International Journal of Emerging Technologies in Engineering Research (IJETER)
Volume 1, Issue 1, July (2015) www.ijeter.everscience.org

Performance Improvement of Vision Based Fire Detection System

Supriya Bhargava
Digital Communication, BabulalTarabai Institute of Research and Technology, Sagar, Madhya Pradesh, India.

Anand Vardhan Bhalla
Assistant Professor, BabulalTarabai Institute of Research and Technology, Sagar, Madhya Pradesh, India.

Abstract – In this paper an optimized fire detection system using image processing is proposed. This system is based on combination of various methods used for fire detection using image processing. This system can also be adjusted according to different sensitive area requirement by applying different combination of fire detecting techniques. The proposed system gives optimized way to detect the fire in terms of fewer false alarms by giving the accurate result of fire occurrence. Conventional fire detection systems use physical sensors to detect fire. Chemical properties of particles in the air are acquired by sensors and are used by conventional fire detection systems to raise an alarm. However, this can also cause false alarms. In order to reduce false alarms of conventional fire detection systems, we proposed vision-based fire detection system. The proposed fire detection system consists of main parts: fire edge detection, colour detection, motion detection, gray-cycle pixel detection of smoke and area spread.

Index Terms – Fire Detection, Image Processing, Colour Detection, Motion Detection, Edge Detection, Grey Cycle Detection.

1. INTRODUCTION

Fire detection systems are among the most important components in surveillance systems used to monitor buildings and the environment. Fire is one of the a natural serious phenomenon that is out of control due to that it can cause irreversible serious loss of human life and property, it is also a cause of atmospheric pollution once it has occurred. Fire is a great threat when it affects highly populated area or an area of high environmental value. In last few decades it is found that human activities have enhanced the fire rate. As a part of early mechanism, a detection system should generate an alert at earlier stages of fire. Currently, almost all fire detection systems in use have built-in sensors in these the detection depends mainly on the location and density of sensors. It is essential that for a high precision fire detection system these sensors should be densely distributed. In a sensor-based fire detection system for an outdoor environment, coverage of large areas is impractical due to the necessity of a regular distribution of sensors in close proximity. Due to rapid developments in digital camera technology and video processing techniques, there is a major trend to replace conventional fire detection methods with vision based systems [1][2][3].

Fires are usually easy to extinguish in an early stage; once a fire has reached a fairly large size, operations for fire-fighting become very complicated and the control of the fire depends largely on the meteorological conditions that determine fire spread. In sparsely populated areas, where fires are not extinguished, fire detection is only needed for monitoring the environmental impact. So it is of prime importance to detect occurrence of fire at early stages. These all circumstances need development of a reliable system which can detect an occurrence of fire at early stage so that the losses can be reduced [1][2][4][5][6].

2. TRADITIONAL FIRE DETECTION METHOD

In earlier day's and at some places at recent days automated fire detection systems installed are based on sensors, these sensor based fire detection system senses various parameters of fire such as temperature, smoke etc these sensors based on the analysis done, issues a signal to the fire alarm system and finally the alarm acts on the basis of the signal received. These sensor based system are activated only when the smoke particles or flames in contact or close to the fire detection device, moreover those devices cannot provide more information in terms of the exact location of fire, magnitude, growth rate and so on. However, these sensor based automated system are not able to detect fire at early stage as it require some input to sense which is one of the most considerable disadvantage and also the response time of this system is high. In these systems for the purpose of the sensing, sensors have to be placed at appropriate locations and the system needs some specific level of these inputs to sound alarm. Also as the area to be sensed increases the density of sensors is also to be increased due to which the cost of the system increases. As the traditional system has many drawback so it is not the best way to ensure a timely response at earlier stages when safety is concern, as lot of damage might have happened by then.

A smoke detector is a device that detects smoke, typically as an indicator of fire. Commercial, industrial, and mass residential devices issue a signal to a fire alarm system, while household detectors, known as smoke alarms, generally issue a local audible and/or visual alarm from the detector itself. Conventional point smoke and fire detectors typically detect the presence of certain particles generated by smoke and fire by ionization or photometry.

