



A Literature Study on Image Processing for Forest Fire Detection

PRIYADARSHINI M HANAMARADDI

M.Tech-Student

Computer Science and Engineering,
 R V College of Engineering,
 Bangalore, Karnataka, India.

Abstract: Forests can purify water, stabilize soil, cycle nutrients, moderate climate, and store carbon. They can create habitat for wildlife and nurture environments rich in biological diversity. They can also contribute billions of dollars to the country's economic wealth. However, hundreds of millions of hectares of forests are unfortunately devastated by forest fire each year. Forest fire has been constantly threatening to ecological systems, infrastructure, and public safety. In the image processing based forest fire detection using YCbCr colour model, method adopts rule based colour model due to its less complexity and effectiveness. YCbCr colour space effectively separates luminance from chrominance compared to other colour spaces like RGB. The method not only separates fire flame pixels but also separates high temperature fire centre pixels by taking in to account of statistical parameters of fire image in YCbCr colour space like mean and standard deviation. This paper presents a literature study on Image processing for forest fire detection.

Key words: Forest Fire Detection, Image Processing, Colour Model, Colour Space

I. INTRODUCTION

Image processing is processing of images using mathematical operations by using any form of signal processing for which the input is an image, such as a photograph or video frame the output of image processing may be either an image or a set of characteristics or parameters related to the image. Most image-processing techniques involve treating the image as a two-dimensional signal and applying standard signal-processing techniques to it. A **colour model** is an abstract mathematical model describing the way colours can be represented as tuples of numbers (e.g. triples in RGB or quadruples in CMYK).

1. **CMYK Colour Model:** Colours can be created in printing with colour spaces based on the CMYK colour model, using the subtractive primary colours of pigment (cyan (C), magenta (M), yellow (Y), and black (K)). To create a 3-D representation of a given colour space, we can assign the amount of magenta colour to the representation's X axis, the amount of cyan to its Y axis, and the amount of yellow to its Z axis. The resulting 3-D space provides a unique position for every possible colour that can be created by combining those three pigments.
2. **RGB Colour Model:** Colours can be created on computer monitors with colour spaces based on the RGB colour model, using the additive primary colours (**red**, **green**, and **blue**). A 3-D representation would assign each of the three colours to the X, Y, and Z axes. The colours generated on given monitor will be limited by the reproduction medium.

3. **YCbCr Colour Model:** YCbCr is a family of colour spaces. Luminance information is stored as a single component Y. Chrominance information is stored as two colour-difference components Cb and Cr resp. Cb represents the difference between the blue component and a reference value. Cr represents the difference between the red component and a reference value.

II. RESEARCH WORK ON FOREST FIRE DETECTION

The line of sight and the early stage of the fire process problem could be solved with the second type of sensors. A new technology called wireless sensor network (WSN) is nowadays receiving more attention and has started to be applied in forest fire detection. The wireless nodes integrate on the same printed circuit board, the sensors, the data processing, and the wireless transceiver and they all consume power from the same source batteries. Unlike cell phones, WSN do not have the capability of periodic recharging. The sensors are devices capable of sensing their environment and computing data. The sensors sense physical parameters such as the temperature, pressure and humidity, as well as chemical parameters such as carbon monoxide, carbon dioxide, and nitrogen dioxide. The sensors operate in a self-healing and self-organising wireless networking environment. One type of wireless technology is ZigBee which is a new industrial standard based on IEEE 802.15.4. This technology emphasises low cost battery powered application and small solar panels and is suited for low data rates and small range communications. Wireless sensor networks have

seen rapid developments in a large number of applications. This kind of technology has the potential to be applied almost everywhere; this is why the research interest in sensor networks is becoming bigger and bigger every year.

The researchers defined more than 27 mathematical models to describe the fire behaviour where they stated that those models developed according to different countries experience of forest fire and each model is different according to the input parameters and the environments nature (fuel indexing). The researchers of forest fires manage to use some of these models in simulations or even create their own methods to create maps that can be used to analyse the fire behaviour at any time in the future so that they can help the fire fighters to determine the best method to extinguish the fire, such as BehavePlus, FlamMap, FARSITE, Geodatabase, and ArcSDE. On the contrary, researchers are trying to initiate a reliable technology that can detect the fire, localise the fire, and help in decision making in terms of requiring an immediate reaction in case of crisis possibility or a high fire risk situation. As a result, the fire can be extinguished in early stages within a short time to minimise the damage save lives, environment, fire fighter equipment, time and effort.

