A generic Framework for Landmine detection using statistical classifier based on IR images

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Abstract -Landmine detection with passive infrared images can depend quite heavily on the environmental conditions, and there are cross over periods when the thermal contrast is negligible and the mines may be undetectable. Conventional antipersonnel mine detection has not evolved the perfect betterment in the methodological process. Here a generic framework is proposed using most adaptable methods and techniques. The IR captured image is being used for the detection and identification of buried targets by adopting high efficiency and better reliability image processing techniques for landmine detection. Results on diverse landmine data, collected using IR sensors show that the adopted method can identify meaningful and coherent clusters and that different expert algorithms can be identified for the different contexts. The initial experiments have also indicated that the need of preprocessing the images will highly increase the individual classifier performance. In future, the sensing technology can also be combined with processing power and wireless communication to make it profitable for various types of security threats.

Keywords- landmine detection, KNN classifier, h-maxima, IR images, feature extraction

I. INTRODUCTION

Mine detection using infrared techniques is primarily based on exploiting temperature and/or spectral color differences between pixels on the mines and background pixels[6][9]. In case of surface mines, temperature differences are introduced by the differential thermal mass and thermal inertia of the mine body itself with respect to the surrounding background, while color phenomena are based on the spectral reflectance characteristics of the surface materials on the mine (painted metal, plastics, etc.)[1]. The use of spatial information (e.g., size, shape, pattern) can provide additional discriminants, particularly if the mines are resolved into multiple pixels by a high-resolution imaging sensor. An effective mine detection system is proposed here that is capable of handling spectral and spatial differences for discrimination [7]. Various mine detection techniques are reviewed with particular emphasis on image processing methods. A set of image processing techniques including filtering, enhancement, feature extraction, and segmentation are surveyed. Segmentation is used to extract mine signal from various competing signals. Most of the image processing techniques covered here are mine detection related experimental results. The paper is organized as follows: Section 2 deals with the construction of the framework for landmine detection. Section 3 deals with the preprocessing the image before detection. Section 4 converses the proposed algorithm for detecting the landmine with high probability of detection. Section 5 and 6 converse the feature extraction and classification phase in which different landmines are recognized. Section 7 explains the experimental results and findings of the landmine objects. The paper concludes with the need and the future work of the system.

II. PROPOSED FRAMEWORK FOR DETECTION SYSTEM

This proposed framework combines the existing and recent techniques of image processing techniques for recognizing landmines. The output of the system delivers a Matlab-based application development platform intended for detection system. It allows the user to investigate, design, and evaluate algorithms and applications using landmine images. It offers standardized, which do not require detailed knowledge of the target hardware. The proposed figure is given if figure 1

III. PREPROCESSING

The most serious problem in mine-detection applications is the ambiguity of the target signal due to low contrast. In order to enhance contrast, noise removal and edge detection have been surveyed and used. Although these two methods are used in general image processing applications, specific mine signals have been used to evaluate performance of the two methods. According to the literature additive Gaussian White Noise is being eliminated using linear filters for IR images. They are as follows (i) Laplacian of Gaussian (LoG)

