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A COST EFFECTIVE APPROACH TO REAL TIME VIDEO-SURVEILLANCE OF OUTDOOR SCENES

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ABSTRACT: Real time interpretation of outdoor scenes for video-surveillance applications is a complex task. These kind of systems are supposed to work day and night, 365 days per year, under changing environmental conditions, variable weather and lighting conditions, with a minimum ratio of false alarms. Video-surveillance systems should be able to detect moving objects of different size moving at different speeds, and provide this information in real time to those persons who may need it at a reasonable price. This paper describes a system which provides a cost-effective solution to these kinds of problems based on the idea of processing sequences of images in real time.

Keywords: video motion detection, image processing, video-surveillance

1. INTRODUCTION

During the last years within the computer vision community, a great deal of attention have been paid to topics like motion detection and interpretation by processing image sequences. A good overview of existing methods and problems is given by Mitichie and Bouthemy[1]. Image Motion Detection for Surveillance Systems is strongly related to image temporal change detection. If there are moving objects in a scene this will imply changes in the image brightness distribution. Several methods have been proposed to detect moving objects in outdoor scenes. Although different approaches have been established and very important goals have been achieved [2], [3], it is not a exaggeration to affirm that there is still an important gap between scientific solutions and what market demands in the field of video-surveillance of outdoor scenes.

Let's define some of the most demanding capabilities that video-surveillance systems are asking for :

- It should work under changing environmental conditions
- It should be able cover wide areas
- It should be able to work in real time, (usually 40 ms. to process each frame)
- It should be cheap, cost should be approximately less than $900 per camera under control
- It should provide in real time an efficient and understandable help to the security guard
- It should be able to detect objects moving in different directions at a variable speed
- It should detect moving objects of variable size

- It should provide an acceptable ratio of false detection (usually less than 5%)
- It should be easy to integrate the system with other existing security systems.

Therefore, a video-surveillance system should be able to detect moving objects of different size moving at different speeds and provide this information in real time to those persons who may need it. This paper presents a cost-effective solution to these demands based on a specific image processing hardware and simple image motion detection algorithms.

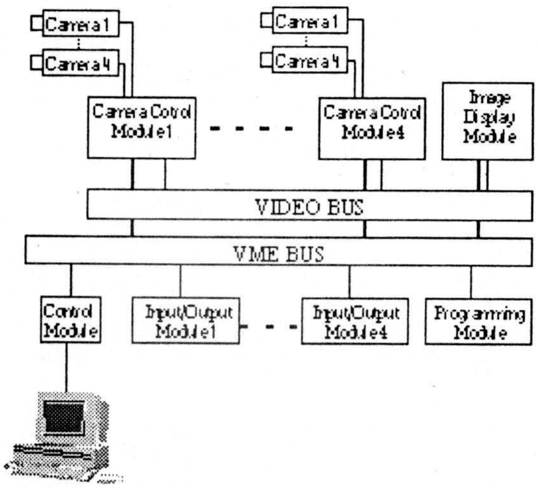

Figure 1 : Architecture of a Video-Motion Detector

2. PROPOSED ARCHITECTURE FOR A VIDEO-MOTION DETECTOR

This design is based on the industrial VME bus (see figure 1). The Camera Control Module performs video motion detection. Each of these modules is able to control four different cameras in real time (maximum processing time for the four frames of 160 milliseconds). Each of these modules controls 4 cameras and the basic system can hold four of them. This means that 16 cameras can be controlled in a maximum time of 160 milliseconds. Up to 100 systems can be connected together, making it possible to cover almost unlimited areas.

Any time that the camera control module detects motion in the sequence of images, it checks if the moving object is making an acceptable movement according to the programmed parameters. If a moving object is detected and it is making an unacceptable movement, the video motion detector stores all of the images related to this movement, the prior one, the one that triggers the process and the four following ones. This sequence of images can be displayed through the *Image Display Module*.

