A Novel Fire Detection System using Image Processing and Artificial Intelligence Techniques

R.Divya
Sri Sairam Engineering College
Saileo Nagar,West Tambaram
Chennai

D.Mageshwari
Sri Sairam Engineering College
Saileo Nagar,West Tambaram
Chennai

ABSTRACT

Fire is a terrifying weapon, with nearly unlimited destructive power. Fire accidents are a major cause of human suffering and material loss and the one that perhaps are predicted the least accurately. Most existing work in fire occurrence prediction focuses on prediction of wildfires in forests and those caused by volcanic eruptions. Surprisingly prediction of fire occurrence in residential and official buildings has not been fully explored because the factors that influence fires are too many. The idea behind this research is to provide an alert to fire stations in the event of fire in hospitals, official and commercial buildings by the use of Image processing and Artificial Intelligence techniques that might significantly reduce the death toll and loss of property caused by fire accidents. The Digital snapshots of the building can be taken (1,600 x 1,200 pixels at 1MB image per second) continuously using Closed circuit digital photography (CCDP) and these snapshots are then automatically sent to the server for storage as timed and dated JPEG files. The digital images are converted from RGB to XYZ color space and then segmented by utilizing anisotropic diffusion to identify the presence of fires. Subsequently, Radial Basis Function Neural Network is trained with the color space values of the segmented fire regions and is employed in the design of this novel system. The proposed intelligent system will thus aid in alerting the fire stations with the help of a Global System for Mobile Communications in event of any fire to take immediate actions before fire spreads quickly and causes traumatizing loss.

Keywords

Image processing, Artificial Intelligence, Closed circuit digital photography (CCDP), Anisotropic Diffusion Segmentation, Radial Basis Function Neural Network (RBFNN), Global System for Mobile Communications (GSM)

1. INTRODUCTION

For longer than recorded history, fire has been a source of comfort and catastrophe for the human race [1].Fire is rapid, self-sustaining oxidation process accompanied by the evolution of heat and light in varying intensities. A fire hazard is any situation in which there is a greater than normal risk of harm to people or property due to fire [2]. Fire hazards can take the form of ways that fires can easily start, such as a blocked cooling vent, or overloaded electrical system, ways fires can spread rapidly, such as an insufficiently protected fuel store or areas with high oxygen concentrations. Fire accidents mostly occur in circumstances that are unexpected. All fire incidents can be divided in many ways depending on the cause of fire outbreak, but broadly there are two types of fires, one is natural and other is manmade [1]. Forest fires can be either due to natural or manmade reasons. All residential and non-residential structural fires are largely manmade. Some of the major fire incidents that occurred in India include:

- A fire breakout in a school at Kumbakonam, TamilNadu on 16th July 2004 resulted in 93 deaths of primary school children.
- Horrific fire at one of Kolkata's posh healthcare facilities (AMRI hospital) killed at least 89 people in November 2011. The victims - nearly all were patients in critical care units - suffocated to death.

Had fires been predicted at their earlier stages the loss of men and material would have been significantly reduced.

1.1 Overview of Proposed Paper

This paper proposes an intelligent system that is capable of detecting fires in commercial buildings with the aid of Image Processing and Artificial Intelligence techniques. Our proposed system is designed to utilize the images captured using CCDP to identify the fire at their initial stages. The images of confined areas with the presence of fires are utilized in training the Radial Basis Function Neural Network as they are less prone to generate false results. Initially, the digital images are converted from RGB to *XYZ* color space and segmentation of the image in *XYZ* color space is carried out with the aid of the anisotropic diffusion approach. For a given *XYZ* color space value of a pixel, the trained radial basis function neural network will identify whether that pixel corresponds to fire region or not. Based on this result an immediate alarm can be raised to the occupants of the building and the fire stations in case of an adverse event.

2. RELATED WORKS

Louis Giglio, Jacques Descloitres, Christopher O. Justice, Yoram J. Kaufman[3] presented an improved fire detection algorithm that offers increased sensitivity to smaller, cooler fires as well as a significantly lower false alarm rate has been presented. The authors made use of the theoretical simulation and high-resolution Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) scenes to establish the performance of their algorithm.

A sensor network was used for real-life forest fire detection in (Vescoukis, Olma et al. 2007). Each sensor node was equipped with a GPS and a thermometer. The authors proposed that each sensor node should be mounted on a tree with a height of at least 3.5m. Since the sensor nodes might be destroyed by fire, a dynamic routing protocol was proposed.