FIRESENSE (Fire Detection and Management through a Multi-sensor Network for the Protection of Cultural Heritage Areas from the Risk of Fire and Extreme Weather Conditions, FP7-ENV-2009-1-244088-FIRESENSE) is a Specific Targeted Research Project of the European Union's 7th Framework Programme Environment (including climate change).

The FIRESENSE FP7 project aims to implement an automatic early warning system to remotely monitor areas of archaeological and cultural interest from the risk of fire and extreme weather conditions.

FIRESENSE is a very complicated system; it consists of multi-sensors, optical, IR, and PTZ cameras in addition to temperature sensors, and weather stations. In this system, each sensor collects the data and applies some processing techniques and different models and data fusion algorithms in order to provide a clear understanding for the event to the local authority. Demonstrator deployments will be operated in selected sites in Greece, Turkey, Tunisia, and Italy.

This project builds on very complicated scientific models, algorithms, concepts, and comparisons, such as the following.(i)Scene model: the fire and smoke, heat flux or emitted thermal (Planck's radiation formula), the fire flickering, the reflectance, absorption emission lines, and analysis of the atoms (e.g., potassium) and the molecules

(water and carbon dioxide) are characteristics to be investigated.(ii)The background emits the thermal heat, the reflectance of sunlight, the clouds (clouds shadow) the buildings and the sky polarisation.(iii)The atmosphere has a number of gases (N_2 , O_2 , CO , CO_2 , H_2O , etc.); each one has its own absorption and reflection behaviour. Water vapour concentration could vary as a result. Carbon dioxide is more uniformly distributed but its value is larger over industrial cities and vegetation fields than over oceans and deserts.

III. RESEARCH PAPERS RELATED TO FOREST-FIRE DETECTION

Infrared image processing and its application to forest fire surveillance.

This paper describes a scheme for automatic forest surveillance. A complete system for forest fire detection is firstly presented although we focus on infrared image processing. The proposed scheme based on infrared image processing performs early detection of any fire threat. With the aim of determining the presence or absence of fire, the proposed algorithms performs the fusion of different detectors which exploit different expected characteristics of a real fire, like persistence and increase. Theoretical results and practical simulations are presented to corroborate the control of the system related with probability of false alarm (PFA). Probability of detection (PD) dependence on signal to noise ration (SNR) is also evaluated.

The Identification of Forest Fire Based On Digital Image Processing.

In the light of the problem of monitoring forest fire, the design strategy and practical implementation of establishing the fire monitoring system based on digital image information are proposed. The system is based of the continuous image sampling provided by CCD camera. We can obtain the configuration characteristics, dynamic characteristics and color information of interesting region with an application of the digital image processing algorithm, and then to identify the fire source according to the acquired characteristics. The experimental results show that the system can accurately identify and confirm the fire. Besides, the amount of data processed can be reduced because of the use of sampling algorithm thus shortening the execution time.

UAV-based Forest Fire Detection and Tracking Using Image Processing Techniques.

In this paper, an unmanned aerial vehicle (UAV) based forest fire detection and tracking method is proposed. Firstly, a brief illustration of UAV-based forest fire detection and tracking system is presented. Then, a set of forest fire detection and tracking algorithms are developed including median filtering, color space conversion, Otsu

threshold segmentation, morphological operations, and blob counter. The basic idea of the proposed method is to adopt the channel “a” in Lab color model to extract fire-pixels by making use of chromatic features of fire. Numerous experimental validations are carried out, and the experimental results show that the proposed methodology can effectively extract the fire pixels and track the fire zone.

