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HOMOMORPHIC ENHANCEMENT OF INFRARED IMAGES USING THE ADDITIVE WAVELET TRANSFORM

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Abstract—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 based on decomposing the image into subbands in an additive fashion using the additive wavelet transform. This transform gives the image as an addition of subbands of the same resolution. The homomorphic processing is performed on each subband, separately. It is known that the homomorphic processing on images is performed in the log domain which transforms the image into illumination and reflectance components. Enhancement of the reflectance reinforces details in the image. So, applying this process in each subband enhances the details of the image in each subband. Finally, an inverse additive wavelet transform is performed on the homomorphic enhanced subbands to get an infrared image with better visual details.

1. INTRODUCTION

Image enhancement is a very popular field in image processing. Enhancement aims at improving the visual quality of an image by reinforcing edges and smoothing flat areas. Several researchers have evaded this field using different approaches such as simple filtering, adaptive filtering, wavelet denoising, homomorphic enhancement etc., [1–7]. All these approaches concentrate on reinforcing the details of the image to be enhanced.

Infrared image processing is a new field emerging for the evolution of night vision cameras. It also has applications in thermal medical imaging [1–3, 5]. This evolution of night vision cameras has encouraged the research in infrared image enhancement for information extraction from these images. These images have a special nature of large black areas and small details due to the absence of the appropriate amount of light required for imaging. So, the main objective is to reinforce the details to get as much details as possible.

The enhancement of infrared images is slightly different from traditional image enhancement in dealing with the large black areas and the small details. So, our suggested approach aims at separating the details in different subbands and processing each subband, separately. We have found that the additive wavelet transform is a powerful tool in image decomposition. If the infrared image is decomposed using the additive wavelet transform, the details can be separated into the higher frequency subbands. Also, we use the homomorphic enhancement algorithm for transforming these details to illumination and reflectance components. Then, the reflectance components are amplified showing the details, clearly. Finally a wavelet reconstruction process is performed to get an enhanced infrared image with much more details.

The rest of the paper is organized as follows. Section 2 explains the additive wavelet transform. Section 3 surveys the homomorphic enhancement algorithm. Section 4 presents the proposed enhancement algorithm. Section 5 gives the experimental results. Finally, Section 6 gives the concluding remarks.

2. ADDITIVE WAVELET TRANSFORM

The additive wavelet transform decomposes an image into subbands using the "a' trous" filtering approach [6–8] in several consecutive stages. The low pass filter used in this process has the following mask for all stages [8]:

$$H = \frac{1}{256}\begin{pmatrix} 1 & 4 & 6 & 4 & 1 \\ 4 & 16 & 24 & 16 & 4 \\ 6 & 24 & 36 & 24 & 6 \\ 4 & 16 & 24 & 16 & 4 \\ 1 & 4 & 6 & 4 & 1 \end{pmatrix} \tag{1}$$

Each difference between filter outputs of two consecutive stages is a subband of the original image. We can use these subbands for further processing using homomorphic enhancement.

3. HOMOMORPHIC IMAGE ENHANCEMENT

An image can be used represented as a product of tow components as in the following equation [9]:

$$f(n_1, n_2) = i(n_1, n_2)r(n_1, n_2) \tag{2}$$

where $f(n_1, n_2)$ is the obtained image pixel value, $i(n_1, n_2)$ is the light illumination incident on the object to be imaged and $r(n_1, n_2)$ is the reflectance of that object.

It is known that illumination is approximately constant since the light falling on all objects is approximately the same. The only change between object images is in the reflectance component.

If we apply a logarithmic process on Eq. (2), we can change the multiplication process into an addition process as follows:

$$\log(f(n_1, n_2)) = \log(i((n_1, n_2)) + \log(r(n_1, n_2)) \tag{3}$$

The first term in the above equation has small variations but the second term has large variations as it corresponds to the reflectivity of the object to imaged. By attenuating the first term and reinforcing the second term of Eq. (3), we can reinforce the image details.

4. THE PROPOSED APPROACH

In this approach, we merge the benefits of the above motioned techniques. First, the image is decomposed into subbands using the additive wavelet transform. Then, each subband is processed, separately, using the homomorphic approach to reinforce its details. The steps of the proposed approach can be summarized as follows and are depicted in Fig. 1.