3. LIMITATIONS OF TRADITIONAL SYSTEM

Most of the available sensors used such as smoke detector, flame detector, heat detector and etc., take time to response. These sensors require product of combustion (example: smoke, CO2, temperature and etc.) from fire to reach the sensors before an alarm is issued. Because of that, it has to be carefully placed in a various locations [11][12]. Also, these sensors are not suitable for open spaces as products of combustion tend to spread away which can reduce the detection. Conventional fire detection systems use physical sensors to detect fire. Chemical properties of particles in the air are acquired by sensors and are used by conventional fire detection systems to raise an alarm [11]. However, this can also cause false alarms; for example, a person smoking in a room may trigger a typical fire alarm system almost all fire detection systems use built-in sensors that depend primarily on the reliability and the positional distribution of the sensors. It is essential that these sensors are distributed densely for a high precision fire detection system. In a sensor-based fire detection system for an outdoor environment, coverage of large areas is impractical due to the necessity of a regular distribution of sensors in close proximity [12]. An important weakness of point detectors is that they are distance limited and fail in open or large spaces.

4. FIRE DETECTION USING IMAGE PROCESSING

Due to the drawbacks of sensor based fire detection system and due to rapid development of image processing techniques vision based fire detection system came into existence. Moreover vision based fire detection system offers several advantages. Firstly installation cost of this system is low as CCTV cameras are required. Secondly it has faster response time as it does not have to wait for the products of combustion to come near it this was not the case with sensor based systems. Thirdly in case of false alarm, confirmation can be done from the room by person without rushing to location of fire. Fourthly these systems can be used in open environment and on increasing the area to be covered the cost of the system is not much affected. Lastly fire detection technology based on video image can extract much more information from smoke and flame which is helpful for the detection.[11][12][14]

Fire has number of visual features such as colour, motion, shape, smoke and growth etc. For detection of fire these feature are analyzed. During the occurrence of fire, smoke and flame both can be visualized. And with the increase in the intensity of fire visibility of both smoke and flame increases. Hence for fire detection, both smoke and flame needs to be analyzed. One reason to analyze both smoke and flame is that in the daytime, smoke analysis is the best approach for fire detection, since smoke is always associated with fire and becomes quickly visible even if the fire source is occluded and at night the visibility of smoke decreases but the detection capability of fire flames becomes high. Thus, fire flame extraction is effective for fire detection at night.[11][12][17][18]

5. FIRE DETECTION METHODS BASED ON IMAGE PROCESSING

In this section different fire detection techniques based on image processing are discussed. With the rapid development of digital camera technology and advanced content based image and video processing many fire detection techniques based on image processing came into existence. These techniques analysed visual features of fire like colour, motion, edge, shape etc...

5.1 Edge detection method

The sharp transition characteristics of the object are the mean of edge detection. Basically edge detection detects the colour variance in an image. The edge detection system compares the colour difference and provides an edge of the flame based on it. The flame edges are basis for the quantitative determination of range of flame characteristic parameter such as shape, size, location and stability. By flame edge detection amount of data processing and filter out uncontrolled information such as background noise within image can be reduced to great extent.[21][22]

There are many methods of edge detection which can be categorized into two depending on the derivative used they are gradient and laplacian The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image. The Laplacian method searches for the zero crossings in the second derivative of the image to find edges. Examples of gradient-based edge detectors are Roberts, Prewitt, and Sobel operators. All the gradient-based algorithms have kernel operators that calculate the strength of the slope in directions which are orthogonal to each other, commonly vertical and horizontal. Later, the contributions of the different components of the slopes are combined to give the total value of the edge strength. Example of Laplacian method is Marrs-Hildreth operator. An edge-detection filter can also be used to improve the appearance of blurred or anti-aliased video streams. The basic edge-detection operator is a matrix- area gradient operation that determines the level of variance between different pixels. The edge-detection operator is calculated by forming a matrix centered on a pixel chosen as the centre of the matrix area. If the value of this matrix area is above a given threshold, then the middle pixel is classified as an edge.[11][12][49] [64]

5.2 Colour Detection Method

Fire can by described by its colour properties. For fire colour detection two models are widely used RGB colour model and YCbCr colour model.