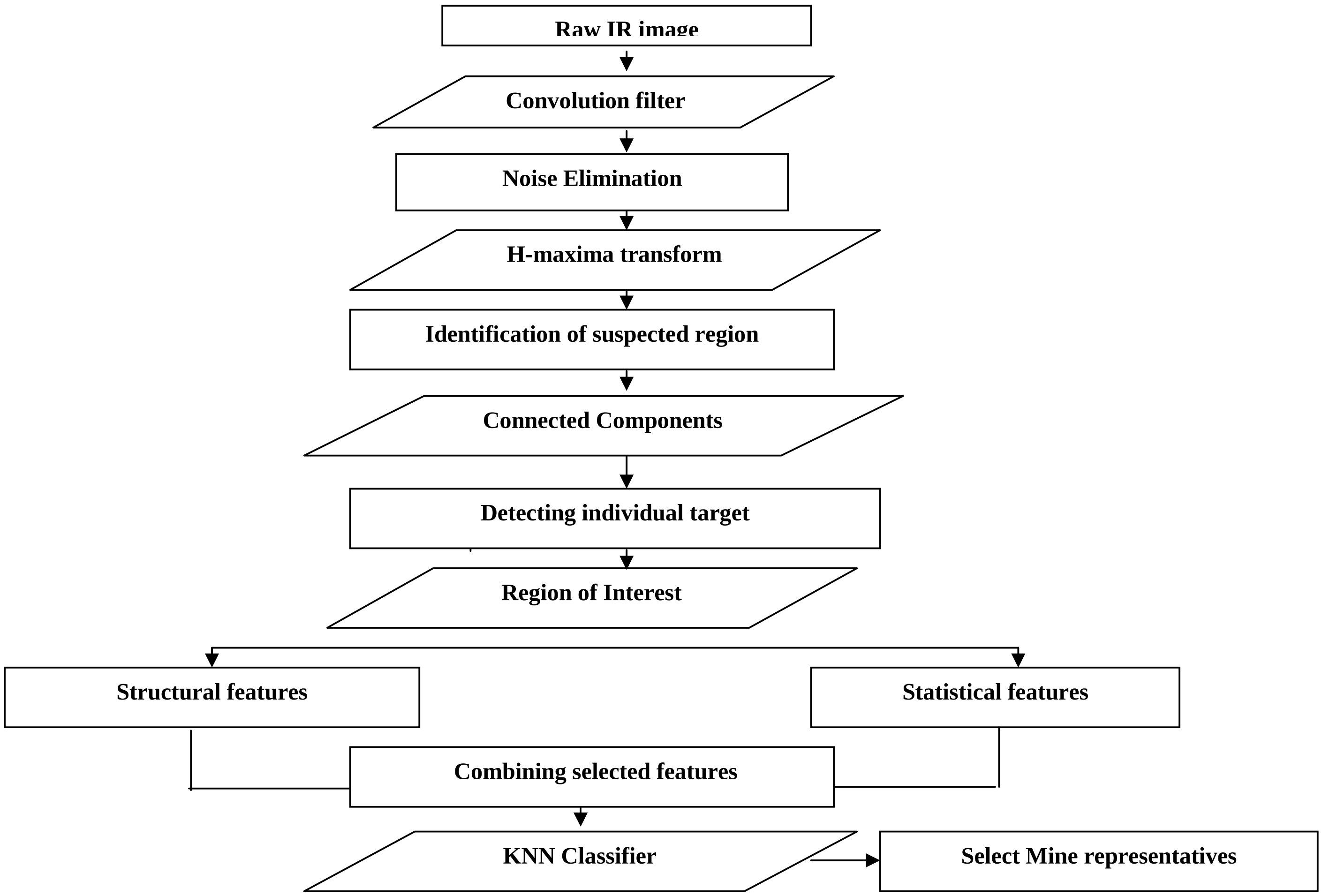

Figure 1: Proposed Framework for landmine detection

(ii) Gaussian Filter (GF) (iii) Mean Filter (iv) Circular Averaging Filter (v)Unsharp Masking Filter.Experimental results prove that Gaussian filter outperforms the rest of the related filters.

A. Noise removal using Gaussian Filter (GF)

Gaussian low pass filter is the filter which is impulse responsive, Gaussian filters are designed to give no overshoot to a step function input while minimizing the rise and fall time. Gaussian is smoothing filter in the 2D convolution operation that is used to remove noise and blur from image. In this sense it is similar to the mean filter, but it uses a different kernel that represents the shape of a Gaussian (`bell-shaped') hump. In 2-D, an isotropic (*i.e.* circularly symmetric) Gaussian has the following form

$$G(x,y) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

B. Edge detection using sobel filter

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 center of the matrix area. However, the majority of different methods may be grouped into two categories: Gradient, Laplacian. The Sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial gradient that correspond to edges. Typically it is used to find the approximate absolute gradient magnitude at each point in an input grey scale image. For a continuous function f(x, y), in the position (x, y), its gradient can be expressed as a vector (the two components are two first derivatives which are along the X and Y direction respectively):

$$\forall f(x, y) = \begin{bmatrix} G_x & G_y \end{bmatrix}^T = \begin{bmatrix} \frac{\partial f}{\partial x} & \frac{\partial f}{\partial y} \end{bmatrix}$$