1. Decompose the infrared image into four subbands p_3, w_1, w_2 and w_3 using the additive wavelet transform and the lowpass mask of Eq. (1).
2. Apply a logarithmic operation on each subband to get the illumination and reflectance components of the subbands w_1, w_2 and w_3 as they contain the details.
3. Perform a reinforcement operation of the reflectance component in each subband and an attenuation operation of the illumination component.
4. Reconstruct each subband from its illumination and reflectance using addition and exponentiation processes.
5. Perform an inverse additive wavelet transform on the obtained subbands by adding p_3, w_1, w_2 and w_3 after the homomorphic processing to get the enhanced image.

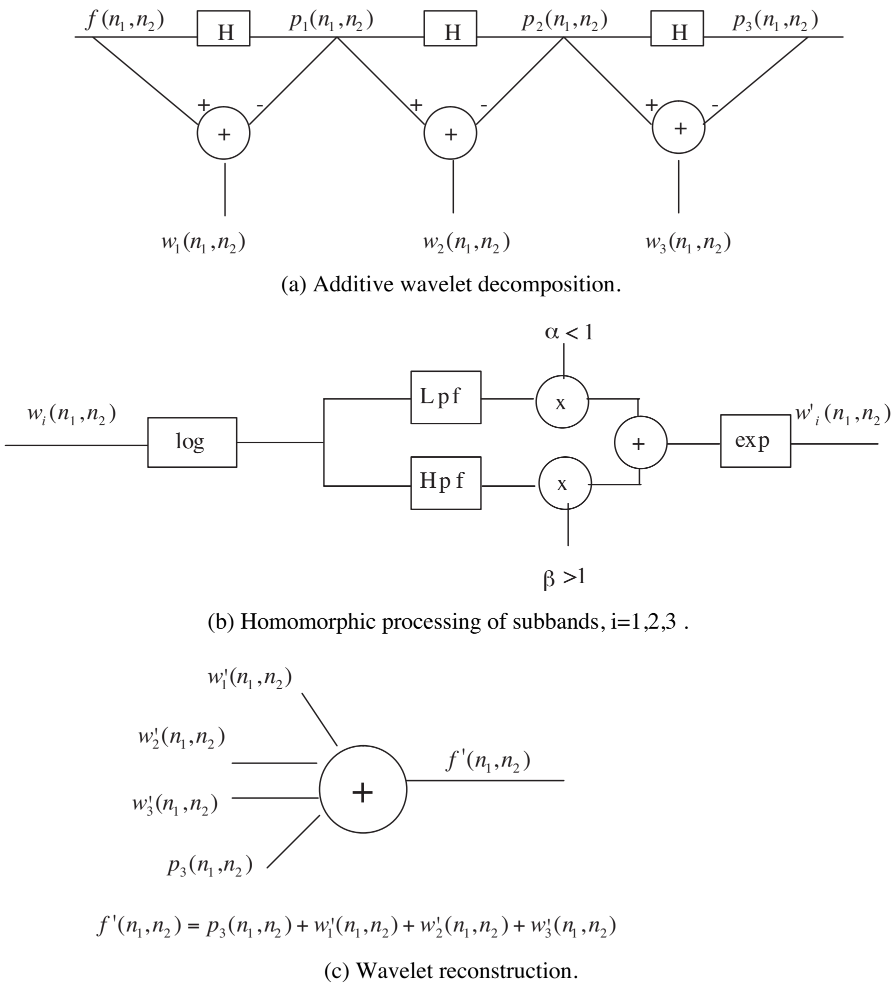


Figure 1. Steps of the proposed algorithm.

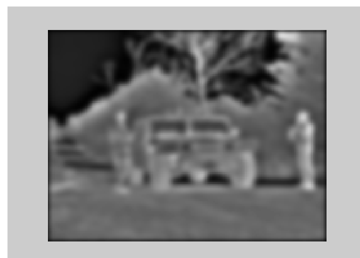
5. EXPERIMENTAL RESULTS

In this section, two experiments are performed on two different infrared images to test the performance of the proposed enhancement algorithm. The steps of the algorithm mentioned in Section 4 are performed on these two images. The results of the first experiment are shown in Fig. 2. Part (a) gives the original infrared image. Parts (b, c and d) give the approximation images p_1, p_2 and p_3. Part (e) gives the enhanced infrared image using the proposed algorithm.

(a) Original infrared image.