5.2.1 RGB colour model:

In this model colour pixel can be extracted into the individual R, G and B elements which can be used for colour detection. The flame colour can provide useful information relates to temperature of the flame and fire phase. All the conditions for fire colour detection in image are summarized as following:

Condition1: $R > R_{TH}$

Condition2: $R \geq G \geq B$.

Condition 3: $S \geq (255 - R)*S_{TH} / R_{TH}$

Condition 1 states that the value of R should be over some predetermined threshold value R_{TH}. The condition 2 in detecting fire colours is defined as $R \geq G \geq B$. Furthermore, there should be a stronger R in the captured fire image due to the fact that R becomes the major component in a colourful image of fire. This is because that fire is also a light source and the video camera needs sufficient brightness during the night to capture the useful video sequences. However, the background illumination may affect the saturation of flames or generate a fire alias, which leads to false detections. To avoid being affected by the background illumination, the saturation value of the extracted flame needs to be larger than a specified threshold, S_{TH} .Based on the basic concept, the saturation will degrade with the increasing R component, and thus the term of $((255 - R)*S_{TH} / R_{TH})$ illustrates when R component increases toward the upmost value and then saturation will decrease downward to zero.[11][12][13][14]

In the decision rules, both R_{TH} and S_{TH} are defined according to various experimental results, and typical values range from 55 to 65 and 115 to 135 for S_{TH} and R_{TH} , respectively.

5.2.2 YCbCr colour model:

YCbCr is an efficient model because of its ability to distinguish luminance information from chrominance information. In order to create Y, Cb, Cr components from obtained RGB Image colour space transformation equation can be used to transform each RGB pixel in corresponding Y Channel, Cb Channel, Cr Channel pixel to form a corresponding Y, Cb, Cr image. When the image is converted from RGB to YCbCr colour space, intensity and chrominance is easily discriminated. YCbCr colour space can be easily model as following for the fire:

$$Y = 16 + R * 65.481+ G * 128.553 + B * 24.996;$$

$$Cb= 128 + R * -37.797 - G * 74.203 + B * 112.0;$$

$$Cr = 128 +R * 112.00 + G * -93.7864 + B * -18.214;$$

In YCbCr colour space, Y′ is the luma component (the "black and white" or achromatic portion of the image) and Cb and Cr are the blue-difference and red-difference chrominance components, will be chosen intentionally because of its ability to separate illumination information from chrominance more effectively than the other colour spaces.

Out of the two colour models RGB colour model is widely used because of its less computational complexity.

5.3 Motion detection:

Motion detection method for fire is used to detect occurrence of any movement in a video. It is done by analysing the difference in images of video frames. The most common approach used for motion detection is background subtraction which can identify any movement in the video frame. There are three main approaches used in background subtraction for motion detection in a continuous video stream:

- *Frame/Background subtraction:* In this difference between two consecutive input frames of a video stream is calculated. Simultaneously a background difference map is generated by comparing the present frame with the previous background frame stored in the buffer
- *Background registration*: In This on the basis of past several difference frames pixels which are not moving for long time are used to identify the background for background registration.
- *Moving pixel detection:* In this step, the binary background difference map and the binary frame difference map are used together to create the binary moving pixel map.

This method has two major advantages that is the less computations are required and the background model is highly adaptive.[11][12][13][14]

5.4 Area Spread:

This method is used to compare fire pixel area of two sequential images comes out after the colour detection. Area counts the number of pixels in a frame. In area spread detection method we take two sequential frames which comes out from colour detection method and check the dispersion on the basis of minimum and maximum values of X and Y coordinates. On the basis of this dispersion, System will provide result on the basis that if area increases then a fire is detected. This property of fire helps us to detect fire accurately. If the area of the current image is greater than the area of the previous image then we can say that area of fire pixel is increasing which shows the presence of fire. This method enhances the accuracy level of fire detection system.[11][12]

