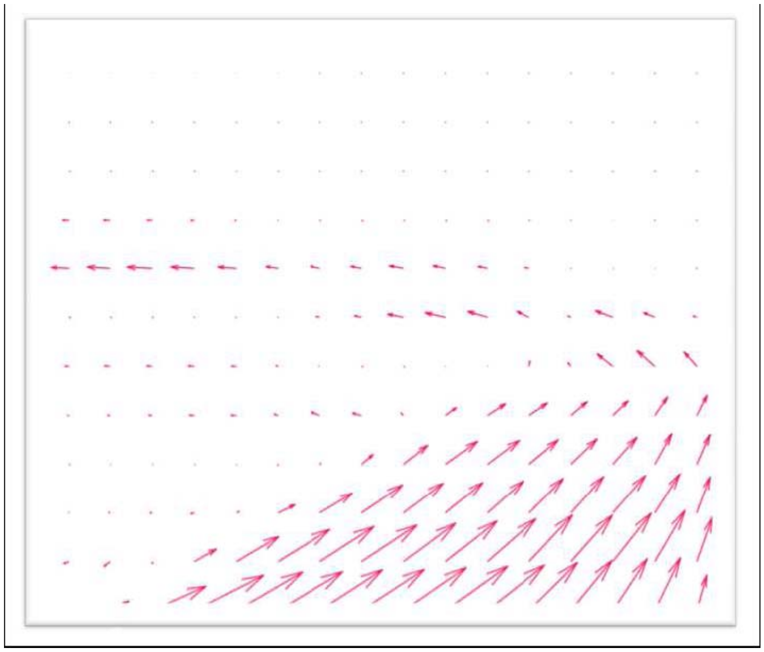


Figure 5. Flow representation of Statistical model

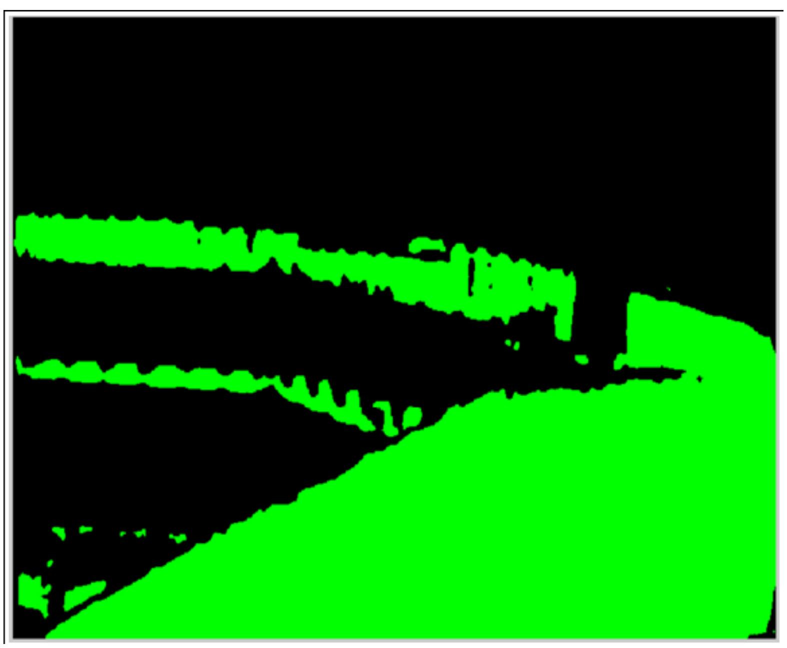


Figure 6. Green for foreground and Black for background

Block diagram of proposed system is given in 7

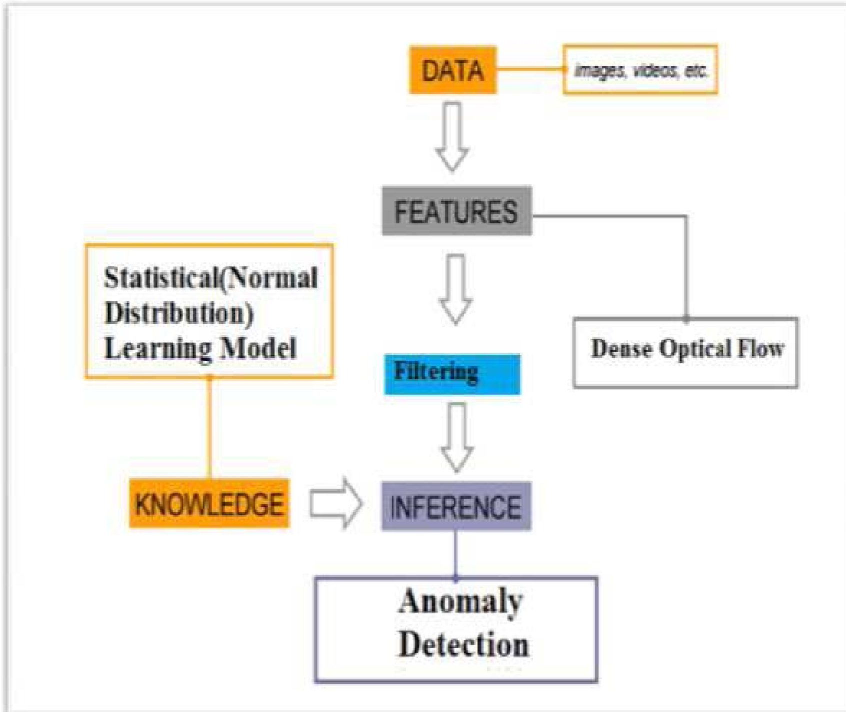


Figure 7. Main stages in Dense Crowd anomaly detection algorithm

1) Calculation of dense optical flow: By finding Dense optical flow of ith frame we get Instantaneous Velocity against each pixel $P_{xy}(U_i,V_i)$