The magnitude and direction angle of the vector are:

$$mag(\forall f) = \left| \forall f_{(2)} \right| = \begin{bmatrix} G_x^2 & G_y^2 \end{bmatrix}^{1/2}$$

$$\phi(x, y) = \arctan\left(G_x / G_y \right)$$

The effect of noise can also be reduced by Sobel method by inherent averaging of neighbor pixels. Two main advantages are taken for constructing this framework. They are: (i) it has some smoothing effect to the random noise of the image.(ii) the elements of the edge on both sides are enhanced, and the edge seems thick and bright.

The subjective evaluation of both noise and edge is explained in below figure 2 and figure 3.

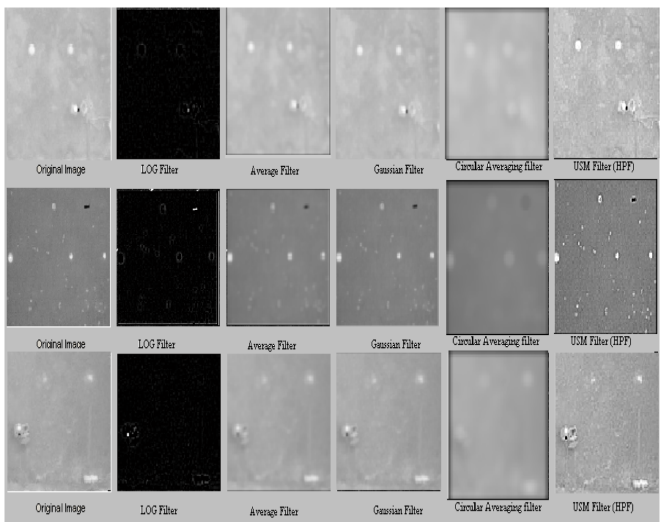

Figure 2: Subjective evaluation for noise removal filters

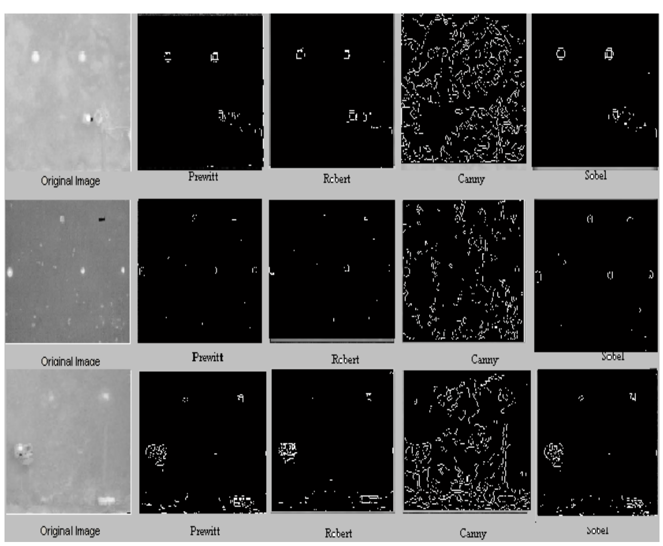

Figure 3: Subjective evaluation for edge detection filters

IV. SEGMENTATION

The signature of buried land mine in IR images varies significantly depending on external parameters such as weather, soil moisture, solar radiation, burial depth, and time[8]. Thus, there is always a need for robust algorithm that has the capability to analyze the pattern of distribution of the pixels to separate pixels of the mines from background pixels [2]. Implementation results shows that h-maxima transformation is more adoptable for IR target images when compared to kmeans, intensity and boundary based methods.

