Visual Surveillance System under Bad Weather Conditions

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Abstract— **This paper is focus on the development and implementation of algorithms under Bad Weather Conditions, including moving object detections, Automatic Brightness Correction, Shadow Removal, and Rain Removal. Moving object detection plays an important role in intelligent surveillance system. Although there are many people propose many different methods to detect moving objects, but also based on PC or embedded platforms to achieve it. If want to provide object detection, tracking and identification, always depend on a highly complex algorithms to make accurate judgments. So it would be difficult to achieve real time. This paper proposes an implementation base on FPGA and using Verilog HDL to design it. It achieves real-time monitoring purposes, and it can be applied to bad weather conditions. It is useful to exclude the external environment and improve detection of accuracy.**

***Keywords*— bad weather conditions; brightness correction; moving object detection; surveillance system; FPGA**

I. INTRODUCTION

There are many different algorithms to detect moving objects and tracking [1-16]. For different applications usually adopt different solutions. Divided into three cases: (1) fixed camera; (2) multiple cameras from different perspectives; (3) mobile camera. In this paper, we using D5M camera module which provide by Altera DE2-70 platform. It used to detect the status of the outdoor environment by a fixed camera angle.

The method of detecting moving objects usually used the ways like background subtraction algorithm [1-3], the temporal difference algorithm [4-6], optical flow algorithm [7] and so on. Background subtraction are mostly used in the case of a fixed camera. In the absence of any moving object appears, Establish a solid background as a background model. In Literature [2], it is proposed that establish progressive background. The less variation pixel will be regarded as background, and be record in tabular form. After a period of time, we will get the background, and then subtract the background for the image. Thus we can get the moving parts. And it can updates on demand background. Timing subtraction rules does not need to create a background model, because the background will change over time. This method is simple relatively, and it only need two memory space to record two frame. Subtract them we will get the block of moving objects. There will be no ghosting, but image usually broken even has empty phenomenon, and it may only get moving object edges or contours.

Moving object detection in a monitoring system is a very important step for detecting moving objects fast and accurately. Whether in object tracking, event detection, and behavioral analysis are highly dependent on its accuracy. In order to improve the accuracy of detection of moving objects, in this thesis, we propose a new algorithms to solve many problems faced by the research literature in the past, like brightness correction, Shadow Removal, and Rain Removal. However, the emphasis of "brightness correction, Shadow Removal algorithms, and Rain Removal algorithm" is to improve the fixed camera resistance to external interference. Therefore, this paper use the HSV color model to achieve inclement weather image compensation. It can obviously enhance the clarity of image when the monitoring system in rains. Thus, it will greatly reduce the probability of misjudgments due to poor control environment arising from the monitoring personnel.

