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A PATH FOR HORIZING YOUR INNOVATIVE WORK

ENHANCEMENT OF INFRARED IMAGE FOR ROOF LEAKAGE DETECTION

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Abstract

Infrared Image enhancement is the recently developed area because of its application in various fields. This paper presents a new enhancement technique for infrared images. This technique combines the benefits of homomorphic image processing and the additive wavelet transform. The idea behind this technique is to decompose the image into three sub bands in an additive fashion using an additive wavelet transform. This transform gives the image as an addition of sub bands of the same resolution. The homomorphic processing is performed on each sub band, separately. The homomorphic processing on image is performed in the log domain which transforms the image into illumination and reflectance components. Then applying spatial filter enhances the reflection and illumination components in the image, separately. So, applying this process on each sub band enhances the details of the image. Finally, an inverse additive wavelet transform is performed on the homomorphic enhanced sub bands to get an infrared image with better visual details as well as edge map. Roof Leakage is the major problem faced in almost all the building irrespective of the age of the building. Basically, roof leak is caused because of the natural conditions and material used in construction. So, roof leakage detecting professionals are called for roof inspection. But most of the time these leakages are so small that we cannot see with bare eyes. That's why infrared cameras are used for detecting roof leaks. Based on the images captured by infrared cameras, edge map is drawn and that particular area is repaired.

I. INTRODUCTION

Image enhancement is one of the key areas in digital infrared image processing field. Most of the time because of the natural climatic conditions we cannot gather more information from an image. These conditions lead to necessity of image enhancement for various applications. But due to the limitation of normal image, we can extract the information which is in visible range. That's why researchers started looking for other options to break the limitation of human visible range and infrared image came into picture [18].

Infrared (IR) light is electromagnetic radiation with a wavelength longer than that of visible light, measured from the nominal edge of visible red light at 0.74 micrometers and extending conventionally to 300 micrometers. These wavelengths correspond to a frequency range of approximately 1 to 400 THz [1-2] and

include most of the thermal radiation emitted by objects near room temperature. Infrared Image enhancement is becoming popular in recent days because of various applications of infrared image. The nature of infrared image is little different than normal image which makes it very special and useful. An image I(x,y) is a product of illumination $I_i(x,y)$ and reflectance $I_r(x,y)$. Illumination component defines the light falling on the image which will be constant. Reflectance component concentrate on the detailed information present in the image. In frequency characteristics, Illumination is represented by Low frequency component and Reflectance is represented by High frequency components in an image [8].

Infrared image mostly consist of dark areas with small details. So, in proposed technique we are using additive wavelet transform to decompose an infrared image into sub bands. Separating an infrared image into sub bands, separate the image details into high frequency sub bands. These sub bands are processed separately to extract more information from an image. These sub bands are processed using homomorphic enhancement technique to attenuate the illumination and strengthen the reflectance. At the end, enhanced image is obtained by additive wavelet reconstruction process [5-8].

II. WAVELET TRANSFORM

Qi, H. and J. F. Head [1] suggested that Wavelets have demonstrated some effectiveness for target detection. Traditionally, there are four primary applications of wavelet-based methods for target detection: These are as follows:

- Wavelets as edge detectors.
- Using wavelets to separate targets from clutter based on scale differences.
- Using wavelets as approximate matched filters.
- Capturing target dynamic range differences using wavelet filters.

Using wavelets as edge detectors assumes that target edges differ in some way from clutter edges. For example, edges from natural clutter may be more diffuse whereas edges from man-made objects such as vehicles may be harder, sharper, and more distinct.

It is found that additive wavelet transform is powerful tool in decomposing an image into various sub bands [5]. Wavelet transform provides the time-frequency information which leads to multi resolution analysis of an image. Because of this the information which is not detected in one resolution can be detected in another resolution. This feature makes wavelet transform a powerful tool in image enhancement [1].