5.5 Gray-cycle Detection:

There are many cases in which smoke is generated before actual fire. So by analysing these smoke pixels which are present near fire area in the video we can detect fire at earlier stages. Gray-cycle detection method is used for smoke detection. These smoke pixels have specific colour properties in terms of R, G and B pattern. In smoke particles, the difference between at least two colour combinations of R, G, B will be less than threshold value for difference between two colour combination (D_t). Mathematically, equation for smoke pixel in terms of R.G and B is

1. $R - G < D_t$ and $G - B < D_t$

2. $G - B < D_t$ and $B - R < D_t$

3. $B - R < D_t$ and $R - G < D_t$

It is done by applying the mathematical relation of R,G and B in the above detected area. The coordinate of the area in which smoke detection want to apply is:

$p=[(x_{min}-\alpha) , y_{min}+y_{mid}];$
$q=[(x_{max}+\alpha) , y_{min}+y_{mid}];$
$r=[(x_{max}+\alpha) , y_{min}-y_{mid}];$
$s=[(x_{min}-\alpha) , y_{min}-y_{mid}];$

where

X_{min}= minimum value of X coordinate of possible detected fire area through edge and colour detection

X_{max}= maximum value of X coordinate of possible detected fire area through edge and colour detection

Y_{min}= minimum value of Y coordinate of possible detected fire area through edge and colour detection

X_{max}= maximum value of Y coordinate of possible detected fire area through edge and colour detection

α = margin to get smoke detection area

The rectangular area formed by p, q, r and s is the area to detect smoke pixel. If the detected smoke pixels are greater than pixels covered by 20% of area of the rectangular then we can conclude that smoke pixels are due to fire not by gray colour.[11][12][14]

6. PROPOSED TECHNIQUE

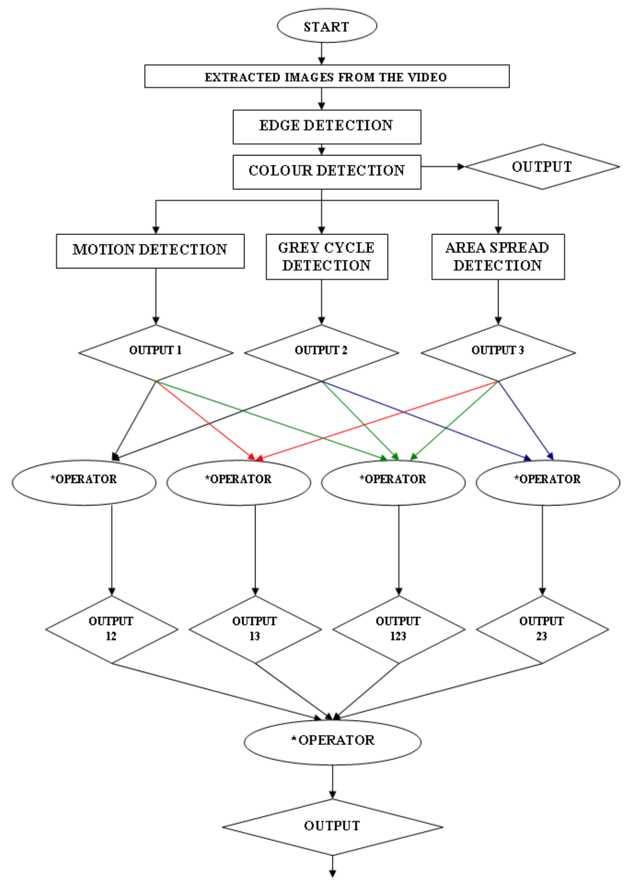

Figure 1. Flowchart of proposed method.

Figure 1 shows the flowchart of the proposed method of fire detection. In this proposed method the images extracted from the video are given as input to edge detection method to determine the edge of the image and then the output of edge detection is passed through colour detection. The output of colour detection is given as input to three different techniques motion detection, grey cycle detection and area spread detection. The different outputs depending on the different combination of outputs from three techniques are generated using the AND operator. OR operator is again applied to the different outputs generated to get the final output of the system.

7. RESULTS

The results obtained for proposed system using MATLAB 2013a are shown in table 1. The results shows that the efficiency of the system for fire detection for motion detection technique is 85.33%, for gray cycle detection technique is 88% and that for area spread the efficiency is 90%. Finally the efficiency of the proposed system using combination of above detection techniques is 95.33%. Thus proposed fire detection system gives us a enhanced system efficiency in term of less false alarms and thus a better system performance is achieved.