II. SYSTEM ARCHITECTURE

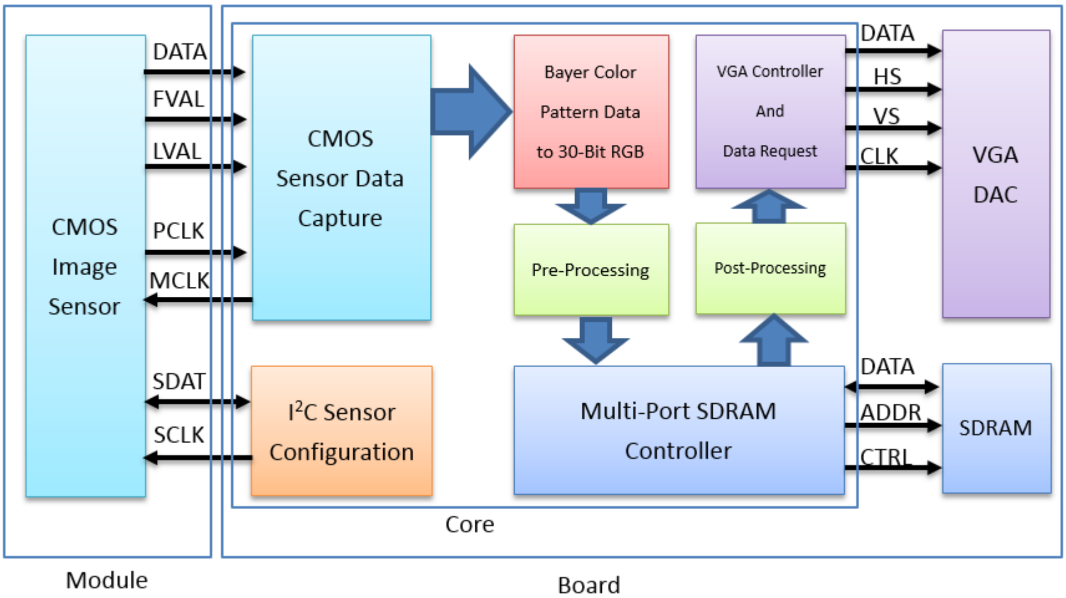

Figure 1. System architecture diagram

This section describes the system architecture, the system architecture shown in Figure 1. We use a 5 million pixel CMOS digital camera module (D5M) to capture the image data. Using the FPGA to do the preprocessing, convert the image from RGB color space into HSV color space. And then using the temporal difference algorithm, get the difference value from compare foreground and background images. By using the difference value, we can get the blocks of moving object and extract it.

When the system start, it will do the parameter setting on CMOS Image Sensor module by "I2C to Sensor Configuration" hardware, including containing images starting point, intermittent vertical and horizontal value (Horizontal / Vertical Blanking), resolution (Resolution), RGB gain values (RGB Gain) and the exposure time value (Exposure), etc. These parameters will vary with different for the CMOS output image.

After complete the setting of "CMOS Sensor Data Capture", hardware block will start to read the CMOS Image Sensor Image RAW Data. Then the RAW data will be converted to RGB values through the "Bayer Color Pattern Data to 30-Bit RGB" hardware blocks. After the image convert to RGB, Next action is the pre-processing algorithms, collocate with "Multi-Port SDRAM Controller" blocks, and send the generated data to the post-processing, and do the filtering and communication actions. Pre-and post-processing algorithms will be described in detail in the next section. Finally, "VGA Controller and Data Request" hardware blocks read out image data. And input it to an external VGA DAC chip ADV7123, this IC chip will convert digital images into a standard VGA analog signal sent to the DE2-70 external screen.

III. Image Processing Flow

Firstly, camera D5M captured image data. I2C initialize data, do color conversion. Those stages make the RAW data convert into 30bits RGB signals. Second, Preprocessing tie in with the frame buffer, and then processed the information to do post-processing algorithms, and finally threw VGA Controller and then do the final data control on the display to VGA Monitor.

Algorithm flow chart shown in Figure 2. RGB to HSV, color quantization, brightness correction, Rain Removal algorithm, Shadows Removal algorithm and Temporal Difference Algorithm are the part of the pre-processing. Post-processing include Binarization, Binary Filter, Dilation, Erosion and Connected Component Labeling.

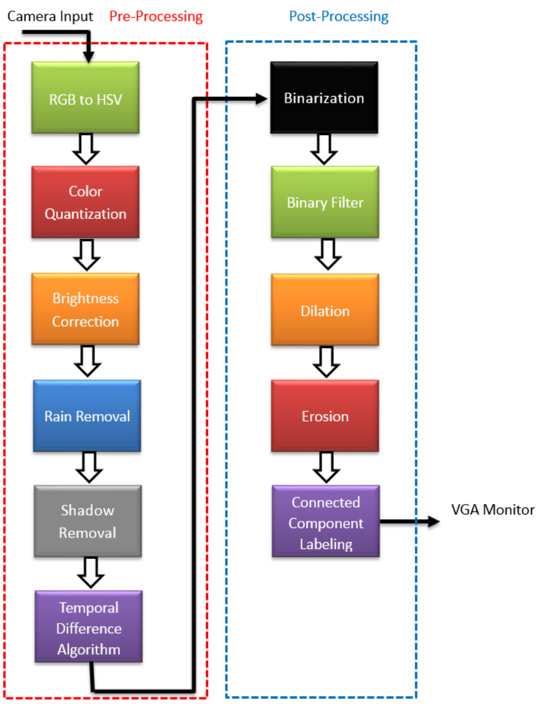

Figure 2. Image processing Flow diagram

A. *Converting RGB Images to HSV Images*

This thesis used DE2-70 platform, its video input model is YUV. Because of the color model used in this research was HSV. So we convert the video input to RGB color mode, and then turn the RGB color model to HSV. H is the hue, S is the saturation, and V is value in it.