They concluded that a sensor node can sense and transmit data more accurately. In addition, they deduced that if three nodes monitor the same location, fire can more accurately be detected.

In the work done by Angayarkkani. K [4], an efficient forest detection employed to detect forest fires from forest spatial data. This approach makes use of spatial data mining and artificial intelligence techniques for the detection of fires. A fuzzy rule base is formed for the detection of fires, from the spatial data with the presence of fires. The digital images are converted to YCbCr color space, and then segmented to identify the fire regions.

Lim et al. proposed an innovative framework for residential fire detection (Lim, Lim et al. 2007). They introduced metric of interval-message-ration (IMR) and evaluated their framework using the IMR metric. They concluded that the framework is not only applicable for fire-detection but can also be applied for other disaster recoveries.

Another paper proposed by Joydeb Roy Choudhury [5], illustrates a Fuzzy Rule Based Intelligent Security to detect the fire. This paper, analyzes the mechanism of fire-catching process, and implement by using a microprocessor based hardware and intelligent fire recognition software. The author also implemented a fuzzy rule based intelligent early fire detection warning system. The early warning prior to the fault without any ambiguity can avoid the disaster against the fault taking some preventive measures.

3. DESCRIPTION OF TERMINOLOGIES USED IN THE PROPOSED SYSTEM

3.1 Color Space

A color space is a method by which we can specify, create and visualise color [6]. A color is usually specified using three co-ordinates, or parameters. These parameters describe the position of the color within the color space being used. Different color spaces are better for different applications. The commonly used color spaces are: RGB, CMY, CMYK, TV color spaces (YUV and YIQ) CIE XYZ and HSV. RGB, CMY (K) is non–linear with visual perception and device dependent. YIQ, YUV are application specific color spaces and are device dependent. A device dependent color space is a color space where the color produced depends both the parameters used and on the equipment used for display.

CIE, the International Commission on Illumination – abbreviated as CIE from its French title Commission Internationale de l'Eclairage - is an organization devoted to international cooperation and exchange of information among its member countries on all matters relating to the science and art of lighting [7]. The CIE has defined a system that classifies color according to characteristics of the HVS (the human visual system). CIE color spaces are spaces proposed by the CIE and have some properties of high importance like device-independency and perceptual linearity. A color can be described as a mixture of three other colors or "Tristimuli". Typically RGB for CRT based systems (TV, computer) or XYZ (fundamental measurements). A CIE specification will enable a color to be made to match another and can be used to predict visual differences between colors.

3.1.1 CIE XYZ

The CIE XYZ (1931) system is at the root of all colorimetry [6]. It is defined such that all visible colors can be defined using only positive values, and, the Y value is luminance. Consequently, the colors of the XYZ primaries themselves are not visible. The chromaticity diagram is highly non-linear, in that a vector of unit magnitude representing the difference between two chromaticities is not uniformly visible. A color defined in this system is referred to as Yxy. Conversion of RGB image pixel values to the CIE XYZ tri-stimulus values of the color displayed on the CRT can be achieved using a two stage process.

Step 1: Calculate the relationship between input image pixel values and displayed intensity. This relationship is the transfer function, often simplified to gamma.

Step 2: Transform between the displayed red, green and blue to the CIE tristimulus values. This is most easily performed using a matrix transform of the following form:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} \mathrm{Xr} & \mathrm{Xg} & \mathrm{Xb} \\ \mathrm{Yr} & \mathrm{Yg} & \mathrm{Yb} \\ \mathrm{Zr} & \mathrm{Zg} & \mathrm{Zb} \end{bmatrix} * \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

Where X, Y, Z are the desired CIE tri-stimulus values, R, G, B are the displayed RGB values obtained from the transfer functions and the 3x3 matrix is the measured CIE tri-stimulus values for RT's three channels(i.e. Xr, Yr,Zr are the measured CIE tri-stimulus values for the red channel at maximum emission).

3.2 Anisotropic Diffusion

Image segmentation refers to the operation of partitioning an image into separate regions, each of which is homogeneous with respect to some image features [8].Most image segmentation algorithms have been proposed for gray-scale images , while segmentation of color images has received much less attention from the scientific community until recent years. While segmentation using the CIE XYZ color space is perfectly valid and may in fact yield better results than using RGB color space. In our intelligent system, we have employed an anisotropic diffusion approach for the segmentation of fire images. The segmentation is carried out on the XYZ color space converted image.