IV. EXISTING WORK

1. **SENSORS:** Nowadays almost all the fire detection system uses sensors. The accuracy, reliability and positional distributions of the sensor determine the betterment of the system. For high precision fire detection systems, large numbers of sensors are needed in the case of outdoor applications. Sensors also need a frequent battery charge which is impossible in a large open space. Sensors detect fire if and only if it is close to fire. This will lead to damaging of sensor.
2. **COMPUTER VISION BASED SYSTEMS:** These replace conventional fire detection systems, due to the rapid development of digital camera technology and video processing. Computer vision based systems use three stages.
 1. Flame pixel classification.
 2. Segmentation of moving object.
 3. Analysis of the candidate region.

The performance of the fire detection system depends on the performance of the fire pixel classifier which generates major areas on which rest of the system operates. Thus a precise fire pixel classifier is needed with high true detection rate and less false detection rate. However there exist some algorithms which directly deals with fire pixel classification. The fire pixel classification can be considered in both in gray scale and colour video sequences.
3. **CCD CAMERAS:** Low cost CCD cameras are used to detect fires in the long range passenger aircraft. This method employs statistical features mean, standard deviation and second order moments along with the non-image features such as humidity and temperature. The system can also be used in smoke detector to reduce the false alarm. The system also provides visual inspection capability to confirm the presence or the absence of fire for the aircraft crew.

Related development

- i. T.Chen et al. [2], developed a set of rules to separate the fire pixels using R, G and B

information.

- ii. B.U. Totryin et al. [3] used a mixture of Gaussians in RGB colour space which is developed from a training set of fire pixels, instead of using a rule based colour model in [2].
- iii. B.U. Totryin et al.[4] employed a hidden markov models to detect the motion characteristics of the fire flame that is fire flickering along with the fire pixel classification.
- iv. G. Marbacr et al.[7] used YUV colour space for the representation of video data, where the candidate fire pixels are obtained by the derivative of the luminance component Y and the candidate fire pixels are confirmed by using the information from the chrominance components U and V. But in this method the number of test conducted was not mentioned.
- v. Wen- Homg et al. [8], used HSI colour model to separate the fire pixels. They have developed the rules for brighter and darker environments. After segmenting the fire region based on HSI rules the lower intensity and lower saturation pixels are removed to avoid fire aliases (fire like region). They also formed a metric based on binary counter difference images to measure the burning degree of fire flames such as no fire, small, medium, and big fires. Their result includes false positives and false negatives. But there is no way to reduce the false positives and false negatives by changing their threshold value.
- vi. T. Celik et al. [5] formed number of rules using normalized (rgb) values in order to avoid the effects of changing illumination. In this method statistical analysis is carried out in rg, rb and gb planes. In each plane three lines are used to specify a triangular region representing the region of interest for fire pixels. A pixel is declared as fire pixel if it falls in to the triangular region of rg, rb and gb planes. Even though the normalized RGB colour space overcomes the effects of variation in illumination to some extent further improvement can be achieved by using YCbCr colour space which separates luminance from chrominance.
- vii. Turgay Celik et al. [9] proposed a generic colour model to segment the flame pixel from the background using YCbCr colour model. This method segments the flame region except the flame centre. But this method classifies fire pixels only based on colour information.

- viii. Vipin V[10] proposed a model to segment the fire from the image which uses RGB and YCbCr colour space. This method does not work well under all environmental conditions and is not reliable.

Open source tools for image processing

1. OPENCV

OpenCV(Open source computer Vision) is a library of programming functions mainly aimed at real-time computer vision, originally developed by Intel research center in Nizhny Novgorod(Russia), later supported by Willow Garage and now maintained by Itseez. The library is cross-platform and free for use under the open-source BSD license. The first alpha version of OpenCV was released to public at the **IEEE Conference on Computer Vision and Pattern Recognition** in 2000. OpenCV is written in C++ and its primary interface is in C++ , but is still retains a less comprehensive though extensive older C interface. There are bindings in Python, Java and MATLAB/OCTAVE. The API for these interfaces can be found in the online documentation. Wrappers in other languages such as C#, Perl, Ch, and Ruby have been developed to encourage adoption by a wider audience. OpenCV runs on a variety of platforms.