In order to achieve rain algorithms, our found that rain texture on HSV color model has the best image features. Using HSV color model can enhance the effect of algorithms. This paper will use the two color modes, RGB and HSV. These two color modes can be independently operations. By this way, it will improve the overall image of the computing speed by reach pipelined processing. And achieve the Real time operation. The color mode conversion as shown in the following equation:

$$h = \begin{cases} 0^\circ & ,if\ max = \min \\ 60^\circ \times \dfrac{g-b}{max-min} + 0^\circ & ,if\ max = r\ and\ g \geq b \\ 60^\circ \times \dfrac{g-b}{max-min} + 360^\circ & ,if\ max = r\ and\ g < b \\ 60^\circ \times \dfrac{b-r}{max-min} + 120^\circ & ,if\ max = g \\ 60^\circ \times \dfrac{r-g}{max-min} + 240^\circ & ,if\ max = b \end{cases}$$

$$s = \begin{cases} 0 & ,if\ \ max = 0 \\ \dfrac{max-min}{max} = 1 - \dfrac{min}{max} & ,if\ otherwise \end{cases}$$

$$v = max(r, g, b)$$

Color conversion formulas (RGB to HSV)

B. *Color Quantization*

After color mode conversion, original RAW data convert into RGB and HSV information. Because one pixel in RGB color model requires 30bits storage space, Each R, G, B data is 10bits .But SDRAM memory data width only 16bit, so the R, G, B data quantify to each 5bits information in order to carry out follow-up procedures and implementation.

C. *Brightness Correction*

In outdoor surveillance, environment brightness will change with time. However, the brightness change always tends to affect the accuracy of the judgment. Therefore, this paper proposes a brightness correction algorithm to solve this problem. The brightness will change because the sun light. Too bright or too dark will affect the result and make misjudgments. Therefore, this paper adds a band-pass filtering. At the part of subtract the background threshold, this band-pass filtering can reduce the misjudge factors .Probability of misjudgments will also decrease.

D. *Rain Removal Algorithm*

From the literature shows compensation or without it is significant difference. In this thesis, the algorithm uses the HSV color model to achieve rain removal. Shown in Figure 3. Process can be divided into two main parts, capture the single point pixel and rain removal algorithms.

In this research, we use the value of V in HSV color mode (value, brightness) for statistical and computing experiment. During research, we find that comparison the rain pixel with Normal pixel, the V of normal pixel is higher than Rain pixel. However, the pixel value of H (Hue, hue) and S value (Saturation, saturation) is no significant changes. Thus, we find that correct rain pixel brightness V and approximate to Normal pixel values of V. The effect of rain pattern will be significantly diminished. And do the horizontal median filter to filter out the rain pattern. With this algorithm can achieve the effect of rain removal. Improve the overall clarity of the monitor screen. And lower the image interference due to inclement weather. Also improve the accuracy of object detection.

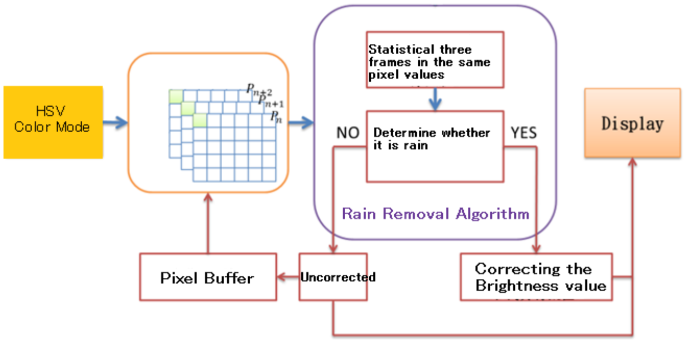

Figure 3. Flow chart of Rain Removal Algorithm

E. *Shadow Removal*

It will make the shadow when the object is exposed to light. So when we take the picture of foreground image, the unobvious shadow may not affect the result. But if the shadow too obvious, it is determined as appearance of error -movement.