Wavelet transform is implemented using "a Trous" filtering approach to decompose an infrared image into sub bands. In this, below mentioned low pass filter is used as a mask to decompose an infrared image into 3 sub bands [5, 8, 14].

$$H=\frac{1}{256}\begin{pmatrix} 1 & 4 & 6 & 4 & 1 \\ 4 & 16 & 24 & 16 & 4 \\ 6 & 24 & 36 & 24 & 6 \\ 4 & 16 & 24 & 16 & 4 \\ 1 & 4 & 6 & 4 & 1 \end{pmatrix} \quad \ldots\ldots..(1)$$

Output of each is defined as approximation (P1, P2 and P3) and each sub band is obtained by difference of 2 consecutive stages. After performing different operations on these sub bands we can reconstruct the enhanced image by addition of these enhanced sub bands [1-2].

III. HOMOMORPHIC PROCESSING

The illumination component of an image is generally characterized by slow special variations, while the reflectance component tends to vary abruptly. Therefore, we need a filter function $\mathrm{H(u,v)}$ affecting low and high frequency components in different, controllable ways. This can be done by applying low pass filter to illumination and high pass filter to reflectance [8].

Butterworth filter has better results for image enhancement. Butterworth low pass filter can be represented mathematically as mentioned below.

$$H(u,v) = \frac{1}{1+[\mathrm{D(u,v)/D_0}]^{2n}} \text{...... (2)}$$

Where,

$$D(u,v)=\sqrt{\left(u-\frac{P}{2}\right)^2+\left(v-\frac{Q}{2}\right)^2}$$

Here, n represents order of butterworth filter, P and Q represents the size of zero padded image and d represents cut-off frequency which can be chosen based on the requirement. 'd' Factor in the above equation, helps in improving the ringing effect and smoothing. Increasing this factor will improve visibility of an image by low pass filter and edge map by high pass filter [14].

It is known fact that Illumination will be constant because light fall on an image is constant. We have to attenuate this component to get more details in an image and this is done by selecting $\alpha < 1$. Reflectance contains more details about the image. So, we have to enhance this factor by selecting proper $\beta > 1$[8,14].

$$F = \alpha * H_{Lp} + \beta * H_{Hp} \text{......(3)}$$

IV. PROPOSED METHODOLOGY

In the proposed dissertation work infrared image enhancement using additive wavelet transform is implemented. The dissertation work will be carried out in following steps.

A. Decomposing Image into Sub bands:

Original infrared image is decomposed into 3 sub bands using additive wavelet transform. This can be done by the method mentioned in the section II.

B. Logarithmic process

Each Sub band can be represented as product of Illumination and reflectance component.

$I(X_1, X_2)$= $I_i(X_1, X_2)$ $I_r(X_1, X_2)$..........*(4)*

It is difficult to process these components separately when it is represented as a product. So, by applying logarithmic process, we can convert product into addition of illumination and reflectance [8].

log $(I(X_1, X_2))$=*log*($I_i(X_1, X_2)) +$ $log\ (\ I_r(X_1, X_2))$............*(5)*

C. Homomorphic Processing

Perform a reinforcement operation on the reflectance component in each sub band and attenuation operation on the illumination component using Homomorphic processing. After processing illumination and reflectance separately, it's time to combine these components to get reconstructed sub band as a product these components. This is performed by inverse of logarithmic process which is exponential. Exponential operation will convert addition into product [8, 14].

$I_1' = e^{(F * log(I_1(X_1, X_2)))}$............*(6)*

D. Wavelet Reconstruction

Above step gives 3 different sub bands which are processed for enhancement. Wavelet reconstruction is performed by combining these enhanced sub bands and approximation P3 (last approximation). It contains low frequency components and 3 enhanced sub bands contain high frequency components [8, 14-15].

$I' = I_1' + I_2' + I_3' + P_3$.........(7)

V. PROBLEMS IN ROOF LEAKAGE DETECTION:

Infrared image is useful for roof leakage detection because of its different nature. Infrared roof inspection is a proven method for detecting trapped moisture problems in flat roofs. It can also prevent equipment down time, production losses and damage to structural components which have been compromised by water [16-18].

But even after using infrared image for moisture detection, roof inspectors will face following problems.

- Because of the thermal nature of the image, edges in the images are not proper.
- Less sharpness of the image makes it difficult to find out exact affected areas.

- Material required for roof leakage repairing is getting waste which makes it costly.

To overcome these problems, we need an image enhancement technique which reduces the human efforts as well as cost. Our proposed methodology has shown better results in infrared image enhancement [17, 18].

