GIS based real time assessment of wildfire and other changes in a forest: A review

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Abstract. Global warming has been one of the major concerns of the century. The causes of this problem are the green-house gases. Due to the manmade mistakes the carbon dioxide (CO_2) emission has reached highest of its level in recent years. Forest fires, haze and deforestation have contributed in increasing the CO_2 emissions to the atmosphere. Diagnosing these problems in the initial stage would definitely avert the major losses. This paper deals on detecting the changes in forest scenarios due to fire, felling of trees, etc. using a Geographical Information System (GIS) information analysis system using a pattern recognition concept, and detect the unusual changes and alert the system in early stage.

1. Introduction

South Asia pacific countries have been found suffering due to the haze conditions frequently. Haze level in Malaysia on 9th Feb 2014 reached the level from 29 to 167 (unhealthy level). Blazes are deliberately lit every year to clear land for palm oil and wood pulp plantations. Haze from fires on Sumatra is an annual problem in Southeast Asia [20]. Hundreds of the haze-causing agricultural fires burning in western Indonesia's Riau province are occurring on land managed by timber, palm oil and logging companies. Figure 1 briefs the data on the logging of trees in a rich forest from logging to plantations.
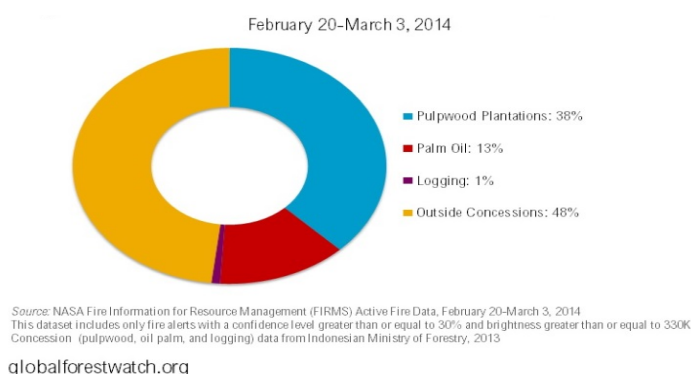

Figure 1. Fire alerts by land use area, Sumatra, Indonesia.

The major threat of the century is global warming. Annually the carbon dioxide (CO_2) emission has reached an alarming stage of spewing of 32 Billion Tons of CO_2 to the atmosphere [19]. The man made inventions and mistakes have contributed in adding a greenhouse gases to the atmosphere. Human activities contribute to increase the emission of greenhouse gases. This is due to the

transportation, industrialization, energy sectors and deforestation carried out for farming, or due to forest fires and mining activities.

2. Deforestation: modern day plague
The remains of forests cover 30% of the land. Deforestation is the process whereby natural forests are cleared through logging and/or burning. Deforestation is clearing forests in large scale. At the current rate the world's rain forest would be vanished in hundred years. The cause is due to the factors like wildfires, overgrazing which may prevent the growth of young trees. Deforestation negatively effects the environment such as loss of habitats, trees. Trees also play a critical role in absorbing the greenhouse gases that fuel global warming. A larger green-house gas can be expected with fewer forests and thus inducing a climate change [21]. Earth's climate is changing. The results so far are as follows:

- Global temperature have risen 5° C
- Glaciers have melted and retreated dramatically
- Ecosystems around the world are being altered