Anisotropic diffusion (ATD) has become a widely used tool for multi-scale non-linear image processing such as denoising or segmentation. The method is based on the numerical solution of nonlinear partial differential equation on two dimensions image. Anisotropic diffusion in image processing discretizes the family of continuous partial differential equations, which incorporate both the physical processes of diffusion and the Laplacian. Provided that there are no sinks or sources that exist, the following equation illustrates the above mentioned process(for any measurement):

$$\frac{\partial}{\partial t}\mathrm{u}(\bar{\mathrm{x}},\mathrm{t})=\mathrm{div}\big(\mathrm{c}(\bar{\mathrm{x}},\mathrm{t})\nabla\mathrm{u}(\bar{\mathrm{x}},\mathrm{t})\big). \quad (2)$$

Diffusion strength is controlled by$c(\bar{x},t)$. Vector x represents the spatial coordinates. The ordering parameter is the variable t. The function $u(\bar{x},t)$ is considered as image intensity $I(x,t)$

3.3 Artificial Neural Networks

Artificial Neural Networks (ANNs) are non-linear mapping structures based on the function of the human brain [9]. It is a

massively parallel distributed processing system made up of highly interconnected neural computing elements that has the ability to learn and thereby acquire knowledge and make it available for use. They are powerful tools for modelling, especially when the underlying data relationship is unknown. ANNs can identify and learn correlated patterns between input data sets and corresponding target values. After training, ANNs can be used to predict the outcome of new independent input data. ANNs imitate the learning process of the human brain and can process problems involving non-linear and complex data even if the data are imprecise and noisy. Thus they are ideally suited for fire images which are known to be complex and often non-linear.

The neuron has two modes of operation; the training mode and the using mode. In the training mode, the neuron can be trained to fire (or not), for particular input patterns. In the using mode, when a taught input pattern is detected at the input, its associated output becomes the current output. If the input pattern does not belong in the taught list of input patterns, the firing rule is used to determine whether to fire or not. Feed-forward ANNs allow signals to travel one way only; from input to output. In the presented intelligent system, Radial Basis Function Neural Network is employed and is described below.

3.3.1 Radial Basis Function Neural Network (RBFNN):

RBF networks were autonomously proposed by many researchers and are a popular variant to the Multilayer Perceptron MLP. RBF networks are also excellent at modelling non-linear data and can be trained in one stage rather than using an iterative process as in MLP and also learn the given application speedily. The RBF network has a feed forward structure consisting of a single hidden layer of J locally tuned units, which are fully interconnected to an output layer of *L* linear units. All hidden units concurrently receive the *n* - dimensional real valued input vector *X* [10]. The prime difference from that of MLP is the absence of hidden layer weights. The hidden-unit outputs are not computed using the weighted-sum mechanism/sigmoid activation; rather each hidden-unit output Z_j is obtained by closeness of the input X to an *n* -dimensional parameter vector μ_j associated with the j^{th} hidden unit [4]. The response characteristics of the j^{th} hidden unit (j = 1, 2, *J)* is assumed as

$$\mathrm{Z_j} = \mathrm{K}\left(\frac{\left\|\mathrm{X}-\mu_\mathrm{j}\right\|}{\sigma_\mathrm{j}^2}\right) \qquad (3)$$

Where *K* is a strictly positive radially symmetric function with a unique maximum at its 'centre' μ_j and which drops off rapidly to zero away from the centre. The parameter σ_j is the width of the receptive field in the input space from unit j. This implies that Z_j has an appreciable value only when the distance $\|X-\mu_j\|$ is smaller than the width σ_j . Given an input vector *X*, the output of the RBF network is the *L* - dimensional activity vector *Y*, whose l^{th} component (*l* = 1, 2, *L*) is given by

$$\mathrm{Y_l(X)} = \sum_{\mathrm{j}=1}^{\mathrm{J}} \mathrm{W_{lj}}\, \mathrm{Z_j(X)}. \qquad (4)$$

For *l* = 1, mapping of (3) is similar to a polynomial threshold gate. However, in the RBF network, a choice is made to use radially symmetric kernels as 'hidden units'.RBF networks are best suited for approximating continuous or piecewise continuous real- valued mapping $f: R^n \rightarrow R^L$, where n is sufficiently small. These approximation problems include classification problems as a special case. From (3) and (4), the RBF network can be viewed as approximating a desired function $f(X)$ by superposition of non- orthogonal, bell-shaped basis functions. The degree of accuracy of these RBF networks can be controlled three parameters; the number of basis functions used, their location and their width.