Methods	No. of faulty detection	System performance
Motion detection	22/150	85.33%
Gray cycle detection	18/150	88%
Area spread detection	15/150	90%
Proposed fire detection system	7/150	95.33%

Table 1: Proposed system performance.

8. CONCLUSIONS

The proposed system is based on combination of various methods used for fire detection using image processing. The proposed system provides us facility to adjust the system by using different combination of image processing based fire detection techniques and implementing the system according to different area requirement. The proposed system provides us better way to detect the fire in terms of decreased false fire detection rate and hence increasing the accuracy of the system. The proposed fire detection system consists of main parts: fire edge detection, colour detection, motion detection, gray-cycle pixel detection of smoke and area spread.

REFERENCES

[1] TurgayÇelik, HüseyinÖzkaramanlı, and HasanDemirel- "Fire and Smoke detection without sensors: image processing based approach", 15th European Signal Processing Conference (EUSIPCO 2007), Poznan, Poland, September 3-7, 2007, copyright by EURASIP.

[2] Gareth J. Roberts and Martin J. Wooster- "fire Detection and Fire Characterization OverAfrica Using Meteosatseviri", IEEE Transactions on Geoscience and Remote Sensing, Vol. 46, No. 4, April 2008.

[3] Vision Jean Paul Dukuzumuremyi1, BeijiZou and Damien Hanyurwimfura- "A Novel Algorithm for Fire/Smoke Detection based on computer", International Journal of Hybrid Information Technology Vol.7, No.3 (2014), pp.143-154.

[4] Mengxin li, WeijingXu, KeXu, Jingjing Fan, DingdingHou- "Review of fire detection technologies based on video image", Journal of Theoretical and Applied Information technology 20th March 2013. Vol. 49 No.2.

[5] P.T. Bharti, Dr. P. Subhashini, Wseas- "Optimization of image processing techniques using Neural Networks:A review", Transactions on Information Science and Applications ISSN: 1790-0832 Issue 8, Volume 8, August 2011.

[6] MamtaJuneja , Parvinder Singh Sandhu- "Performance Evaluation of Edge Detection Techniques for Images in Spatial domain", International Journal of Computer Theory and Engineering, Vol. 1, No. 5, December, 2009 1793-8201.

[7] Surya.T.S, Suchithra.M.S- "Survey on Different Smoke Detection Techniques Using Image processing", International Journal of Research in Computer and Communication Technology.

[8] Ali Rafiee, Reza Ta vakoli, Reza Dianat- "Fire and Smoke Detection Using Wavelet Analysis and Disorder characteristic",2011 ieee.

[9] Rashmi- "Algorithm and Technique on Various Edge Detection: A servey", An International Journal (SIPIJ) Vol.4, No.3, June 2013.

[10] Mukesh Kumar, Pedro gomes and RohiniSaxena- "A Vision Based Approach To Fire Detectio"-,International Journal of Advanced Robotic Systems, Received 24 Apr 2014; Accepted 18 Jun 2014.

[11] Gaurav Yadav- "Optimized Flame Detection using image processing based techniques", Indian Journal of Computer Science and Engineering (IJCSE), ISSN : 0976-5166 Vol. 3 No. 2 Apr-May 2012.

[12] S.P. Kale et al Int- "Novel Technique for Fire detection". Journal of Engineering Research and Applications, ISSN : 2248-9622, Vol. 4, Issue 1(Version 3), January 2014, pp.203-205.

[13] Swetha ,Jyohsna- " Boundary detection in Medical Images using Edge Field Vector based on Law's Texture and Canny method", Proceedings of TEQIP II sponsored National Conference on Wireless Communication, Signal Processing, Embedded Systems-WISE 2013.

[14] Walter Phillip, Mubarak Shah, Nielsda, Vitoria Lobo ,Flame Recognition in Video", 0-7695-0813-8/00 2000 IEEE.