2.1. Carbon dioxide emissions
Healthy forests help absorb greenhouse gasses and carbon emissions "Tropical forests hold more than 210 Giga tons of carbon, and deforestation represents around 15 percent of greenhouse gas emissions," according to the [22]. Major players for carbon emissions are Electricity and heat (24.9%), Transportation (14.3%), Industry (14.7%), deforestation (11.3) and afforestation is -0.4 %, as shown in the figure 2.
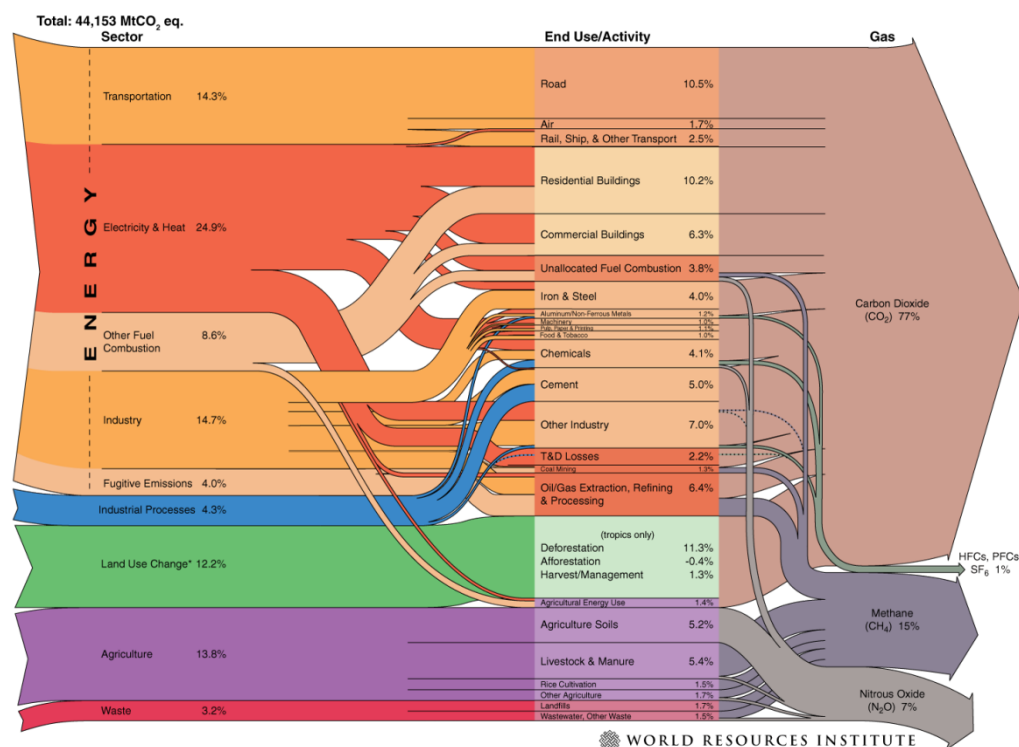

Figure 2. World greenhouse gas emissions in 2008.

Some other statistics:
- About half of the world's tropical forests have been cleared [23].
- Forests currently cover about 30 percent of the world's land mass [24].
- Forest loss contributes between 12 percent and 17 percent of annual global greenhouse gas emissions (Figure 2).

3. Tracking system for changes in forest

The menace of damages made to the forest by the humans is mainly due to felling of trees, fire, poaching, farming etc have some imbalancing effects on the eco system. There is a need of an accurate real time system which will detect the changes in forests at an early stage and alert the concerned authorities to enact. Equally educating people, governance, and legal actions are also necessary to avoid the forest accidents. Many government, state, and private forestry organizations and agencies today utilize geospatial technology such as Geographical Information System (GIS) and remote sensing for various applications supporting analysis, assessment, and management of our forests. The geospatial technologies help in the detection of forest fires, analysis of deforestation and felling of trees, prevention of poaching etc.

4. Geographical information systems (GIS) and wildfire prevention

The first known use of the term "Geographic Information System" was by Roger Tomlinson in the year 1968. A geographical information system integrates the use of hardware and software to acquire, store, analyze, manipulate, manage and represent geographic information. The basic applications of a GIS involve geographical mapping, meteorological survey, study of ecology and geology, natural resource management (oil, gas, forestry etc), disaster management, sociology, archeology, defense, intelligence, public safety (i.e emergency management and criminology), global positioning systems and regional planning. Earth's natural and man-made features are represented in spatial data form. A GIS references these real-world spatial data elements to a coordinate system. These features can be separated into different layers; a GIS system stores each category of information in a separate "layer" for ease of maintenance, analysis, and visualization [8]. A GIS can be classified into four categories which are not necessarily mutually exclusive.