The *Control Module* board is a 68000 microprocessor based board that controls all of the different components of the video motion detector, VME bus and video bus.

Programming of the Video Motion Detector is done by the *Programming Module*. This is also a VME board that allows the user to define all of the parameter to be used during the motion detection phase. A PC connected to the system through the Control Module could also do this programming.

The proposed architecture is also provided with an *input/output* module that will be used to communicate the system with other installed security systems, making it possible to easily integrate the video motion detector with other existing security systems.

3. MOVING OBJECT DETECTION IN AN IMAGE SEQUENCE

The approach presented in this paper is based on the use of a reference image of the static background [4], [5]. A representation of that image is built in real time by hardware, dividing it into programmable 16 detection zones (DZ) where motion detection algorithm will be applied. Each detection zone has an associated array of values that defines its gray level distribution and these values are calculated in real time by hardware (see figure 2). Images are grabbed and processed with 64 gray levels and 512 x 512 pixels resolution. The shape of each detection zone can be also be programmed, irregular detection zones are also accepted (see figure3).

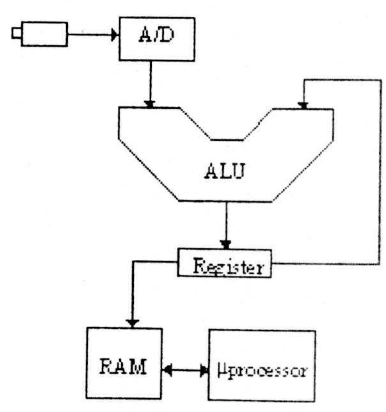

Figure 2 : Motion detection in real-time

The internal representation of the reference image is built as follows. Each detection zone is divided into *detection subzones* (DSZ). 240 detection subzones can be used distributed over the 16 main detection zones. This distribution depends on the size of the main detection zones, (usually 15 per detection zone). For the first subzone corresponding to each programmable detection zone, the sum of all of the gray levels is calculated by the ALU (see figure 2) and this value is stored in memory. For the second subzone, the sum of all of the gray levels is again calculated and stored in memory, but in this case the value calculated for the previous subzone is added. This process is repeated until the representation of each detection zone is stored in memory. Therefore, each detection zone has an associated internal representation consisting of a subvalue for each subzone and total value for the whole zone. This can be considered as an array of values that defined each detection zone :

$$
\begin{aligned}
A (DZ_n) = \{ & \Sigma SDZ_1 (x_i, y_j), \\
& \Sigma SDZ_1 (x_i, y_j) + \Sigma SDZ_2 (x_i, y_j), \\
& \ldots\ldots \\
& \Sigma SDZ_1 (x_i, y_j) + \ldots + \Sigma SDZ_{p-1} (x_i, y_j) \\
& + \Sigma SDZ_p (x_i, y_j) \}
\end{aligned}
$$

Where $\Sigma SDZ_p (x_i, y_j)$ is the sum of the values of all the gray levels of the pixels within the detection subzone and p is the number of subzones for the detction zone n. Therefore, each detection zone has an associated array of values calculated by hardware in real time that will be used during the detection phase.