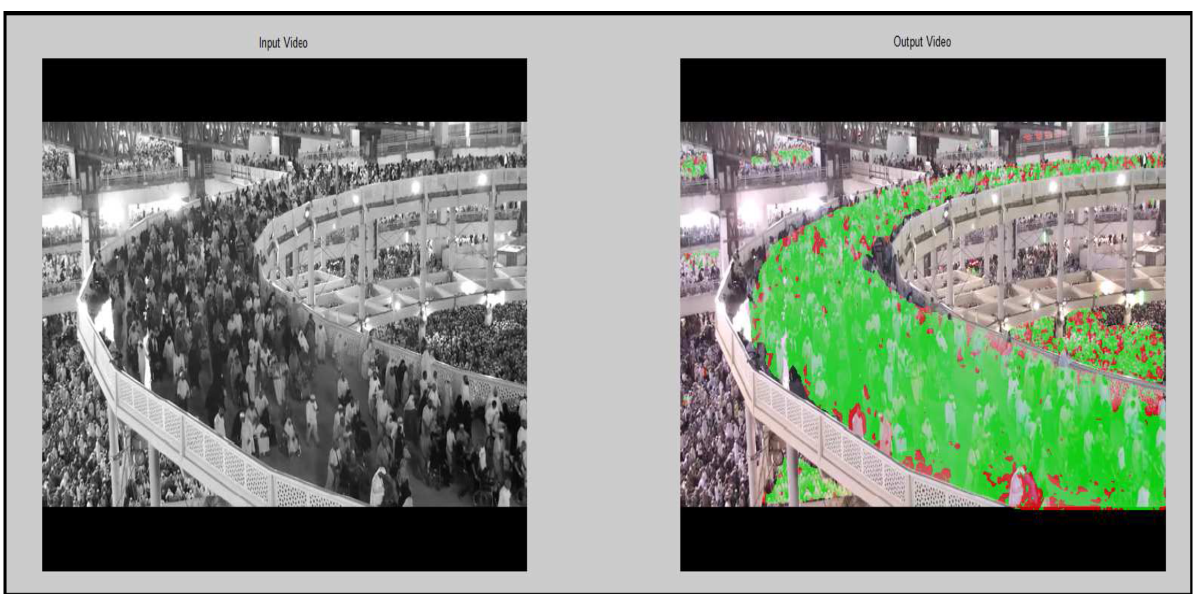


Figure 8. Anomaly detection with out filtering

Where U_i is Instantaneous Horizontal velocity of nth frame of *xy* pixel

Where V_i is Instantaneous Vertical velocity of nth frame of *xy* pixel

2) Filtering: As we know human body is non rigid while moving in particular direction its many parts may move in other direct due to this noise could be introduced as shown in 8 to remove this noise we apply Gaussian filter.