- Four Dimensional GIS: Designed to analyse the geographical data with three dimensions of space and one dimension of time.
- Multimedia and Hypermedia GIS: Facilitates an access to a wide range of geo-referenced multimedia data by selecting resources from a geo-referenced image map base.
- Web GIS: A web based GIS which allows the user to access new forms of multimedia geo-representations on the web.
- Virtual Reality GIS: Utilises Virtual Reality Modelling Language (VRML) to create, manipulate and explore geo-referenced virtual environment.

When it comes to wildfire management, GIS provides accurate and comprehensive information to analyse, visualize, and prioritize values at risk, such as housing developments, utility infrastructure, wildlife, and natural or cultural resources. Within the scope of wildfire management, wildfire prevention comprises of all the activities that can be performed in order to reduce or prevent wildfire occurrences as well as to minimise wildfire potential impacts and damage. For the purpose of mitigation a GIS plays a vital role in mapping fire-prone areas, monitoring fuel load and risk modelling; for preparedness and response it helps in fire detection, predicting spread/direction of fire, early warning and coordinating fire-fighting efforts. For recovery a GIS can be used as a damage assessment tool useful for mapping the extent of burn, understanding biological responses due to differential surface heating (i.e fire severity) and quantifying extent and pattern of burned areas.[10]

This paper provides an overview of the real time system in identifying the fires and changes in the forest land. The intension is to avoid massive damages caused due to the bush fire or wild fire which is needed to be identified at the smaller scale and alert the concerned system. The system is intended to

identify the felling of trees, illegal logging, and alert the system. Here an important thing to be noticed is fire to be pointed at the early stage and the location and alert the system, as soon the accident occurs. The watching of the forest area, capturing of images, comparison with test case image and the standard image is done iteratively for round the clock.

5. Image processing for wildfire detection

Image processing is the study of any algorithm that takes an image as input and returns an image as output. The image processing involves image display and printing, image editing and manipulation, image enhancement, feature detection and image compression. Latest advancements in digital camera technologies and content based video processing have led to the development of sophisticated vision based fire detection systems. The two major categories for wildfire detection are sensor based systems and image based systems.

5.1. Colour models for fire and smoke

Images with fire or smoke samples are analysed in order to create colour models. The rules defined for *RGB* colour space to detect possible fire pixel [1][2][5] are transformed into *YCbCr* for analysis. The implicit fuzziness in the rules obtained from repeated experiments and the impreciseness of the decision variable can be encoded in a fuzzy representation [3]. The output is expressed as a number between 0 and 1which will give the probability that a pixel is a fire-pixel or smoke-pixel.

Figure 3 explains different stages of the fire alerting system. *RGB* image is converted to *YCbCr* and the data is analysed by a predefined fuzzy logic rule set.
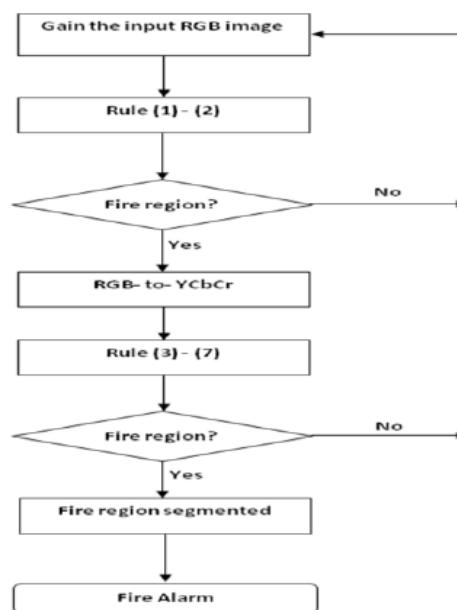

Figure 3. Flow chart of algorithm for forest fire detection [7].

For detection of fire pixel the greater the difference between *Y(xy)* and *Cb(xy)* components of pixel higher the probability that it is a fire pixel because the luminance information which is related to the intensity is naturally expected to be dominant for a fire pixel.
Hence for a fire pixel to exist-

$$Y(x, y) \geq Cr(x, y) \geq Cb(x,y) \qquad\qquad (1)$$

Table 1 represents the fuzzy logic rule set used to encode impreciseness of the decision variable.

Table 1. Rule table for fuzzy interference system [3].

