Monitoring, Surveillance and Control of the Crowds in the Holy Sites Using SCADA System

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ABSTRACT. In this paper the design of SCADA system for Monitoring, Surveillance and Control (MSC), is suggested .The selection of the appropriate sensor, as well as, the detailed algorithms for both automatic crowd estimation and pedestrians control are also presented. The dynamic model of the Jamarat Bridge is given and illustrated.

Key words: SCADA, FLC, Texture analysis, neural network, and Image processing.

1. Introduction

The management and control of crowds is a crucial problem for Human Life and Safety [1]. In order to carry out such task, there is an established practice of using extensive closed-circuit television system. However, the large number of video cameras often used by such systems requires a huge recording and storage capacity and a number of people to observe the television monitors. As routine monitoring is tedious, the observers are likely to lose concentration. The advantages and necessity of the automatic surveillance for routine crowd monitoring and controlling are, therefore, clear. In trying to automate the mentioned surveillance, many problems arise.

What is the appropriate sensor and data acquisition system, which can be used in real time monitoring and control? What is the appropriate S/W algorithm to estimate crowd density? , and; What is the dynamic model of the flow of large crowd of pedestrians?

The last question is necessary to dynamically simulate the large crowds of pedestrians, as well as, the suggested control algorithm, and in finally to simulate the overall system with all kinds the scenarios which contain all types of the possible disasters. By such simulation, the predicted disasters can be avoided.

What is the appropriate actuator to implement the control algorithm?

During this paper, the above mentioned problems are partially answered.

In section 2, the suggested SCADA system is illustrated with the philosophy of the system design. Section 3, discusses the different types of the possible sensors with the selection of the appropriate one. In section 4, survey of the different algorithms to estimate crowd density are given with the choice of the best one which is verified for crowd monitoring. Section 5 gives the dynamic model of the flow of large crowds of pedestrians .Section 6 gives Matlab simulation for crowded prayers. Section 7 illustrates the suggested H/W and S/W development systems, which are necessary to implement the SCADA system.

2. SCADA System Overview

The management and control of crowds in consecutive areas is a highly coupled system. In Jamarat bridge, for example, the number of people who enter the smallest Jamra is proportional to the number of people who enter the Jamarat bridge. And the number of people who enter the Jamarat bridge is proportional to the number of people who come from the different street and areas, which communicate the Jamarat bridge with Mena city. To manage and control the crowds, the total area, which consists of the Jamarat bridge and the entrance of the bridge, is divided to consecutive areas. Each area is to be controlled with a closed loop system to manage and control the crowds in such area. Fig (1) gives the SCADA system overview.

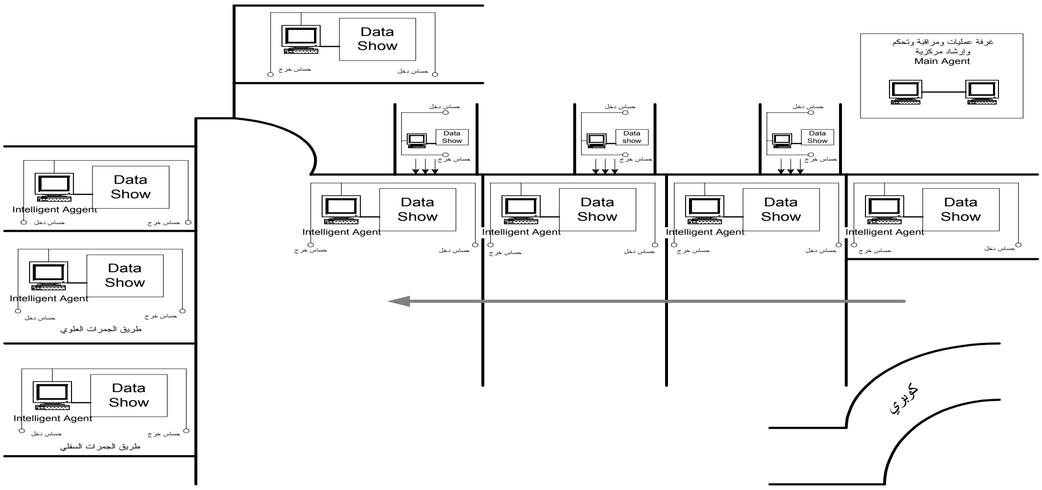

Fig (1): SCADA system overview

The appropriate sensor is illustrated in the next section. Fig (2) shows the proposed closed loop system.