[15] Liang-Hua Chen and Wei-Cheng Huang- "Fire Detection Using Spatial-temporal Analysis" Proceedings of the World Congress on Engineering 2013 Vol III, WCE 2013, July 3 - 5, 2013, London, U.K.

[16] Michael J. Jones and James M. Rehg- "Statistical Color Models with Application to Skin Detection"

[17] Leonardo Millan-Garcia, Gabriel Sanchez-Perez, Mariko Nakano, Karina Toscano-Medina, Hector Perez-Meana and Luis Rojas-Cardenas- "An Early Fire Detection Algorithm Using IP Cameras".

[18] Abidha T E, Paul P Mathai- "Reducing False Alarms in Vision Based Fire Detection with NB Classifier in EADF Framework", International Journal of Scientific and Research Publications, Volume 3, Issue 8, August 2013.

[19] N. Senthilkumaran and R. Rajesh- "Edge Detection Techniques for Image Segmentation – A Survey of Soft Computing approach", International Journal of Recent Trends in Engineering, Vol. 1, No. 2, May 2009.

[20] Xiaojun Qi and Jessica Ebert- **"**A computer vision-based method for fire detection in color videos".

[21] G.T. Shrivakshan, Dr.C. Chandrasekar- "A Comparison of various Edge Detection Techniques used in Image Processing",IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 5, No 1, September 2012 ISSN (Online): 1694-0814.

[22] ShaikRasool, Dr.P.Pandarinath- "An Autoadaptive Edge-Detection Algorithm for Flame and Fire Image Processing", International Journal of Computer & Organization Trends –Volume 3 Issue 11 – Dec 2013.

[23] PietroMorerio, LucioMarcenaro, Carlo S. Regazzoni, Gianluca Gera- "Early Fire and Smoke Detection based on colour feature and motion analysis".

[24] B. UgurT¨oreyin, YigithanDedeoglu, A. Enis C¸ etin- "Flame Detection in video using hidden markov model".

[25] Swetha.M, Jyohsna.C- "Boundary detection in Medical Images using Edge Field Vector based on Law's Texture and canny method", Proceedings of TEQIP II sponsored National Conference on Wireless Communication, Signal Processing, Embedded Systems-WISE 2013.

[26] Zia Wadud,faudyasinhuda, nizamuddinahmed- "Assessment of Fire risk in the readymade industry, accepted manuscript, published in Fire Technology.

[27] M. Kalpana, G. Kishorebabu, K.Sujatha- "Extraction of Edge Detection using digital image processing techniques", International Journal Of Computational Engineering Research (ijceronline.com) Vol. 2 Issue.5.