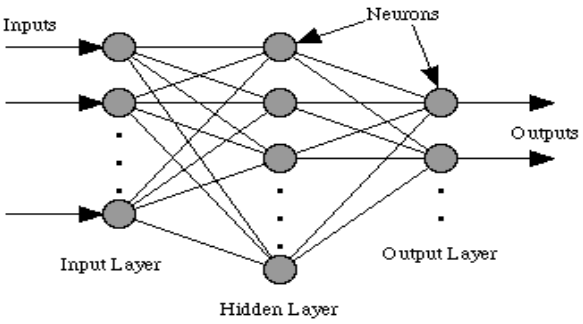

Figure 1

3.4 GSM(Global Communications For Mobile Systems)

GSM (Global System for Mobile Communications) is a global digital mobile communication system, whose coverage is considerably wider and reliability is very high. A GSM modem is a wireless modem that works with a GSM wireless network. A GSM modem can be an external device. Typically, an external GSM modem is connected to a computer through a serial cable or a USB cable. Like a GSM mobile phone, a GSM modem requires a SIM card from a wireless carrier in order to operate [11].Annunciators, which are activated when a fire is detected by the neural network, include audible alarms (eg.,sirens,bells) and multiple messages and voice call.

4. WORKING OF THE PROPOSED INTELLIIGENT SYSTEM

4.1 Steps Involved in Detection Of Fire Occurrence

4.1.1 Training Phase

The Radial Basis Function Neural Network is trained with the images of confined areas with the presence of fires (i.e.) the *XYZ* color space values of the pixels that belong to fire regions.

4.1.2 Image Processing

- The images captured by the CCDP are converted from RGB to *XYZ* color space.
- The *XYZ* color space converted image is segmented using anisotropic diffusion segmentation.

4.1.3 Detection Phase

For a given *XYZ* color space value of a pixel, the trained radial basis function neural network will identify whether that pixel corresponds to a fire region or not.

4.2 Transmitting an Alert on Positive Detection

GSM (Global System for Mobile Communications) is a global digital mobile communication system, whose coverage is considerably wider and reliability is very high. A GSM modem is a wireless modem that works with a GSM wireless network. A wireless modem behaves like a dial-up modem. The main difference between them is that a dial-up modem sends and receives data through a fixed telephone line while a wireless modem sends and receives data through radio waves. A GSM modem can be an external device. Typically, an external GSM modem is connected to a computer through a serial cable or a USB cable. Like a GSM mobile phone, a GSM modem requires a SIM card from a wireless carrier in order to operate [11]. While these GSM modems are most frequently used to provide mobile internet connectivity, many of them can also be used for sending messages and making calls. Annunciators, which are activated when a fire is detected by the neural network, include audible alarms (eg.,sirens,bells) and multiple messages and voice call sent using the telecom path to a fire station and to the central station where operators monitor alarms [12].

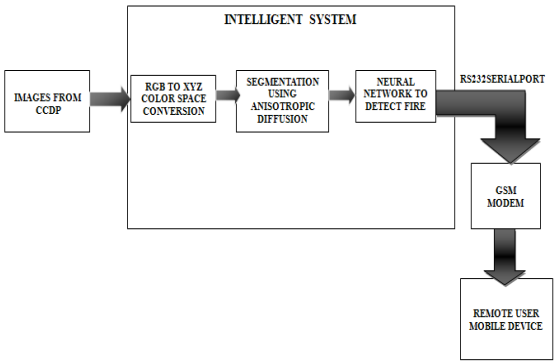

Figure 2-Architecture of Proposed System

5. CONCLUSION

New Fire detection technologies bear the potential to improve the safety of buildings by making a fire warning more reliable and by reducing the false alarm rate. The only effective way to minimize damage caused by fires is their early detection and fast reaction, apart from preventive measures. Hence, the most important goals in fire surveillance are quick and reliable detection and localization of the fire. Information about the progress of fire is also highly valuable for managing the fire during all its stages. Based on this information, the fire fighting staff can be guided on target to block the fire before it reaches other buildings and to suppress it quickly by utilizing the required firefighting equipment and vehicles. Thus the proposed paper aims to detect fire occurrence while it is in its early stages so that it is much easier to suppress a fire and prevent loss of property and invaluable human lives.

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