VI. RESULTS AND ANALYSIS:

Roof leakage is the mostly observed problem in rainy season. Because of the nature of leak we cannot identify the exact leak area. As these leakages are difficult to observe with bare eyes, we will use infrared image for inspecting the leaked area. But edges of the infrared images are blurred due to the thermal nature of the infrared image which makes it difficult to detect exact affected area. Our proposed methodology helps roof inspector in two ways mentioned below [16-20].

- Increase the visibility of the infrared image.
- Find out the exact edge of the roof leak area.

This section explains the experimental results of proposed methodology performed on the different infrared images related to roof leak.

A. *Experiment 1:*

Figure 1 shows the original image of the roof captured using infrared camera. In this image, dark violet region represents the moisture content and other region represents normal content [16-18].

Fig 1 Original Infrared Image

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Fig 1.1 - Original Gray Scale Infrared Image

Fig 1.2- Enhance Infrared Gray Scale Image

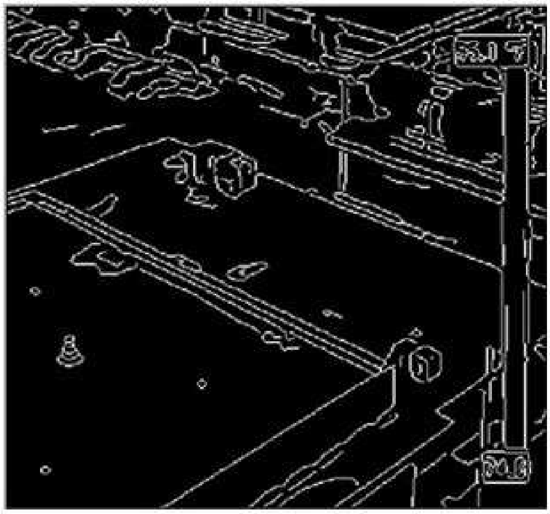

Fig 1.3-Edge Map of Original Image

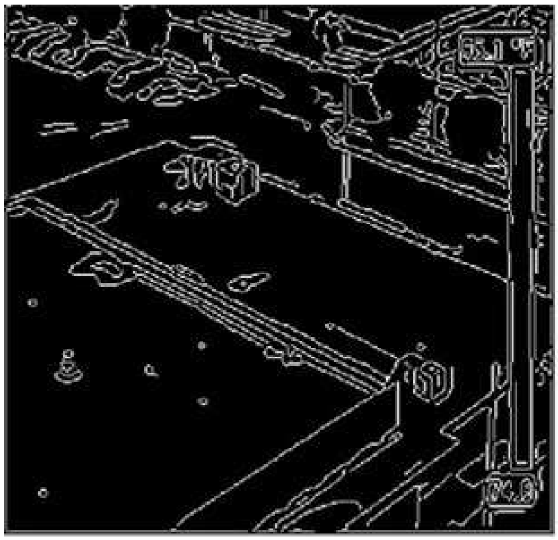

Fig 1.4-Edge Map of Enhanced Image

Fig (1) represents the original image [19]. Fig (1.1) represents original image in greyscale. Fig (1.2) enhanced image in greyscale. Fig (1.3) represents edge map of original image. Fig (1.4) represents edge map of enhanced image.

We can see the visibility difference between original image and enhanced image. With the proposed methodology, we are able to enhance visibility and edge maps both.

B. Experiment 2:

Figure 2 shows the original image of the roof captured using infrared camera. In this image, dark violet region represents the moisture content and other region represents normal content [16-18].