A.H - Maxima Transformation

To remove the unwanted regions, the 3-D h-maxima transform is used for contrast simplification[11]. This morphological operation suppresses all points whose value with respect to their neighbors is smaller than a threshold level h. It is computed using:

$$HMAX_h(f) = R_f(f - h)$$

where $R_f(f - h)$ is the morphological reconstruction by dilation of image f with respect to f − h. The transform is then followed by an extended maxima operation to identify all regional maxima:

$$EMAX_h(f) = RMAX\left[HMAX_h(f)\right]$$

Every IR image taken has been implemented with morphological reconstruction, extended maxima transformation using thresholding. The extended maxima transformation is the regional maxima computation of the corresponding *h*-maxima transformation. As a result, it produces a binary image. A connected-component labeling operation is performed, in order to evaluate the characteristics and the location of every object. As a second object reduction step, objects not located within a region of another object, are also discarded, since mine objects are not typically clustered. The region of interest (ie) the target is got by connected component segmentation in which the relevant pixels of the object will be grouped and extorted. The extended-maxima transform computes the regional maxima of the H-maxima transform. Here H refers to nonnegative scalar. Regional maxima are connected components of pixels with a constant intensity value, and whose external boundary pixels will have a lower value.

The below result in figure 4 states the high performance of detection using H-maxima for landmine detection.

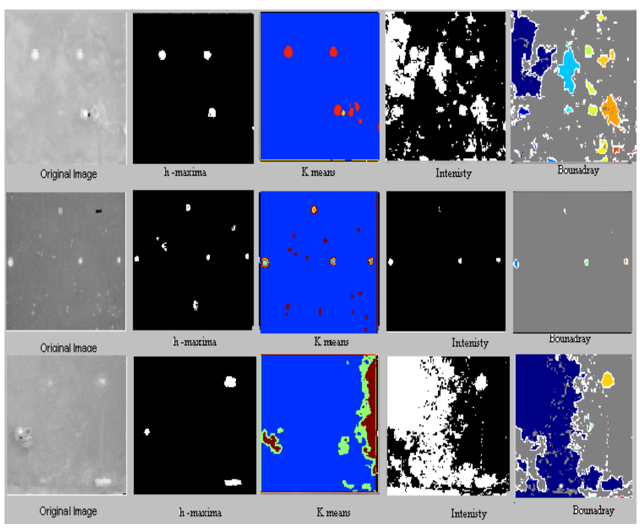

Figure 4 : Subjective evaluation for segmentation methods

V. FEATURE EXTRACTION PROCESS

Feature extraction helps to identify the attributes of the objects which help to classify the objects[5]. The quality of the features is critical for a good classification. In this framework, statistical and structural features are combined to give better classification rate. Here the statistical features need has been introduced for landmine detection system which includes whole information of the image and also the geometric features.

These features improve the accuracy rate of the classifiers used. Typically these properties are computed from the matrix of the image surface. These statistics can characterize the consistency of an image because they provide information about the local variability of the intensity values of pixels in an image.This combination will encourage the identification system more efficiently. The main features likely to be experimented in the prototype are shown in table 1.

Table 1: Features for landmine detection

S.no	Structural Features	Statistics Features
1.	Area of the object	Mean value
2.	Centroid	Standard Deviation
3.	Perimeter	Minimum intensity
4.	Solidity	Median value
5.	Boundary box	Maximum intensity

VI. CLASSIFICATION

Image classification analyzes the numerical properties of various image features and organizes data into categories[10]. Classification algorithms typically employ two phases of processing: training and testing. In the initial training phase, characteristic properties of typical image features are isolated and, based on these, a unique description of each classification category, *i.e.* training class, is created. In the subsequent testing phase, these feature-space partitions are used to classify image features. The description of training classes is an extremely important component of the classification process.

A. k-NN Algorithm

The k-nearest neighbor (kNN) classification algorithm classifies an input based on the class labels of the closest k points in the training dataset[4]. The class label assigned to an input is usually the most numerous classes of these k closest points. The underlying intuition that is the basis of this classification model is that nearby points will tend to have higher “similarity” viz. same class, than points that are far apart. The training examples are vectors in a multidimensional feature space, each with a class label. The training phase of the algorithm consists only of storing the feature vectors and class labels of the training samples.