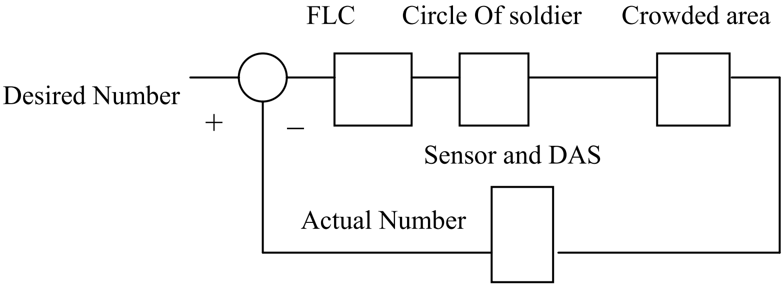

Fig (2): Proposed Closed Loop System

In figure (2), the proposed sensor and DAS gives the actual number of the pedestrians, with the allowed accuracy of any crowded area. A fuzzy logic control algorithm with the input of error and the change of error is designed to give a manipulated variable, MV, from zero to100%.

A zero MV corresponds to a zero diameter of the circle of the soldiers, while the 100% is corresponding to the maximum diameter of the circle of the soldiers, which is completely preventing the input flow to the controlled area.

3. Crowd Monitoring Sensor

In general, to detect the number of the people, there are many ideas of detectors [2]. Some types require contact with people, which obstruct the path. From these types, e.g., are turnstiles and mat-type foot switches. The above sensors are suitable only for counting a few people and are not adequate for crowd monitoring. On the other hand, there are non-contact and non-obstruct sensors. From these types, are CCD visual camera, the IR sensor and the ultrasonic sensors Ultrasonic sensors are widely used for industrial application to measure both object distance in the atmosphere and flow velocity. Ultrasonic waves are much slower than microwaves. The last two types are not also adequate for crowd monitoring. In [2], a mole-element IR sensor made of piezoelectric pbtio3 ceramics is developed. There is a trial in [3] to use much like the last sensor for crowd monitoring. To the authors's knowledge, there are some problems associated with the mentioned thermal imager, due to the high temperature environment in the holy sites (i.e. Mena and Makkah).

Recently, three read-time crowd density estimation systems in London [4], Geneva [5] and Hong Kong [6], were proposed based on their existing CCTV. Fig (3) illustrates such systems [7]. The video images are digitized at a resolution of 512x512 pixels and 256 grey levels. As shown a standard domestic camera (camcorder) is used to record scenes in a site of interest. The recordings are digitized and processed under the control of a standard workstation (pc or sun). Section 6 proposes a digital CCD camera with the associated H/W and S/W.