$P_f(x,y)$		$Cr(x,y) - Cb(x,y)$			
		NS	**PS**	**PM**	**PB**
$Y(x,y)-Cb(x,y)$	**NS**	LO	LO	LO	LO
	PS	LO	LO	HI	HI
	PM	LO	HI	HI	ME
	PB	LO	ME	ME	ME

Smoke pixels are formulated as follows,

$$|R(x\ y)- G\ (x\ y)|\leq Th$$
$$|G\ (x\ y)- B\ (x\ y)|\leq Th \qquad (2)$$
$$R\ (x\ y)- B(xy)\leq Th$$

where *Th is* a global threshold ranging from 15 to 25.

The smoke pixels however do not show chrominance characteristics like fire pixels. At the beginning, when the temperature of the smoke is low, it is expected that the smoke will show colour from the range of white-bluish to white. Toward the start of the fire, the smoke's temperature increases and it gets colour from the range of black-grayish to black. Most smoke samples have a grayish colour. Thus recognition of fire and smoke pixel can be carried out using colour model.

6. Satellite and aerial remote sensors
Satellite Imaging Corporation provides advanced remote sensing techniques, multi-spectral and panchromatic image data processing services (including orthorectification), haze reduction and removal, pan sharpening, image enhancements, geo-referencing and mosaicing, and color/grayscale balancing. Optional satellite imaging features may incorporate specialized processing procedures, which are used to analyze land cover and change detection, extraction of culture data, normalized difference vegetation index (NDVI) classification and mapping, lithological classification, environmental analysis, urban development, and monitoring emergencies[25].

6.1. Detection of abnormalities
The task is to develop a pattern recognition system for the detection of abnormalities in the images. The goal is to classify the images into number of categories or classes. The system will be presented with satellite images and it must detect the abnormalities in the image if found such as fire/smoke/felling of trees/new plane land. The proposed method of forest fire detection uses the statistical approach of pattern recognition that requires careful attention to the issues such as the image acquisition, definition of pattern classes, pattern representation, feature extraction and selection, clustering and segmentation, classifier design and learning, selection of training and test samples, and performance evaluation and analysis [13][2][3][12][16].

6.1.1. Statistical pattern recognition
Most of the commercial pattern recognition systems use statistical pattern recognition in which a pattern is represented by a set of n features, or attributes, viewed as a n-dimensional feature vector [11]. The effective way of establishing decision boundaries between the pattern classes is very important here. The proper use of statistical decision theory is expected to establish decision boundaries effectively. The recognition system is operated in either training (learning) or classification (testing) [4][11].

The input image is preprocessed for example, color domain transformation, filtering etc (Figure-4). The background removal requires certain initialization. The basic background modeling or statistical technique or soft-computing technique can be used to model the background in a known background environment. In order to address issues in foreground extraction, the background removal techniques are used. The extracted object is classified to a class (for example, a fire or smoke) using a classifier. A qualitative and quantitative evaluation of existing state of the art techniques and proposed technique is done. The qualitative parameters include noise, clouds, obstructions and camouflage. Quantitative parameters such as precision is considered [12].
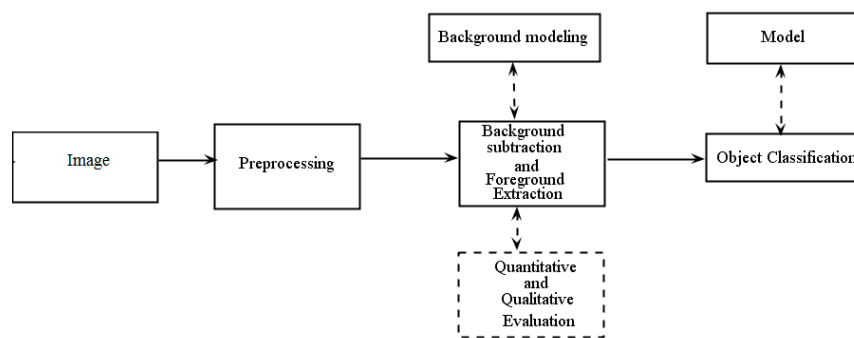

Figure 4. Feature extraction for classification of fire and smoke.