[28] Megha Jess Mathew- “A study on fire detection system using statistic color model”,IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834, p- ISSN: 2278-8735. Volume 7, Issue 2 (Jul. - Aug. 2013), PP 01-04.
[29] B.U. Toreyin, E.B. Soyer, O. Urfalioglu, A.E. Cetin- “Flame detection using PIR sensors”, in Proceedings of the IEEE 16th Signal Processing, Communication and Applications Conference, SIU 2008, 2008.
[30] Liu Peixun- “All-weather fire detection system based on video surveillance”, Jilin University. 2011.
[31] Rule Huang- “Research on forest fire smoke recognition based on video images”, Beijing Forestry University. 2011.
[32] Zhiying ZHANG- “The research of fire detection technology in video monitoring system”, University of Electronic Science and Technology of China. 2010.
[33] Aijun XU, Luming FANG, Xiongwei LOU- “Forest fire identification algorithm based on a visible light video”, Journal of Beijing Forestry University. 2010; 32(2): 14-20.
[34] Lei SHENG, Kejun XU- “Design and realization of real-time video-processing platform based on DSP and FPGA”, Journal of University of Science and Technology of China. 2006; 36(3): 304-308.
[35] Yunyang YAN, Zhibo GUO, Hongyan WANG- “Fire detection based on feature of flame color”, Pattern Recognition, 2009. CCPR 2009. 2009; 4-6: 1-5.
[36] Shuen LU- “Research on fire detection rules based on flame recognition”, Chongqing University, 2009.
[37] Jinhua ZHANG, Jian ZHUANG- “A Flame Detection Algorithm Based on Video Multi-feature Fusion”, Lecture Notes in Computer Science. 2006; 38(2): 784-792.
[38] Sail Prabhakar- “Fingerprint Classification and Matching Using a Filter Bank”, Michigan State University, 2009.
[39] Wei HU, Huiqin WANG- “Image fire detection technology based on DSP”, Modern Electronics Techniques 2010; 17: 166-168.
[40] Celik T, Demirel H- “Fire detection in video sequences using a generic color model”, Fire Safety Journal. 2008; 2-11.
[41] Huijing LIU, Hui LIU, Hong LIN - “Implementing fire detection based on machine vision and Gaussian mixture model”, Process Automation Instrumentation. 2012; 33(3): 60-62.
[42] Jing HOU, Mengxin LI, Languang ZHAO- “A region-based image matching algorithm combining global and local features”, Journal of Shenyang Jianzhu University (Natural Science). 2012; 28(2): 380-381.
[43] James Clerk Maxwell, 1868- “Digital Image Processing”, Mathematical and Computational Methods”.
[44] R .Gonzalez and R. Woods- “Digital Image Processing”, Addison Wesley, 1992, pp 414 - 428.
[45] S. Sridhar- “Digital Image Processing”, Oxford university publication.
[46] Shamik Tiwari- “Digital Image processing”, Danpat Rai & co.(P) LTD.
[47] J. F. Canny- “A computational approach to edge detection”, IEEE Trans. Pattern Anal. Machine Intell., vol.PAMI-8, no. 6, pp. 679-697, 1986 Journal of Image Processing (IJIP), Volume (3) : Issue (1)
[48] Geng Xing, Chen ken , Hu Xiaoguang- “An improved Canny edge detection algorithm for colour image”, IEEE TRANSATION ,2012 978-1-4673-0311-8/12/$31.00 ©2012 IEEE.
[49] K. Nakau, M. Fukuda, K. Kushida, H. Hayasaka, K. Kimura,and H. Tani- “Forest Fire Detection Based on MODIS Satellite Imagery, and Comparison of NOAA Satellite Imagery with Fire Fighters Information”, 2006.
[50] Y. Aslan- “A framework for the use of wireless sensor networks in the forest fire detection and monitoring”, Department of Computer Engineering, The Institute of Engineering and Science Bilkent University, 2010.
[51] S. Mathews, P. Ellis, and J. H. Hurle- “Evaluatuion of Three Systems”, Bushfire Cooperative Research Centre, Australia, 2010.
[52] K. Hough- “Vision Systems for Wide Area Survillance: Forest-Watch—along range outdoor wildfire detection system”, Wildfire, 2007.
[53] J. Lloret, M. Garcia, D. Bri, and S. Sendra- “A wireless sensor network deployment for rural and forest fire detection and verification”, Sensors, vol. 9, no. 11, pp. 8722–8747, 2009.
[54] Lin Zhou Xiao– “Early Fire Detection Based on Flame Contours in Video”, Inf.Tech.J.Vol9, pp 899-908.2010.
[55] R.C. Gonzalez and R.E. Woods- “Digital Image Processing”, Addison Wesley, 1993.
[56] H. Levkowitz- “Color Theory and Modeling for Computer Graphics, Visualization, and Multimedia Applications”, Kluwer Academic Publishers, 1997.
[57] P. Trahanias and A.N. Venetsanopoulos, “Color edge detection using vector statistics", IEEE Trans. on Image Processing, vol. 2, pp. 259-264, April 1993.
[58] Y. Yang “Colour edge detection and segmentation using vector analysis”, University of Toronto, Toronto, ON, Canada.
[59] M. Hedley and H. Yan- “Segmentation of color images using spatial and color space information’’, Journal of Electronic Imaging, vol. 1, pp. 374-380, October 1992.
[60] T. Carron and P. Lambert- “Color edge detector using jointly hue, saturation and intensity,"in Proc. IEEE International Conference on Image Processing, pp. 977-981, October 1994.
[61] Jakovcevic, T.; Setic L.; Stipanicev D. Krstinic D.- Wildfire Smoke-Detection Algorithms Evaluation”, In Proceedings of International Conference on Forest Fire Research, Coimbra, Portugal, 15–18 November 2010.
[62] N. Senthilkumaran and R. Rajesh- “A Study on Edge Detection Methods for Image Segmentation”, Proceedings of the International Conference on Mathematics and Computer Science (ICMCS-2009), 2009,Vol.I, pp.255-259.
[63] D. Mintz, - “Robust Consensus Based EdgeDetection”, CVGIP: Image Understanding, Volume 59, Issue 2, March 1994, pp. 137–153, 26 April 2002.
[64] Seif, A.,et.al.- “A hardware architecture of Prewitt edge detection”, Sustainable Utilization and Development in Engineering and Technology 2010 IEEE Conference, Malaysia, pp. 99 – 101, 20-21 Nov. 2010.
[65] N. Senthilkumaran, R. Rajesh- "Edge Detection Techniques for Image Segmentation and A Survey of Soft Computing Approaches", International Journal of Recent Trends in Engineering, Vol. 1, No. 2, PP.250-254, May 2009.
[66] T.G. Smith Jr., et.al.- “Edge detection in images using Marr-Hildreth filtering techniques”, Journal of Neuroscience Methods, Volume 26, Issue 1, pp. 75–81, November -1988.
[67] D. Mintz,- “Robust Consensus Based EdgeDetection”, CVGIP: Image Understanding, Volume 59, Issue 2, March 1994, pp. 137–153, 26 April 2002.
[68] Nick Kanopoulos, et.al.- “Design of an Image Edge Detection Filter using the Sobel Operator”, Journal of Solid State Circuits, IEEE, vol. 23, Issue: 2, pp. 358-367, April 1988.
[69] Wirth,M. Zaremba,R.- “Flame region detection based on histogram backprojection”. CRV 2010 - 7th Canadian Conference on Computer and Robot Vision, 2010, pp. 167-174.