So in this paper we proposed an algorithm, we use value of H (Hue) as the predication which can detect the movement. We compare the pixel between foreground image and background image, if the value of H has little difference, then we do not subtract the background image, if the value of H has large difference, then we subtract the background image. Based on this principle, it will not only affect the accuracy of frame, but also raise the accuracy of predicate the movement.

F. *Temporal Difference Algorithm*

Temporal Difference Algorithm is the case under the camera fixed. Subtract two continuous images, the outline of a moving object can be obtained. This method is relatively simple and only requires two memory frame can be achieved. But the drawback is easy to be broken phenomenon and it may only get moving object edges or contours.

$$M_n = \begin{cases} I_n(x,y), & if\ |I_n(x,y) - I_{n-1}(x,y)| > \varepsilon \\ B_n(x,y), & otherwise; \end{cases}$$

G. Binarization

Binarized image pixel value is that value of pixel less than the threshold, set to 0 (that is dark spots), whereas greater than the threshold value set to 1 (that is bright). Binarized images can effectively filter noise and entire image becomes simplistic.

$$M_n = \begin{cases} 31, & if\ |I_n(x,y) - I_{n-1}(x,y)| > \varepsilon \\ 0, & otherwise; \end{cases}$$

H. Binary Filter

Binary filter is filtering the image witch after binarized. It can replace the traditional median filtering algorithm and greatly reducing the complexity of algorithms. Because this only has two values, 0 and 31. Just need to make a sum operation to complete it, and can be in accordance with the threshold value (0 ~ 279) determines the strength of the filter.

P_1	P_2	P_3
P_4	P_5	P_6
P_7	P_8	P_9

Figure 4. 3x3 Image block

$$P_5 = \begin{cases} 31, & if\ P_1 + P_2 + \cdots + P_9 > \varepsilon\ ; P_i \in 0 \text{ or } 31 \\ 0, & otherwise; \end{cases}$$

I. Dilation and Erosion

In a real environment, the camera may be capture image in a complex background or moving objects color is similar to background. It will cause the defective image or detecting objects truncated. Therefore, in order to enhance the accuracy of object detection and integrity, so we use the morphology - [closed]. Use further erosion expansion algorithm to make up the broken parts. Expansion Method and erosion method in Equation (1) and (2) below:

$$\mathbf{A \oplus B = \{Z \mid [\ (\hat{B})\ Z \cap A] \subset A\} \ldots Dilation\ (1)}$$

$$\mathbf{A \ominus B = \{\ Z \mid (B)\ Z\ \subset A\} \ldots\ldots\ldots\ Erosion\ (2)}$$

J. Connected Component Labeling

In a real environment, there may be multiple objects simultaneously. In order to be independent of each object and the selected frame detected objects. Then we use the connected component labeling laws to give each moving object a different number. Based on these numbers we can obtain independently moving objects and the number of coordinates. The figure 5, 6 schematic diagrams for the component label connectivity method. However, because lack of hardware memory relationship, we just enable to do a single object connectivity.