Let, $P_{xy}(U_i, V_i)$

$P_{xy}(U_i)$

$P_{xy}(V_i)$

Where $P_{xy}(U_i)$ is Horizontal velocity of *nth* frame of *xy* pixel

Where $P_{xy}(V_i)$ is Vertical velocity of *nth* frame of *xy* pixel and we have Gaussian filter *(G)*

By Convolution of $P_{xy}(U_i)$ and *(G)* and Convolution of $P_{xy}(V_i)$ and *(G)*

we get $Y_{xy}(U_i)$ and $Y_{xy}(V_i)$

Where $Y_{xy}(U_i)$ is filtered Horizontal velocity of nth frame of xy pixel

Where $Y_{xy}(V_i)$ is filtered Vertical velocity of nth frame of xy pixel

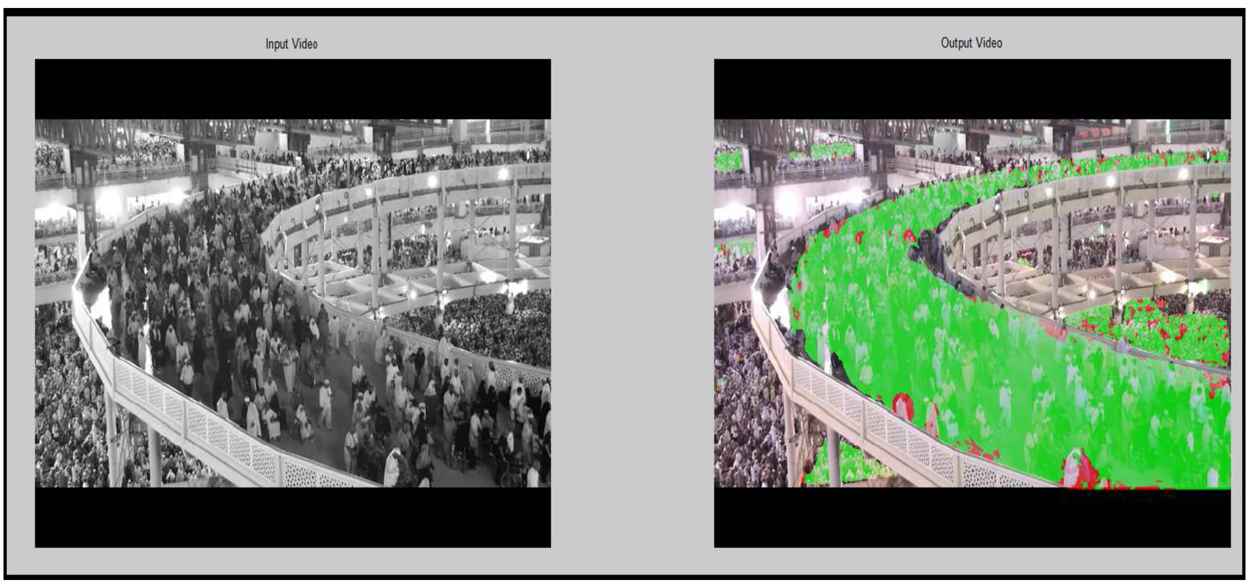


Figure 9. Anomaly detection with filtering

3) Anomaly Detection: $Y_{xy}(U_i, V_i)$

Where Ui is Instantaneous Horizontal velocity of xy pixel

Where Vi is Instantaneous Vertical velocity of xy pixel

$Y_{xy}(U_n, V_n)$ Is the rectangular form of velocity

For more appropriate representation of velocity is its polar form as we did in Model formation

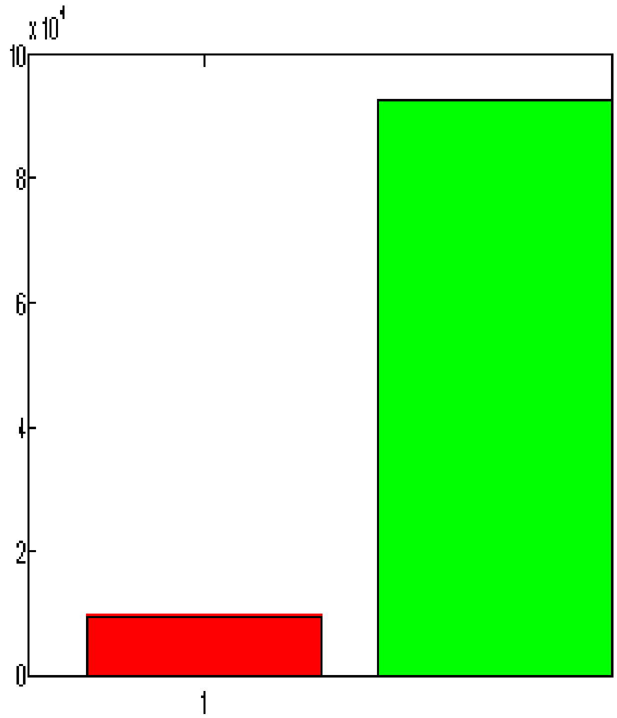
$Y_{xy}(R_i, \theta_i)$ Is the polar form of velocity Where R_i is velocity magnitude of xy pixel