In the classification phase, *k* is a user-defined constant, and an unlabelled vector (a query or test point) is classified by assigning the label which is most frequent among the *k* training samples nearest to that query point. Usually Euclidean distance is used as the distance metric; however this is only applicable to continuous variables. In cases such as text classification, another metric such as the overlap metric (or Hamming distance) can be used. Often, the classification accuracy of k-NN can be improved significantly if the distance metric is learned with specialized algorithms such as e.g. Large Margin Nearest Neighbor or Neighborhood component analysis.

k-NN methodology is necessary if tight statistical characterization is to be provided for classification algorithms.

VII. EXPERIMENTAL RESULTS AND FINDINGS

The image used for image processing is in the format of .PNG and the size of the image is 256 x 256. It is necessary to find out the best method that is suitable of IR landmine image [3]. The performance evaluation of the adopted operation is quantified by following assessment.

A. Noise removal

Peak to signal noise ratio(PSNR)

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right)$$

Larger the PSNR value [40] the performance is good and smaller the MSE value the error rate is low.

Mean Square Error (MSE)

MSE is calculated using formula (1):

$$MSE = \frac{1}{MN} \sum_{i=1}^{M} \sum_{i=1}^{N} \left[g(i,j) - f(i,j) \right]^2$$

where, *M* and *N* are the total number of pixels in the horizontal and the vertical dimensions of image. *g* denotes the Noise image and *f* denotes the filtered image.

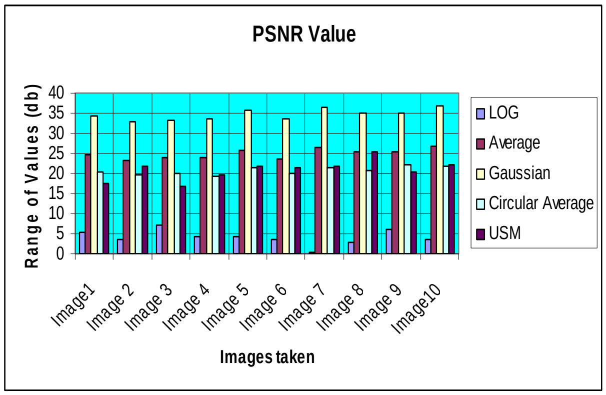

Figure 5 : Graph of PSNR value for five filtered method over ten Images

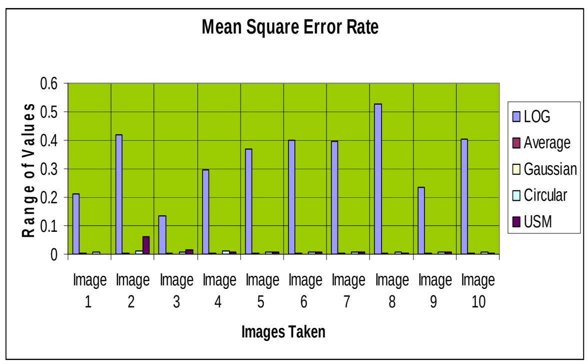

Figure 6. Graph of MSE value for five filtered method over ten Images.

B. Edge detection

The overall image sharpness is measured by computing the average difference between pixel pairs at all locations within the input image. The pixel subtraction operator takes two images as input and produces as output a third image whose pixel values are simply those of the first image minus the corresponding pixel values from the second image. If the operator computes absolute differences between the two input images then the formula is given in the Eq:

$$Q = \left| P_1(i,j) - P_2(i,j) \right|$$

where Q is the absolute difference and the P_1 and P_2 are the pixel of original image and filtered image. The absolute difference is calculated between the image in memory and the current image. Sobel convolution will be applied to emphasis the region between the low and high spatial frequencies.