B（i-1,j-1）	B（i,j-1）	B（i+1,j-1）
B（i-1,j）	B（i,j）	B（i+1,j）
B（i-1,j+1）	B（i,j+1）	B（i+1,j+1）

Figure 5. Connected Component Labeling mask Schematic

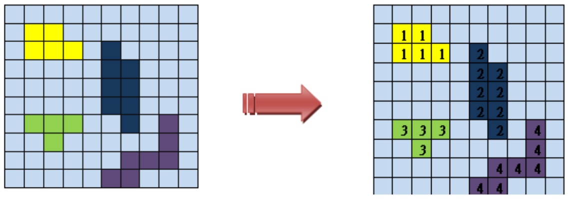

Figure 6. Image labeling Schematic

IV. Experiment Results And Analysis

Experimental results, conduct the following experiment:

1. Image to rain algorithm
2. Object Detection

This thesis, raining experiment, the first to use statistical HSV color histogram mode eigenvalues, and was found by the characteristics of rainfall changes. This stage is based on desktop computers to simulate the operation and implementation of all algorithms. Experiment CPU is Intel ® Core ™ i5-3470 3.2 GHz, memory is DDR3 1600 MHz 4GB.

A. Experimental results of Rain Removal Algorithm

In this research, we find that test image using the HSV color model to statistical characteristic values of 176,144 points. In the HSV color model. We find the value of H and S has unobvious difference in raining frame. As shown in Figure 7-8. However, the peaks to peaks in value of V have obvious change. As shown in Figure 9. Based on this, it can prove that raindrop has an immediately relationship of Brightness Indirectly. So we focused on characteristic values V (brightness) for handling test. And we find that when a pixel is normal pixel, characterized value V is smaller (darker). For Rain Pixel, its characteristic value V is larger (brighter), so the statistical characteristic of value V when is a bimodal phenomenon. We achieved the Rain Removal by this phenomenon.

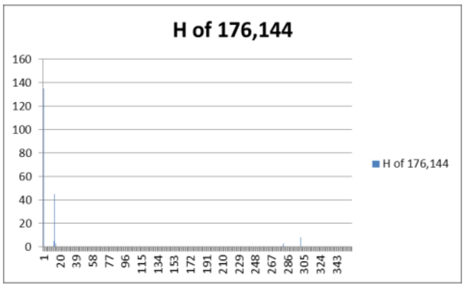

Figure 7. In outdoor image of statistical data H by HSV mode.

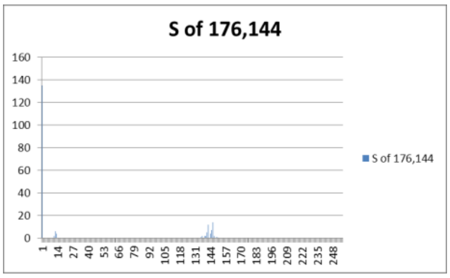

Figure 8. In outdoor image of statistical data S by HSV mode.

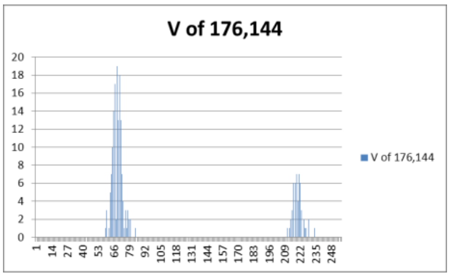

Figure 9. In outdoor image of statistical data V by HSV mode.

Figure 10. the thesis under the rain algorithms to capture the original image. The experimental video resolution of 352x288. FPS is 30fps. The rain experimental video is shotted in schools, is a true image of rainy day, not a Man-made image. The experimental comparison is a single image captures at the same time. In original image that has apparently notice rain texture. Base on thesis, the image after algorithm, as Figure 11 shown. Compared with original image, Rain texture is reduced and enhance the sharpness of the image.

Figure 10. Original image

Figure 11. Final image

B. Moving Object Detection Experiment

In object detection mode experiments, we simulated the situation of a single object, and the object detection algorithm execution and communication method with the object. Figure 12 can be learned from the experiment in the object detection algorithm for intrusion objects correctly out of the box.