2. VTK

The Visualization Toolkit (VTK) is an open-source, freely available software system for 3D computer graphics, image processing and visualization. VTK consists of a C++ class library and several interpreted interface layers including Tcl/Tk, Java, and Python. **BSD license**

3. ITK

ITK is an open-source, cross-platform system that provides developers with an extensive suite of software tools for image analysis. Developed through extreme programming methodologies, ITK employs leading-edge algorithms for registering and segmenting multidimensional data. **Apache 2.0 license**

4. FSL

FSL is a comprehensive library of analysis tools for FMRI, MRI and DTI brain imaging data. FSL is written mainly by members of the Analysis Group, FMRIB, Oxford, UK. FSL runs on Apple and PCs (Linux and Windows), and is very easy to install. Most of the tools can be run both from the command line and as GUIs ("point-and-click" graphical user interfaces). **license**

5. SPM

Statistical Parametric Mapping refers to the construction and assessment of spatially extended statistical processes used to test hypotheses about functional imaging data. These ideas have been instantiated in software that is called SPM. The SPM software package has been designed for the analysis of brain imaging data sequences. The sequences can be a series of images from different cohorts, or time-series from the same subject. The current release is designed for the analysis of fMRI, PET, SPECT, EEG and MEG. **GPL license**

6. GIMIAS

GIMIAS is a workflow-oriented environment for solving advanced biomedical image computing and individualized simulation problems, which is extensible through the development of problem-specific plug-ins. In addition, GIMIAS provides an open source framework for efficient development of research and clinical software prototypes integrating contributions from the Physiome community while allowing business-friendly technology transfer and commercial product development. GIMIAS has functionalities for manual and automatic segmentation, visualization, mesh editing and electro mechanical and CFD simulation among others. **BSD license**

7. 3DSlicer

Slicer, or 3D Slicer, is a free, open source software package for visualization and image analysis. 3D Slicer is natively designed to be available on multiple platforms, including Windows, Linux and Mac Os X. **BSD license**

8. MIA

MIA is a general purpose image processing toolbox written in C++ that puts its focus on 2D and 3D gray scale medical image analysis. It is designed around a plug-in infrastructure that makes adding new functionality easy, uses a test-driven development to ensure reliability of the implementation, and provides command line tools as a means for algorithmic prototyping based on interactive execution of image processing tasks and their combination in shell scripts. **GPLv3+ license**

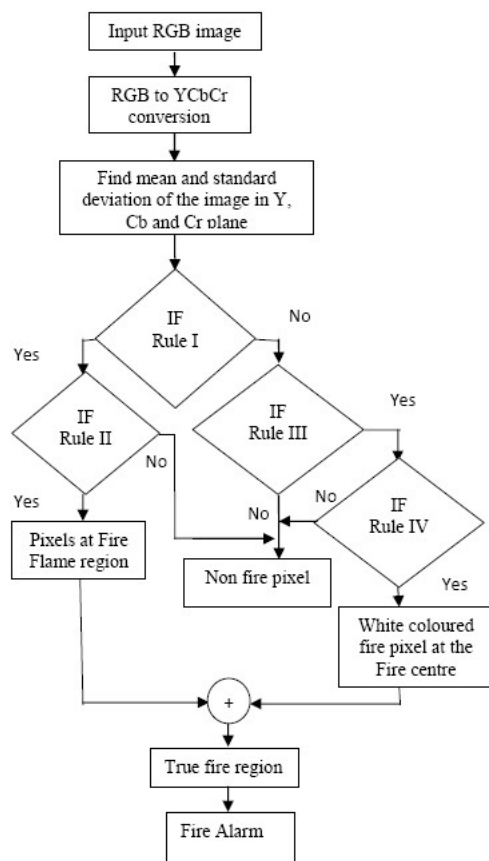
V. IMAGE PROCESSING FOR FOREST-FIRE DETECTION USING YCbCr COLOUR MODEL

The YCbCr Detection Method uses YCbCr colour space. Because YCbCr colour space separates luminance information from chrominance information than other colour spaces. For fire pixel classification, four rules (Rule I, Rule II, Rule III,

and Rule IV) are formed. The colour of the fire at the high temperature centre region is white. However the colour of the fire in the region except the centre region is of the colour that varies from red to Yellow. Among the four rules used in the proposed method, Rule I and Rule II are used for the segmentation of fire flame region. Rule III and Rule IV are used for the segmentation of centre fire pixels (high temperature region). Finally the image obtained by satisfying Rule I & II and the image obtained by satisfying Rule III & IV are added to get the true fire image.