To determine the similarity between two entities (points, curves, or shapes) of the same type template matching is used. In template matching, a template (typically, a 2D image) of the test image or a prototype of the pattern to be recognized is available. The feature comparison between test image and standard image would be performed by classifiers such as Euclidean distance classifier, or KNN for different values of *k* [13].

Euclidean distance:

$$d(x,y) = |x - y| = \sqrt{\sum_{i=1}^{n} (xi - yi)^2}$$

(3)

The available training set is used to optimize the similarity measure. Because the template matching is computational intensive process, the high end processing systems are used for this. The success of the template matching depends upon the image quality, change of the viewpoint and intra class variations among the patterns. If the deformation is difficult to explain or to model, deformation template models or rubber sheet deformations can be used for pattern matching [14].

The benefit of considering the static state of the background image is that in the method of background subtraction, intact target region can be extracted, however if the background image is not updated in time, the extracted target may be vague and inaccurate. For forest environment, the whole scene does not keep still due to waving trees, changing weather, varying light, moving shadow, shaking camera, and so on. Therefore, compared with moving estimation, color based segmentation is more suitable for forest fire extraction [16]. Celik et al. [2] described the color features of fire in RGB color space, and decided whether one pixel belongs to the fire region.

6.1.2. 3D color model for segmentation
The 3D color model can be used in the process of segmentation. For segmentation of possible flame regions, color values of each pixel in an image are checked with a pre-determined color distribution, which represents the range of possible fire colors in a color model such as RGB space. As shown in Figure 5, the flame pixels are segmented manually from the fire regions of sample images.
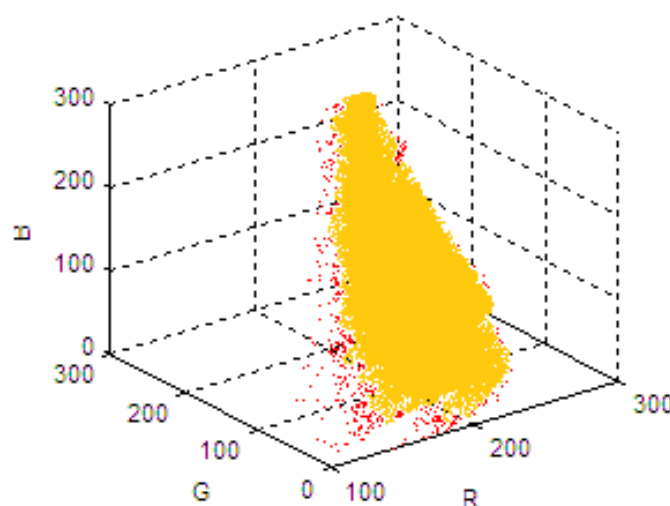

Figure 5.3D color model for image segmentation [2].

The threshold values along R, G and B axis can be used to define a rough space for fire color. To build a more precise color model, 3D shape of the point cloud is represented by Gaussian mixture model (GMM), and the pixel whose color within the range of the GMM distribution model can be taken as a candidate fire pixel [16].

7. Real time forest monitoring system (RFS)
The system involves pattern recognition, features extractions and pattern matching techniques (Figure 6). The satellite image is monitored for every n seconds depending on the season and features of the new case image are extracted. The sample test case (image) features are then compared with a standard image features, by the pattern matching techniques. The system with compare and analyse the proximity value of the test case and standard case and decides the situation is normal or abnormal. If abnormal, then the alerting system is activated and send an alerting message to the concerned people such as ministry/police/forest/disaster management departments [9][12][13][14].