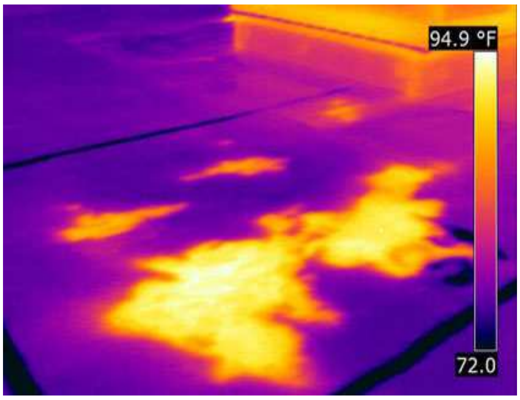

Fig.2. Original Infrared Image

Fig 2.1- Original Gray Scale Infrared Image

Fig 2.2- Enhance Infrared Gray Scale Image

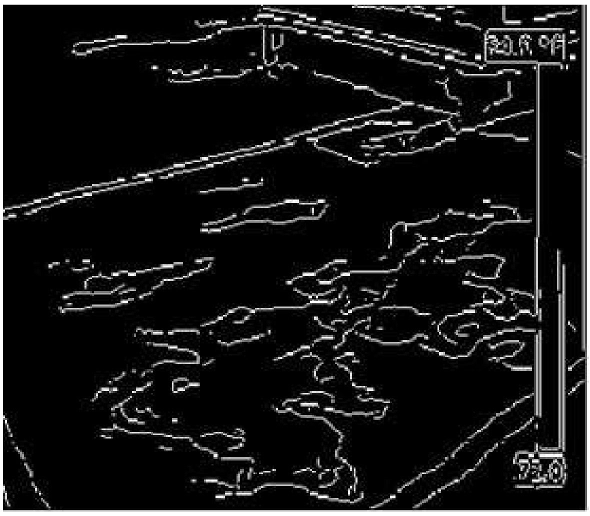

Fig 2.3-Edge Map of Original Image

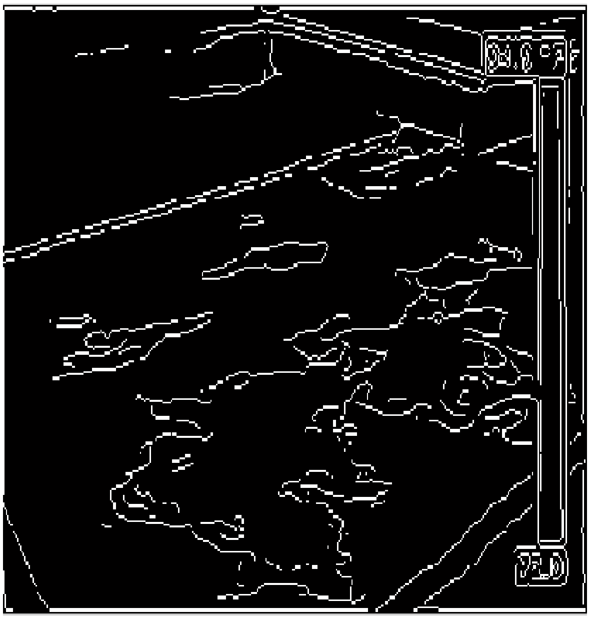

Fig 2.4-Edge Map of Enhanced Image

Figure-(2) represents the original image [19]. Figure (2.1) represents original image in greyscale. Figure (2.2) represents Enhanced image in greyscale. Figure (2.3) represents edge map of original image. Figure (2.4) represents edge map of enhanced image.

In this image also we can see that enhanced image has more information than original image. We performed similar experiments on other images related to roof leak. From this result, it is clear that our approach has succeeded in enhancement of visibility as well as edge map of the infrared image.

VII. COMPARISON OF DIFFERENT FILTERS:

Table: 1. Comparison of Different Filters

Name OF Figure	Name of Filter	Enhance Image		PSNR(db)	MSE
		Visibility	Edge Map		
EXPERIMENT 1	Ideal	Good	Better	21.76	0.03
	Gaussian	Good	Good	20.96	0.03
	Novel Filter	Better	Better	22.74	0.02
EXPERIMENT 2	Ideal	Good	Better	23.24	0.02
	Gaussian	Good	Good	22.46	0.02
	Novel filter	Better	Better	23.85	0.02

In Proposed methodology we are using Butterworth filter. There are other frequency domain filters which can be used with proposed approach. Below mentioned table shows the results of different filters using proposed methodology.

VIII. CONCLUSION & FUTURE SCOPE

This paper, describes detailed professional reports documenting the entrained roof moisture. Roof professionals and building owners or property management companies can use this information to verify the wet areas and write specifications to repair the roof. This paper can be used to document roof conditions to ensure warranty coverage is maintained, to certify the roof substrate is dry prior to applying a roof coating material and for pre purchase inspections.

In the future, the edge map can be more improved with the help of removing the noise.To detect the perfect location of roof leak, distance can be calculate from the center of the image.

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