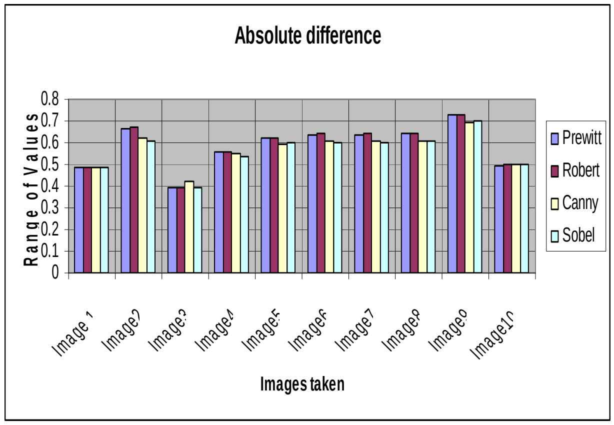

Figure 7. Evaluation graph using Absolute difference

C. Segmentation

Experimented segmentation methods are evaluated using the evaluation metrics by passing different parameter .They are as follows

Global Consistency Error

Global Consistency Error (GCE) forces all local refinements to be in the same direction and is defined as:

$$GCE(S,S') = \frac{1}{N}\min\left\{\sum LRE(S,S',x_i), \sum LRE(S',S,x_i)\right\}$$

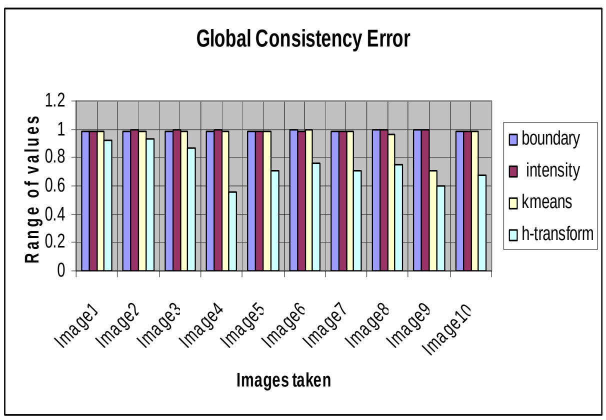

Figure 8. Evaluation graph using GCE

It measures the extent to which one segmentation can be viewed as a refinement of the other. Segmentations that are related in this manner are considered to be consistent, since they could represent the same natural image segmented at different scales.

D. Testing a Classification Model

In this experiment, statistical and structural feature are taken for classification over ten samples of landmines and two samples of clutters. The samples are tested and trained for two classes. Class 1 is for mine and class 2 for non-mine. Due to structural and statistic feature k-NN algorithm is taken for classification. This classification provides 100% exact classification.

Table 2 Confusion matrix for k-NN classification

		Predicted	
		Mine	Non-Mine
Actual	Mine	10	0
	Non-Mine	0	2

Table 2 shows a confusion matrix for a binary classification using k-NN classification. The target values are either mine or non-mine.

The following can be computed from this confusion matrix:

- This classifier made 12 correct classifications (10 + 2).
- This classifier made 0 incorrect predictions (0+0).
- This scored 12 cases (12+0).
- The error rate is 0/12 = 0.0
- The accuracy rate is 12/12 = 1

The classifier correctly classifies a mine 100% and incorrectly predicted a mine 0%. This correctly predicted a non-mine 100% and incorrectly predicted a non-mine 0% times. Here twelve samples are taken, in that there 10 are landmines and 2 are clutters.

VIII. CONCLUSION

The proposed framework is used here to justify the objects using new methods to get a maximum accuracy comparing to existing statistical methodologies. The features fed here are the parameters extracted from the images which are taken from Infra red segmented images .For each object, a measures of properties (mean, median, standard deviation, pixel area, maximum intensity, minimum intensity, centroid, perimeter, solidity, bounding box, area) are taken; the classifier then uses these properties to determine whether each object is a landmine. The probability that an object belongs to each of the candidate classes is estimated. The classifier adopted for the detection system is validated using confusion matrix stating the classification and misclassification error rate according to the sample datasets.

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