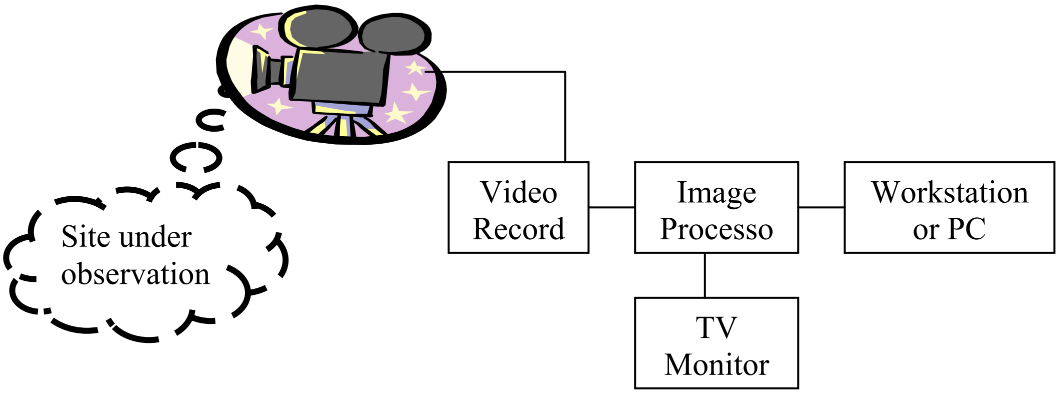

Fig (3): Recording Process of SCADA

4. Techniques for Crowd Density Estimation

In general, there are different techniques for object detection .The philosophy of these techniques is to isolate the object from the background on a single frame or sequence of frames [9]. Some of these techniques are investigated in the following subsections.

4.1 *Threshold.*

This is one of the simplest, but less effective techniques which operates on still images. It is based on the notion that having different intensities from their background. Adaptive threshold can be used for account for lighting changes, but cannot avoid the false detection of parts of the object with similar intensities as its environment.

4.2 *Edge-based detection (spatial differentiation)*

Approaches in this class are based on the edge-feature of the object. Morphological edge-detection schemes have been extensively applied, since they exhibit superior performance. Histogram analysis can be used to identify the object. Edge-based detection is often more efficient than background removed or threshold approaches, since the edge information remains significant even in variations of ambient lighting.

4.3 *Space signature.*

In this detection method, the object to be identified (pedestrians) is described by their characteristics (form, dimensions, luminosity) which allow identification in their environment. Space signatures can also be identified in an image through correlation or template matching technique. Due to the inflexible nature of template matching, a specific template must be created for each type of objects to be recognized.

5. Background Frame Differencing

This method is based on forming a precise background image and using it for separating moving object from their background. The background can change significantly with shadows cast by building and conditions. Adaptive background should be used to overcome the mentioned problems. However, all the above technique can only be used in counting few pedestrians and are not adequate for crowd estimation. The next technique is adequate for crowd estimation [1, 4, 5, 8].

The first technique for crowd density estimation is proposed by Davies [8] to estimate crowd densities extracts two measures from the input image of the area being analyzed. The first measure computes the number of foreground picture elements while the second one computes the number of edge picture elements present in the image. The foreground picture elements are obtained by subtracting the input image from a reference image containing no people. The edge picture elements are obtained by edge detection, followed by a thinning operation. Mat lab simulation is used to count the prayers, using the above algorithm. The result is illustrated in section 6. In addition to the two measurements, it was verified that there exists a linear relationship between the numbers of people and the number of picture elements measured in the input image. Therefore, it was possible to combine these two measurements into an optimal estimation of the crowd density through a linear Kalman filter. Despite the success of this technique for estimating crowd density in areas containing few people, it can not be applied successfully for areas with high density crowds. This is because the linear relationship between the real number of people in the area and the number of pictures and edges elements measured in the image does not hold when there are many overlapped people in the image. To overcome the above problem, atechnique for crowd density estimation based on texture analysis is used [5].

The basic idea of such technique is that, images of crowds with different densities tend to present different texture patterns. An image of high density crowded area is often made up of fine (high frequency) patterns, while an image of low density crowded area is mostly made up of coarse (low frequency) patterns, especially when the background is also of low frequency. The estimation of crowd densities is based on texture measures of the image and is given in terms of ranges such as very low, low, moderate, high, and very high densities. The number of people for each range depends on the particular characteristics of the area being monitored. Fig (4) shows how images have been used in the above technique to estimate the number of people in the area under surveillance.

The fist step of technique is to calculate measures of contrast, homogeneity, energy and entropy for four grey level dependence matrices, which are obtained by applying the GLDM method on the input image with $(d,\theta)=(1,0^0)$, $(1, 45^0)$, $(1, 90^0)$ and $(1, 135^0)$.

The grey level dependence matrix method proposal by Haralick [10] is based on the estimation of second order joint conditional probability density function $f(i,j/d,\theta)$. Each $f(i,j/d,\theta)$ is the probability of a pair of grey level (i, j) occurring in a pair of pixels of the image given that these pixels are separated by a distance d along direction θ. The estimated values from a two-dimensional histogram which can be written in matrix form, the so-called grey level dependence matrix (GLDM).