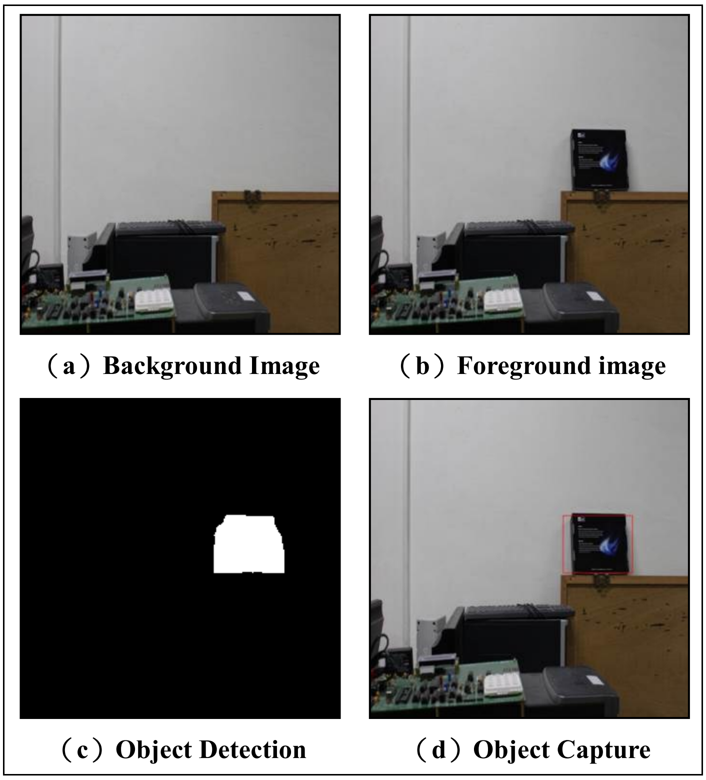

Figure 12. Single object detection test chart

C. Frame Rate Analysis

Currently, the system uses frequency rate of 50MHz, so using PLL (Phase lock loop) for up scaling action. We will use the SDRAM of frequency 166 MHz Since the actual use image data of 2 read 2 write need divide by 4 (i.e. 4 port). The 166 MHz clock rate equivalent to 166 MHz / 4 port = 41.5 M Hz. The SDRAM mechanisms have Refresh and some Command. Take to the overall timing, so it is generally the most practical clock rate than the maximum execution clock rate to down 10%. So we use when calculating about 41.5 MHz * 0.9 = 37.35 MHz to calculate that SDRAM is 166 MHz system clock rate performed under the frame rate of 127 fps (640x480).

In fact, we analysis by the above tested frame rate. The design system performance is better than actual system performance. The reason is the system used TRDB D5M CMOS Sensor modules that highest execution clock is 25 MHz, but the CMOS Sensor needs more exposure time and the waiting Blanking time of each frames. In currently, we setting exposure time can be output image data for work clock is approximately to 50%. Therefore, the work clock is approximately to 25 MHz * 0.50 = 12.5 MHz, and then we calculate the frame rate up to 40 fps.

From the above analysis, we can notice that the problem of system is clock rate of CMOS sensor is not enough, and the CMOS sensor needs long exposure time. Because all about those, lead to effective output image data is fewer than we forecast. Therefore, the overall performance was approximately to 40 fps of the system in VGA (640x480) theoretically. And then we implementation and calculate the frame rate of this system. We design the system, and it can show the number of frame rate at seven-segment display in FPGA breadboard. After image processing system finish each frame, the figures in the seven-segment display plus one. Experimental method is to use a stopwatch to stops the system after one minute. To attention processing frames of seven-segment display, and then divided by 60 seconds. Thereat, we can get 30 fps frame rate.

V. CONCLUSIONS

In this paper, we would like have the best display on the surveillance systems. We propose a new video algorithm. It is new ideas and methods to achieve the image when met raining. This algorithm not only simplifies many algorithms steps but also provide better image. In this study, the original images are actual shooting rainfall real images and did not use any post-processing for produce rainfall effects. The proposed algorithm is able to remove most of the rain pattern phenomenon so that the image can be more clarity and integrates shadow exclusion algorithms, and rain removal algorithms, etc. Raining while pipelined processing operations and improve the efficiency of algorithms.