Where *i* is velocity direction of *xy* pixel

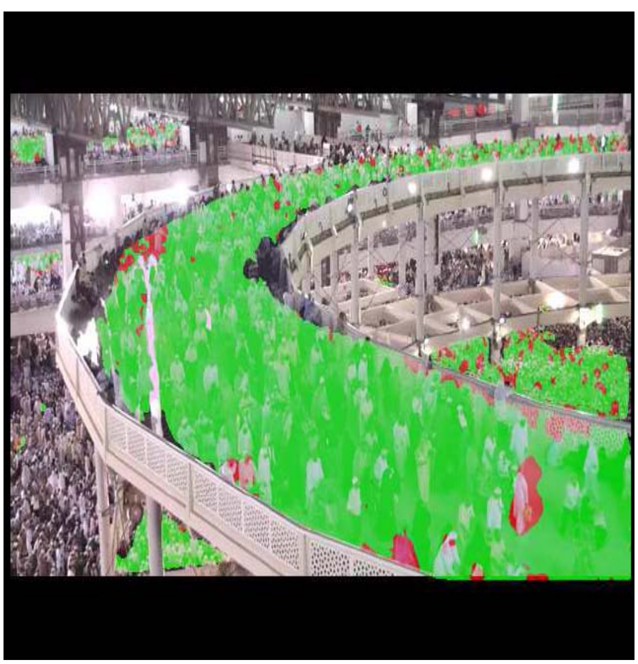
For anomaly detection We have Model $M(\mu_{xy}(R), \mu_{xy}(\theta), \sigma_{xy}(R), \sigma_{xy}(\theta))$ We can Find anomaly abs $(\mu_{xy}(\theta) - \theta_i) > \sigma_{xy}(\theta)$ and abs $(\mu_{xy}(\theta) - \theta_i) \leq \sigma_{xy}(\theta)$