[70] SunJae Ham, ByoungChul Ko, JaeYeal Nam. - "Fire-flame detection based on fuzzy finite automation". Pattern Recognition (ICPR), 2010 20th International Conference. 2010, pp. 3919 - 3922.

[71] Yusuf Hakan Habiboglu. Osman Günay. Cetin, A.E.- "Covariance matrix-based fire and flame detection method in video". Machine Vision and Applications. DOI 10.1007/s00138-011-0369-12011.

[72] Dimitropoulos, Kosmas Tsalakanidou, Filareti, Grammalidis, Nikos- "Flame detection for video-based early fire warning systems and 3D visualization of fire propagation". Proceedings of the IASTED International Conference on Computer Graphics and Imaging, CGIM 2012, pp. 209-216.

[73] Xuan Truong, Tung, Kim, Jong-Myon- "Fire flame detection in video sequences using multi-stage pattern recognition techniques". Engineering Applications of Artificial Intelligence. October 2012, Vol. 25, No.7, pp. 1365-1372

[74] B.U. Töreyin, Y. Dedeoglu. U. Gudukbay and A. E.Cetin- "Computer vision based method for real-time fire and flame detection," Pattern Recognition Letters, 27, 49-58 (2006).

[75] T. Celik, H. Demirel, H. Ozkaramanli and M. Uyguroglu- "Fire detection using statistical color model in video sequences," Journal of Visual Communication and Image Representation, 18, 176-185 (2007).

[76] D. Han and B. Lee- "Development of Early Tunnel Fir Detection Algorithm Using the Image Processing," International Symposium on Visual Computing, 39-48 (2006).

[77] K.H. Cheong, B.C. Ko and J.Y. Nam- "Vision sensor based fire monitoring system for smart home," International Conference on Ubiquitous Information Technology & Applications, B, 1453-1463 (2007).

[78] G. Marbach, M. Loepfe, and T. Brupbacher- "An image processing technique for fire detection in video images," Fire Safety Journal, Vol. 41, No. 4, pp. 285–289, 2006.

[79] Turgay Celik , Hasan Demirel- "Fire detection in video sequences using a generic colour model," Fire Safety Journal 44 (2009) 147– 158, 2009.