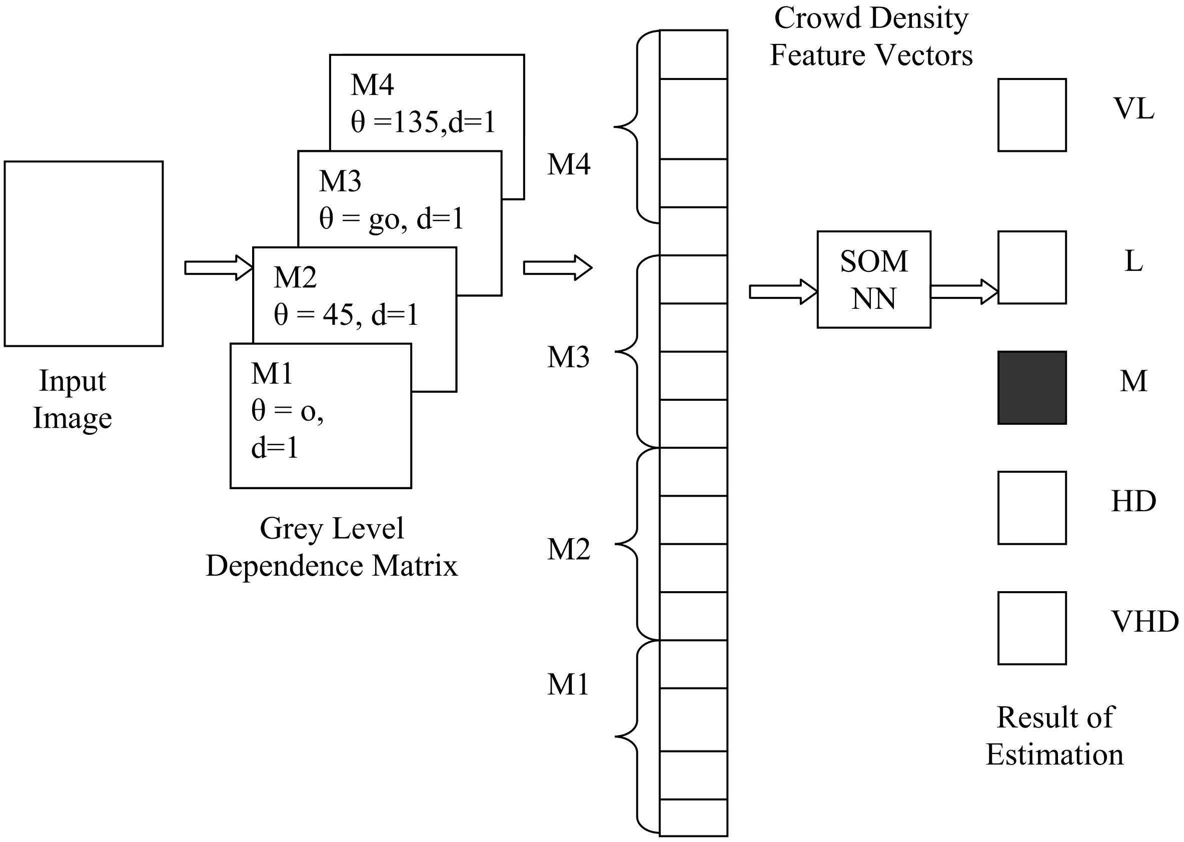

Fig (4): Crowd density feature vectors are extracted from the input image through the texture analysis GLDM

Because GLDM must be estimated for each pair of parameters (d, θ), it is usually computationally necessary to restrict these parameters to a limited number of values, i.e. $(0^0, 45^0, 90^0, 135^0)$ and d is only one pixel. For a given pair (d, θ), the histogram obtained for fine texture tends to be more uniformly dispersed than the histogram for course texture. Texture coarseness can be measured in terms relative spread in histogram occupancy cells about the main diagonal of histogram. Only for of the spread indicators proposed by Haralick for texture measurements have been used:

Contrast:
$$S_c(d, \theta) = \sum_{l=0}^{L-1} \sum_{j=0}^{l-1} (i-j)^2 \, f(i, j/d, \theta)^2 \qquad (4.1)$$

Homogeneity:
$$S_h(d, \theta) = \sum_{l=0}^{L-1} \sum_{j=0}^{l-1} \frac{f(i, j/d, \theta)}{1+(i-j)} \qquad (4.2)$$

Energy: $$S_g\,(d, \theta) = \sum_{l=0}^{L-1} \sum_{j=0}^{l-1} f(i, j/d, \theta)^2 \qquad (4.3)$$

Entropy: $$S_p\,(d, \theta) = \sum_{l=0}^{L-1} \sum_{j=0}^{l-1} f(i, j/d, \theta) \log f(i, j/d, \theta) \qquad (4.4)$$

Where L is the number of grey level of the image.

The 16 measurements obtained from $(d,\theta)=(1,0^0)$, $(1,45^0)$, $(1,90^0)$ and $(1,135^0)$, are put into a vector, which is used as the crowd density feature vector of the image. This feature vector is used by SOM neural network to estimate the range of crowd density. The range of density is estimated as one of the five possibilities as the process of estimation of crowd density is supervised., it requires a previous stage where the neural network is trained. There fore, it is necessary to collect the image from the area of monitoring to be used on the training set of images for the neural network. Such a set must include enough number of samples for each one of the pre defined ranges of crowd densities in order to be statically significant.

6. Model of Jamarat Bridge

In fact two references [11, 12] give an excellent model of flow of pilgrims over the Jamrat bridge. The purpose of this section is only to emphasis the existence of such model, as well as, the importance of using such model in simulation of the whole proposed SCADA system which will be given in feature work.

The model derived by R.L. Hughes is based on the assumption that the flow of pilgrims at very high density, is fluid analogy. The continuity equation is then used. The equation follows simply by equating the net flow of pedestrians into a small region to the time rate of accumulation of pedestrians in the region, and letting the area of the region shrink to zero.

The pedestrian flow is given in terms of two qualities. These qualities are;

(I) density, ρ, of the flow, which is expected number of individuals located within unit area of floor space at the given time, t, and location (x, y) e.g.

(II) velocity, (u, v) of the flow, which is expected velocity of individuals at a given time, t, and location (x, y), e.g. (0.1, 0.5)m/s

Thus, conservation of pedestrians implies the continuity equations

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}(fu) + \frac{\partial}{\partial y}(fv) = 0 \qquad (5.1)$$

Several hypothesis are assumed to give the following governing equation for pedestrian flow.

$$-\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}\left(\rho g(\rho) f^2(\rho) \frac{\partial q}{\partial x}\right) + \frac{\partial}{\partial y}\left(\rho g(\rho) f^2(\rho) \frac{\partial q}{\partial y}\right) = 0 \qquad (5.2)$$

and

$$g(\rho)f(\rho)=\frac{1}{\sqrt{\left(\frac{\partial q}{\partial x}\right)^2+\left(\frac{\partial q}{\partial y}\right)^2}} \tag{5.3}$$

where q is the Potential. Observations of pedestrian motion suggest that $f(\rho)$ and $g(\rho)$ can be approximated by

$$f(\rho)=\begin{cases} A & \rho \le \rho \text{ trans} \\ A\sqrt{\frac{\rho trans}{\ell}} & \rho \text{ trans} < \rho \le \rho \text{ crit} \\ A\sqrt{\frac{\rho trans\,\rho crit(\rho \max-\rho)}{\rho^2(\rho \max-\rho crit)}} & \rho crit < \ell \le \rho \max \end{cases} \tag{5.4}$$

And

$$g(\rho)=\begin{cases} 1 & \rho \le \rho \text{ crit} \\ \frac{\rho(\rho \max-\rho crit)}{\rho crit(\rho \max-\rho)} & \rho crit < \rho \le \rho \max \end{cases} \tag{5.5}$$

When $A=1.4\ \mathrm{ms}^{-1}$, ρ trans $=0.8\ \mathrm{m}^{-2}$

$\rho\,\text{crit} = 3\mathrm{m}^{-2}$ and $\rho \max = 5\mathrm{m}^{-2}$ Typically.