The task is to develop a pattern recognition system for the detection of abnormalities in the images. Classification of the images in to number of categories or classes is the main goal in this task. The

system will be presented with satellite images and it must detect the abnormalities in the image if found such as fire/smoke/felling of trees/new plane land.
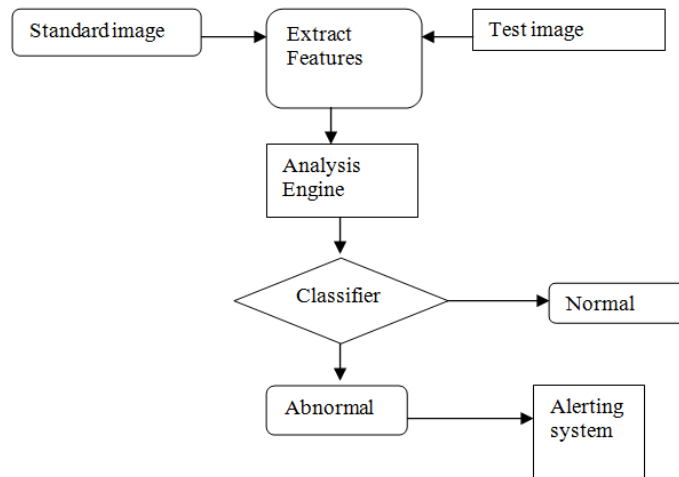

Figure 6.RFS flowchart.

The first stage is to capture the image, and the next stage involves the image processing steps such as image enhancement in order to assist the system by presenting it only useful information for further analysis. The feature selection and extraction is the next stage and the numerical values are used in comparing the features of the standard image (Figure 7). The distance between these image features would yield a decision of the conditions normal or abnormal. The similarity between two feature vectors and choosing an appropriate measure for it determines the result of the image.

Figure 7.Standard image vs test image [26].

There are five possible cases. The pattern recognition system can be designed around a single classifier, which assigns unknown image directly to one of the five classes of the tree structure as shown in figure 8. A separate classifier was used for each node, and each of them perform a decision in two ways normal and abnormal cases. The second node indicts the image as a normal one, are tested

and classified in either smoke, or fire or plane land (new portion in the image) and so on. The similarity in vectors would be measured by the Euclidean distance [13].
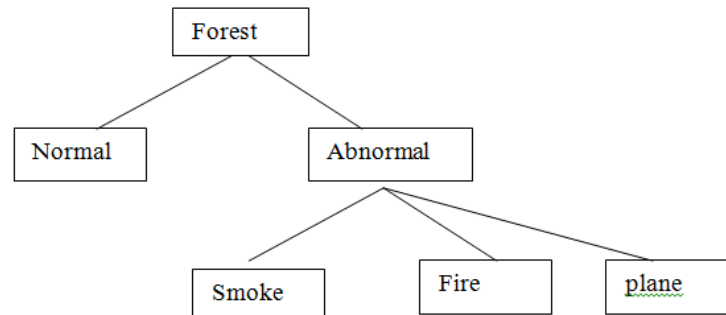
Figure 8. Pattern recognition classes.

7.1. Template matching

The matching of test image template with features matrix, with the standard image template features matrix with certain measure is determined the process of decision making. A first step is to define a measure or a cost measuring the distance or the similarity between the known reference patterns and the unknown (test pattern) which is a pattern matching process yielding % match. Each pattern is expressed in terms of vector matrix with selected features, the distance measure is here is the Euclidean distance.

A similarity measure between two vectors SM_{xy} can be defined as,

$$SM_{xy}= \ 1/ \ (1+ \ \alpha d_{xy}) \qquad (4)$$

where α is a positive constant. The higher the value of d_{xy}, the lower the similarity between vector x and y [18].

The minimum distance between test vector and standard vector is considered as the most matching vector. Higher the distance indicates the abnormalities indication with reference to the new image and the system classifies it as an abnormal case. Further analysis was performed to determine the last set of classification in deciding whether smoke or fire or plane land. Based on the final decision an alerting system would be activated if the decision falls on the abnormal class. Once the abnormality is detected by the RFS system, an alerting mechanism is activated to alert the authorities. In crisp, if any untoward incident in forest, such as fire, smoke, felling of trees etc, RFS detects the changes observed in the test images received form satellite and analyse the condition whether normal or abnormal. This capturing of image and analysis would be carried out in n seconds depending on the season, moisture content, rain, etc.

8. Conclusion

In order to reduce the ill-effects of deforestation, certain measures such as early detection of abnormalities by using the detection and analysis models and focusing on indicating the abnormalities are considered. The models can be extended for applications such as obtaining census data for endangered animals like elephants, tigers etc.

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