This paper, the system image resolution by 640x480. To simulation real-time object detection hardware processing parts on FPGA. Its maximum processing performance can be achieved 75fps. Analog overall development system processing performance is 40fps. The actual experiment are more than 30 fps processing speed. Compare with real-time image processing system (26 fps), our performance of algorithm is enough for normally used, the resolution of our algorithm is also adequate.

REFERENCES

[1] S.Y. Chien, S. Y. Ma, and L. G. Chen, "Efficient moving object segmentation algorithm using background registration technique, " IEEE Transactions on Circuits and Systems for Video Technology , Vol. 12, NO. 7, pp. 577-586, 2002.

[2] Y. C. Chung, J. M. Wang, and S. W. Chen, "Progressive Background Image Generation, " in Proc. of 15th IPPR Conf. on Computer Vision, Graphics and Image Processing, pp. 858-865, 2002.

[3] L. Maddalena and A. Petrosino, "A Self-Organizing Approach to Background Subtraction for Visual Surveillance Applications," IEEE Transactions on Image Processing, Vol. 17, NO. 7, pp. 1168 - 1177, 2008.

[4] S. S. Ghidary, Y. Nakata, T. Takamori, and M. Hattori, "Human Detection and Localization at Indoor Environment by Home Robot," in Proc. of IEEE International Conference of Systems, Man, and Cybernetics, Vol. 2, pp.1360 - 1365, Oct. 2000.

[5] K. K. Ken, S. H. Cho, H. J. Kim, and J. Y. Lee, "Detecting and tracking moving object using an active camera, " in Proc. of 7th International Conference of Advanced Communication Technology, ICACT , Vol. 2, pp. 817 - 820 ,2005.

[6] H. Liu, N. Dong, and H. Zha, "Omni-directional vision based human motion detection for autonomous mobile robots, " in Proc. of IEEE International Conference of Systems, Man and Cybernetics, Vol. 3 , pp.2236 - 2241, Oct. 2005 .

[7] J. L. Barron, D. J. Fleet and S. S. Beauchemin, "Performance of optical flow techniques," International Journal of Computer Vision, pp.43-77, 1994.

[8] M. Irani and P. Anandan, "Video Indexing Based on Mosaic Representations," Proceedings of IEEE, Vol. 86, NO. 5, pp.905 – 921, 1998.

[9] R. Cucchiara, C. Grana, M. Piccardi, and A. Prati, "Detecting moving objects, ghosts, and shadows in video streams," IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 25, No. 10, pp. 1337-1342, 2003.

[10] A. Elgammal, R. Duraiswami, D. Harwood, and L. S. Davis, "Background and foreground modeling using nonparametric kernel density estimation for visual surveillance," Proc. IEEE, Vol. 90, No. 7, pp. 1151-1163, 2002.

[11] C. Stauffer, and W. E. L. Grimson, "Adaptive background mixture models for real-time tracking," IEEE Computer Society Conference on Computer Vision and Pattern Recognition, Vol. 2, pp. 246-252, 1999.

[12] P. KaewTraKulPong, and R. Bowden, "An improved background mixture model for real-time tracking with shadow detection," in Proc. 2nd European Workshop on Advanced Video Based Surveillance Systems, Vol. 25, 2001.

[13] I. Haritaoglu, D. Harwood, and L. S. Davis, "Real-time surveillance of people and their activities," IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 22, No. 8, pp. 809-830, 2000.

[14] S. Kang, J. Paik, A. Koschan, B. Abidi, and M. A. Abidi, "Real-time video tracking using PTZ cameras," in Proc. of SPIE 6th International Conference on Quality Control by Artificial Vision, Vol. 5132, pp. 103-111, 2003.

[15] Y. S. Yan, and L. J. Kau,"The Development of a Moving Object Detection Algorithm for Visual Tracking System with Background Interference," in Proc. National Symposium on Telecommunications (NST 2011), pp. 678-681, Hualien, Taiwan, Nov. 18-19, 2011.

[16] TRDB D5M User Guide http://www.terasic.com.

[17] DE2-70 Datasheets, http://www.altera.com, 2009.