The flow of pedestrian per unit width, F, is related to the density of the flow by

$$F = \rho\ f(\rho) \tag{5.6}$$

The solution of the equation is compared with the result obtained by Selim and Al-Rabeh's model. The last model (i,e given by Selim and Al Rabeah) shows that the density can reach above 4/m2 at pillar location. This happens in normal cases. The advantages and necessity of a closed loop control system are, therefore clear. Dynamic Simulation with the proposed FLC will be given in another future work.

6. Simulation of Prayers Counting

The above mentioned algorithm is simulated using Matlab for the crowded prayers. The figure (Fig (5) illustrates the removing of the background.

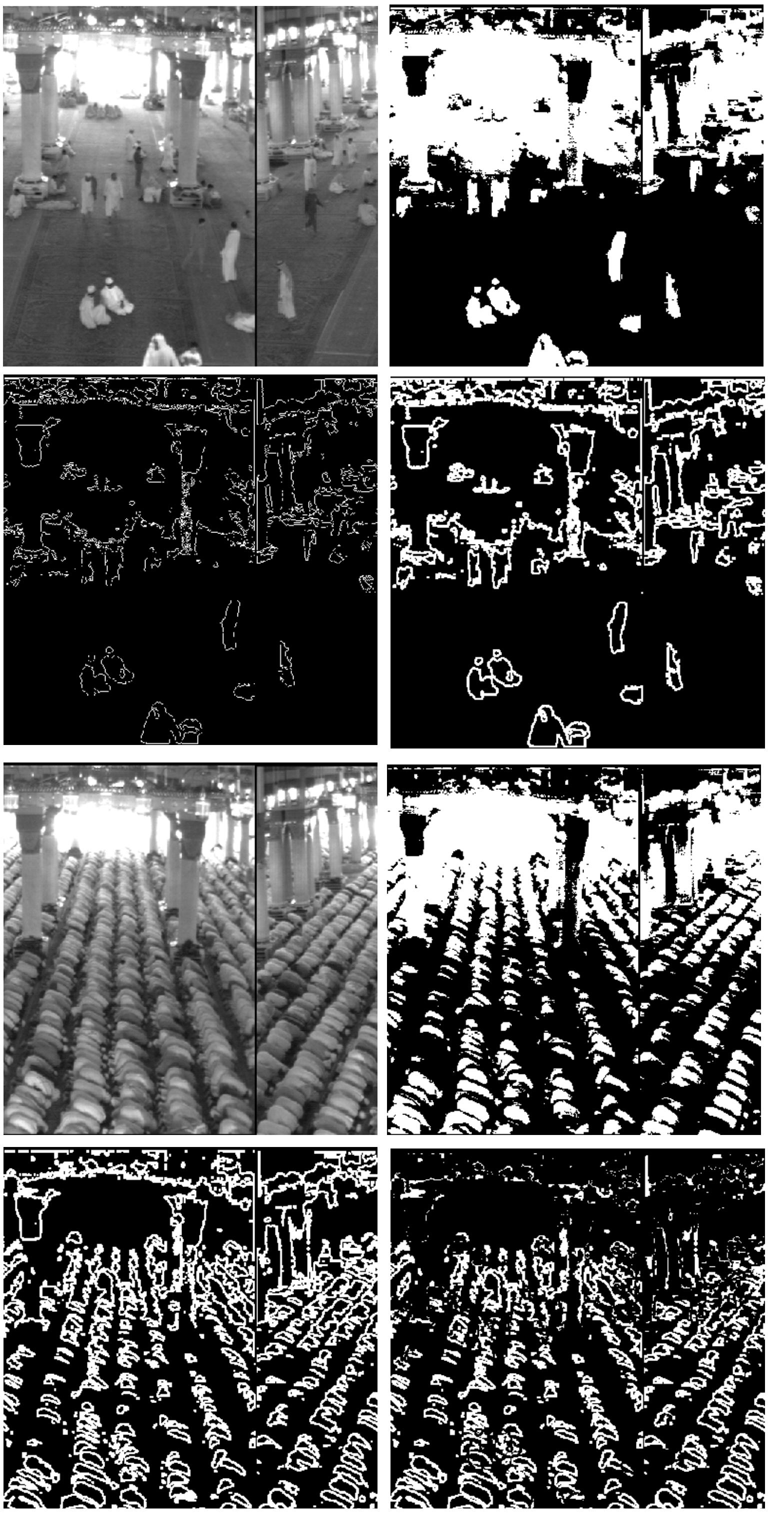

Fig (5): Model Simulation for prayers counting

7. Suggested Hardware and Software Development System

Fig (6) shows suggested machine vision system with Lab VIEW real time. A digital CCD camera is suggested with the appropriate digital camera image acquisition NI 1424 - via the video-out port on the PXI controller.

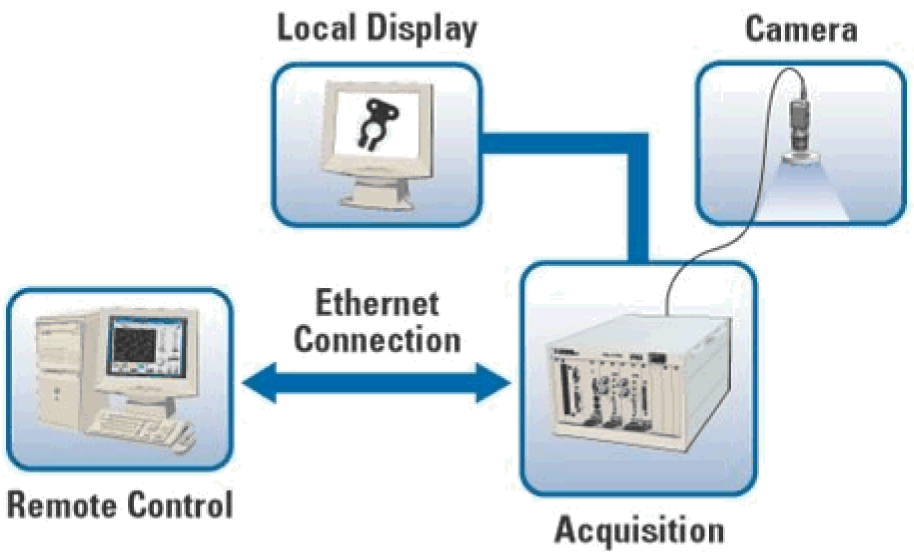

Fig (6): Real-Time Vision Development System

The implementation of the system based on the above suggested hardware and software depends on the progression of the project supported by "The Custodian of the Two Holy Mosques Institute for Hajj Research.".

8. Conclusions and Future Works

This paper suggested SCADA system for monitoring surveillance and control of the pedestrians in the holy sites. The survey of possible algorithms for automatic crowd estimation is given, as well as, the selection of the appropriate one. The model of "Jamrat" bridge is mentioned with the result of the necessity of closed loop control system. The implementation of the proposed system is the future work and will be given in part II.

Acknowledgements

The Authors are especially grateful to the Custodian of the Holy Mosques Institute for Hajj Research to give the chance for a project to automate the flow of crowds. The paper is a result of such project.

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نظام تحكم ومراقبة في الأماكن المشرفة

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المستخلص . يقدم هذا البحث نظامًا للتحكم والمراقبة عن بعد بالحاسب للأماكن المشرفة والمزدحمة (الحرمين الشريفين، ومنطقة الجمرات). ومن ثم تقدم هذه الورقة بعض التجهيزات المطلوبة : حساسات Sensors ، وخوارزميات حساب لعدد الأفراد في هذه الأماكن. وتقدم الورقة أيضا نموذجا رياضياً ديناميكياً لجسر الجمرات لعمل المحاكاة المطلوبة للمشاة بغرض تلافي المشاكل التي قد تنشأ عن الزحام.