abs$(\mu_{xy}(R) - R_i) > \sigma_{xy}(R)$

Input Video



Output Video



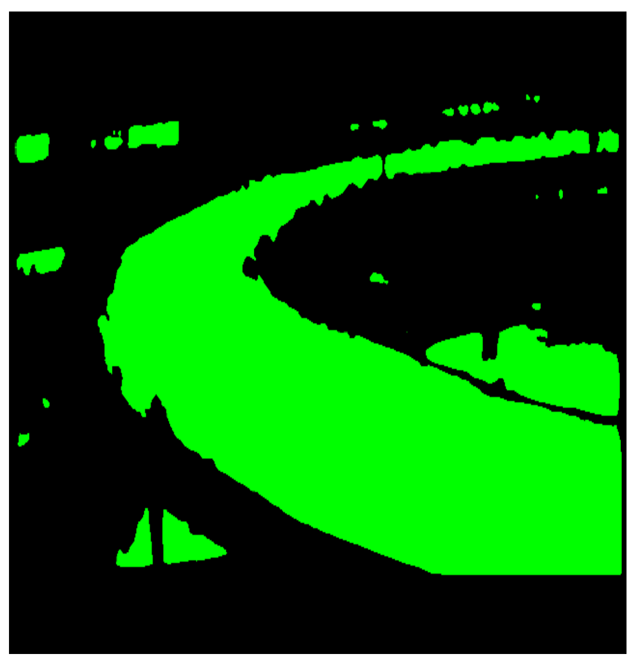


Figure 10. Motion Pattern and anomaly detection of Haram 1

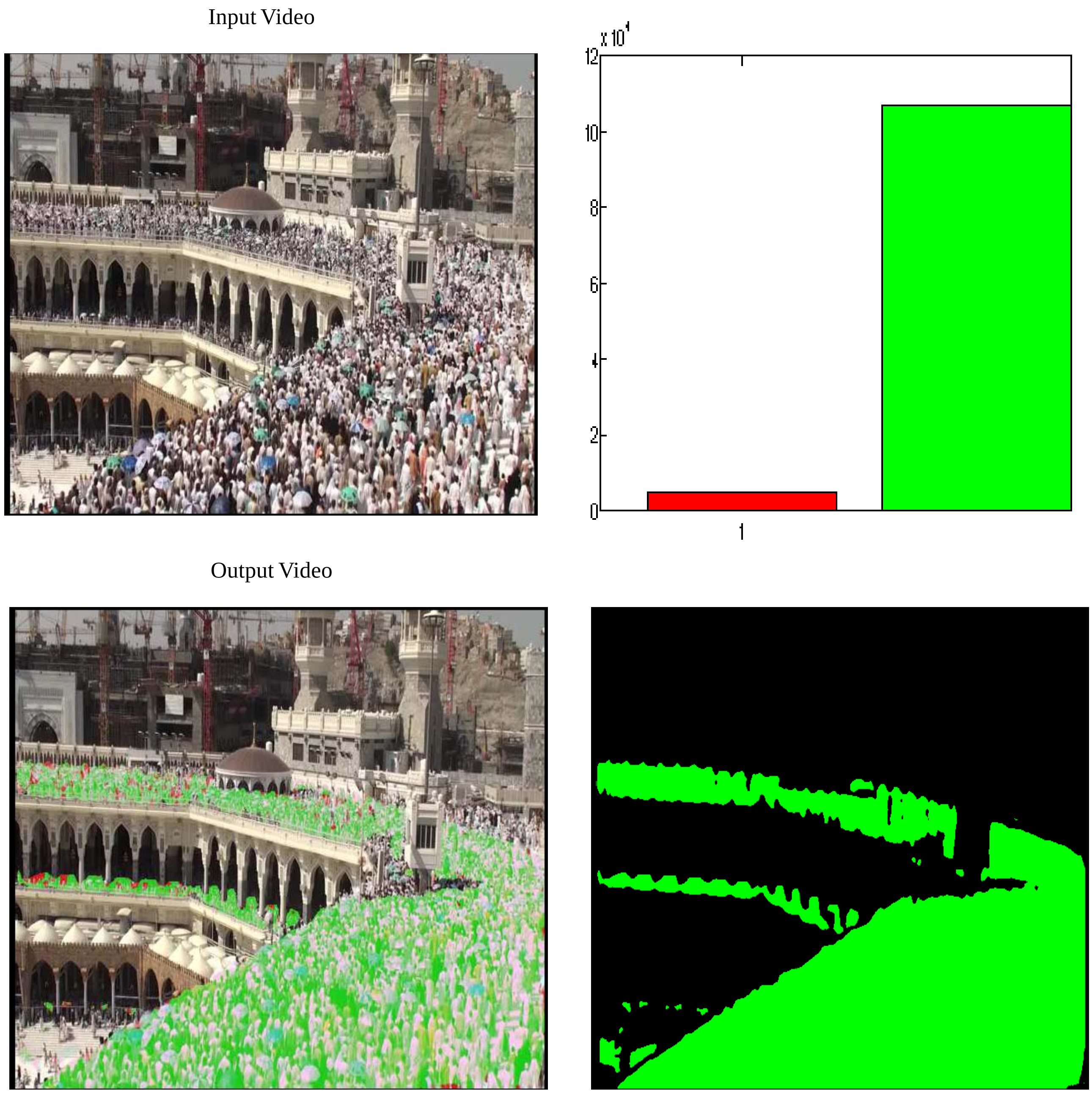


Figure 11. Motion Pattern and anomaly detection of Haram 2

4. Conclusion And Future Work

We have proposed robust and very simple algorithm for dense crowd pattern and anomaly and regularity detection in it for any scene. The concerned topics have grow into powerful research areas in recent time because of their hopeful results for real life problems.it required lot of effort to investigate dense crowd behavior for regularity and anomaly detection.We can divide this problem into two phases.Find a right motion pattern for a scene and then find regularity and anomaly in the scene.

As Matlab is very high level language as compared to C++ as its mapping on CPU is pretty direct on the other hand matlab code takes many steps before mapping on CPU. There for it is very easy to write a code on matlab to test an idea but when it comes to implementation especially for real time applications and you have limited memory resources you required low level language like C++ by which you have more control on CPU and memory management.

In case of algorithm design for investigation of crowd behavior, we can enhance the system by using more complex statistical features of motion vectors and more advanced models like Neural Nets and SVN. This will give more accuracy of the system as compared to existing system.

In case of Real time implementation of the algorithm we can convert it into C++. We can also write kernel for GPU for more efficiency.

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