Understanding the system using flow chart

This section deals with the proposed fire pixel classification method. The flow chart for the proposed method is given below. It uses YCbCr colour space. For fire pixel classification, four rules (Rule I, Rule II, Rule III, and Rule IV) are formed. Rule I and Rule II are used for the segmentation of fire flame region. Rule III and Rule IV are used for the segmentation of centre fire pixels (high temperature region). Finally the image obtained by satisfying Rule I & II and the image obtained by satisfying Rule III & IV are added to get the true fire image.



Flow Chart of Fire Detection System

Firstly a RGB image is considered as input and it is converted in YCbCr image and once that image is obtained the mean and standard deviation of the

image in Y, Cb and Cr plane is calculated then to that image rule I is applied. If rule I can be successfully applied then apply rule II on the image obtained after applying rule I. Then conclude that that image is fire pixel image. If not then apply rule III on the YCbCr image and then rule IV on the image obtained after applying Rule I II. If the rules III and IV are successfully applied then conclude the image as fire centre image. If none of the rules can be applied then conclude that the image is a non-fire image. Once image satisfying Rule I and II is obtained add it with the image that has been obtained by satisfying Rule III and IV and obtain the true fire region image and trigger the fire alarm

Formal Analysis

The method is, YCbCr colour model for flame pixel classification using statistical feature of the fire image i.e, mean and standard deviation because in YCbCr colour space, the relation between pixel is more compared to other colour models. The centre of the flame is white in colour like cloud. We developed a new rule to segment the fire centre from the background in YCbCr colour space. The proposed method was tested for nearly 800 images collected from the internet with different illuminations. Compared to the previously introduced flame pixel classification methods, the proposed method detects fire with high true detection rate and low false detection rate. The proposed method gives 99.2% true detection rate. The proposed method provides significant improvement over other methods used in the literature.

VI. PERFORMANCE ANALYSIS

Performance of the proposed fire detection system is compared with the different models.

The model defined by Chen et al. [2] uses RGB colour space and rules are formed in RGB colour space. Celik et al. [5] uses rgb values to identify the fire region. Turgay Celik et al. [9] uses YCbCr colour space to segment the fire flame pixel from the RGB image. But all the above discussed methods do not separate the high temperature fire pixels in the fire centre region. Analysis is carried out using more than thousands of images. This fire set consists of flame like objects such as sun, red coloured car, red rose etc. Table 3 shows fire flame detection rates of other methods and the proposed method. Celik et al. proposed a method which uses rgb values that shows better detection rates than the method proposed by Chen et al.using RGB values. Turgay et al. [9] proposed a method using YCbCr colour space that produces improved detection rate. Vipin V [10] proposed a model to segment the fire from the image which uses RGB and YCbCr colour space. This method is not reliable under all situations. The proposed method effectively segments fire flame and the high temperature fire

centre (white coloured region) with high detection rate and low false detection rates.

VII. CONCLUSIONS

The proposed system uses YCbCr colour spaces. Because YCbCr colour space separates luminance from chrominance, hence it is robust to changing illumination than other colour spaces like RGB and rgb (normalized RGB). The proposed method not only separates fire flame pixels but also separates high temperature fire centre pixels by taking in to account of statistical parameters of fire image in YCbCr colour space like mean and standard deviation. It uses four rules to classify the fire pixels. Two rules are used for segmenting the fire flame region and two rules are used for segmenting the high temperature fire centre region.

The proposed method is tested on three set of images. First set contain fire. Second set contain fire like regions. The third set contain fire centre like regions. Computational complexity of the proposed system is very less, hence it can be used for real time forest fire detection. The proposed system achieves 99.4% fire detection rate and 12% false alarm rate. The proposed method was compared with other methods in the literature and demonstrates superior performance in terms of higher fire detection rate and less false alarm rate.

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