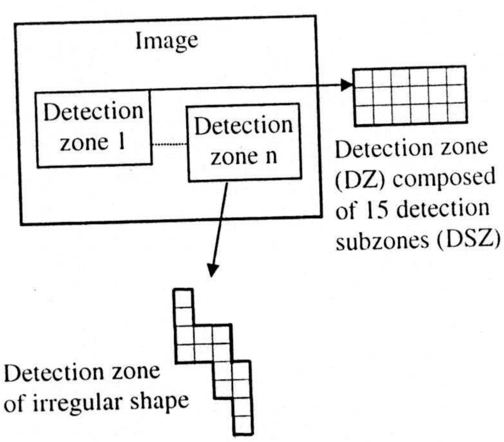

Figure 3 : Programmable detection zones

Each detection zone has also another three associated parameters : *Resolution, Sensibility and Detection Time*. **Sensibility** is the amount of change accepted in the array of values associated to each detection zone, between the reference image and the image being processed. **Resolution** is the percentage of the detection zone (number of detection subzones) where the sensibility parameter should be overpassed to consider that a moving object got into the zone. Resolution parameter should be programmed to detect those objects of the minimum desired size. **Detection time** is the lapsus of time when resolution and sensibility parameters should be overpassed to considered that a moving object got into this detection zone. This parameter should be programmed taking into account that it shouldn't be smaller than the time needed by the fastest object to cross the detection zone.

Different type of detection zones can also be defined. Once moving objects are detected within a detection zone and depending on its type several actions will be carried out. The most important types of detection zones are the following: immediate detection zone, prealarm, inhibition detection zone and related detection zones. Sometimes, information provided by one zone may not be enough. In this case, several detection zones can be associated into **detection groups**. For instance, these detection groups composed of several zones can be used to detect moving objects at a previously defined speed, or objects that follow a predetermined path in the image.

Therefore, an internal representation of the reference image is built consisting of several detection zones of regular or irregular shape, each of them has an associated data structure defined as follows :

Data Structure Per Detection Zone

- Array of gray level values per subzone
- Type of zone
- Resolution
- Sensibility
- Detection Time
- Belonging to group of zones # :

Once the video motion detector has been programmed, it starts processing in real time live images provided by all of the cameras and compare them with the internal representation of the reference image for each camera.

To avoid false alarms when lighting conditions change, the video motion detector uses 16 additional detection zones, whose position is also programmable. If motion is detected at the same time in all of these detection zones, this implies an overall change and not a movement. In this case, several actions can be taken. Most of the times it implies to adapt the reference image.

4. AN EXAMPLE OF MOVING OBJECT DETECTION

Once the internal representation of the reference image has been built, the system is ready to start motion detection process. All the different detection zones need to be programmed. For each zone the following parameter will be programmed : *type of zone, resolution, sensibility and detection time*. Sometimes it will be also necessary to define whether this zone belongs to a group of zones or not.

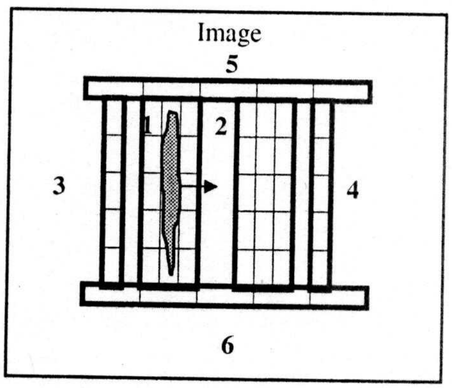

Figure 4 : Different detection zones

Let's suppose that the video motion detector should be programmed to detect moving objects of a predefined size moving at a given speed through detection zone number 2 (see figure 4). We define a group of zones composed by detection zones number 1 and 2. We assign to this group of zones an appropriate *group detection time* **t**, keeping in mind the time needed to go from detection zone number 1 to detection zone number 2 moving at a given speed. Those objects moving at slower speeds will need more than this time **t** to go from one zone to the other and will be ignored. We also define for these two zones the resolution parameter that enables us to detect moving objects of a previous defined size. As it is shown in the image, the object occupies 5 of the 15 detection subzones, therefore a resolution of 33 % could be a good one. We also define several other detection zones that can be useful to see if an object starts moving, gets into detection zone number 1 but never gets to detection zone number 2, or if an object goes to detection zone number 2 without previously going to number 1. In this way, we reduce to zero the number of possible false alarms for this motion detection task.

CONCLUSIONS

This paper presents a cost effective video motion detector for outdoor surveillance applications. This system has been proved in different installations where its performance has been qualified as very good. The image motion detection algorithm is simple and can be implemented with the use of cost effective hardware, making it possible to provide real time moving object detection.

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