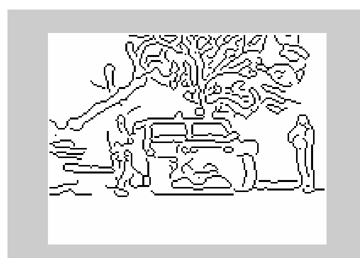
(b) Approximation p_1.

(c) Approximation p_2.

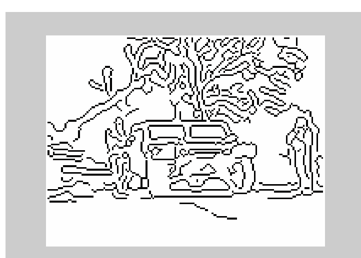


(d) Approximation p_3.

(e) Enhanced infrared image.

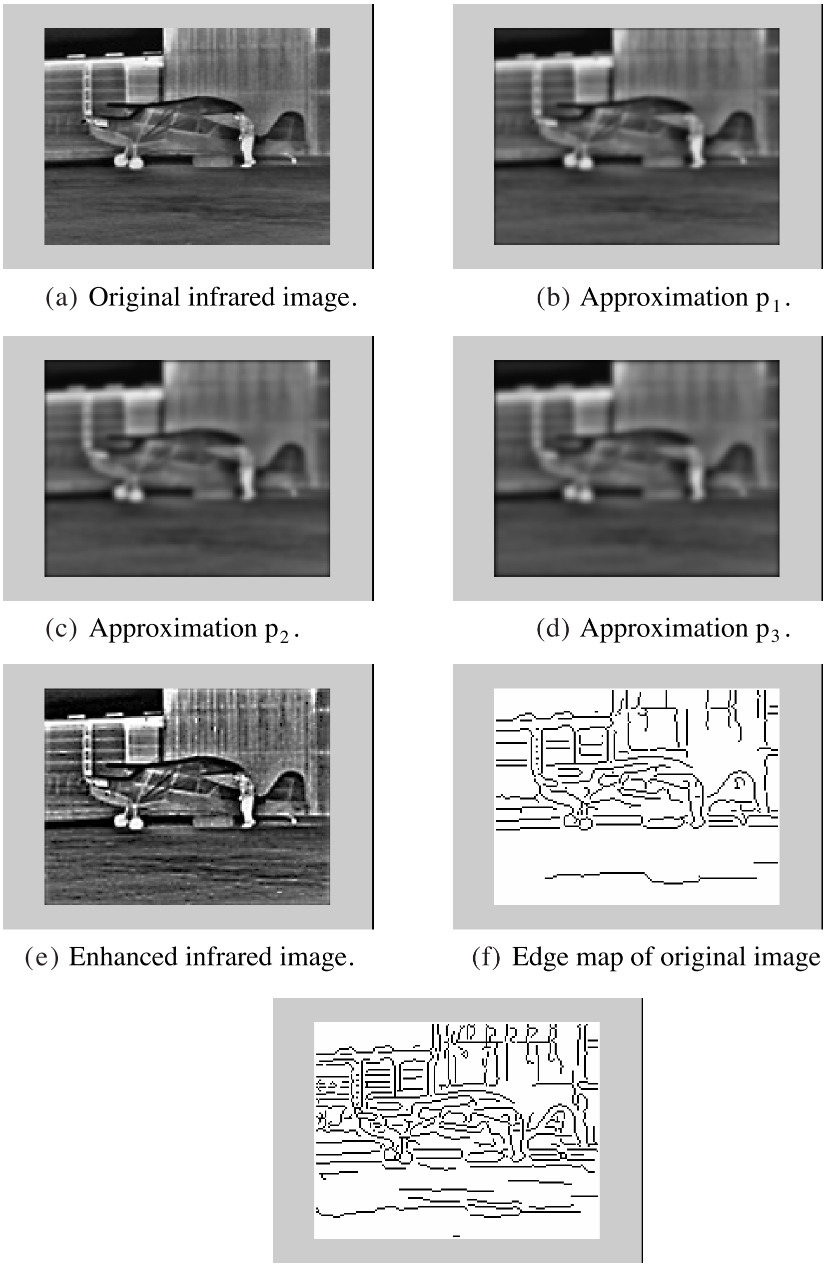


(f) Edge map of original image.



(g) Edge map of enhanced image.

Figure 2. Results of the first experiment.



(a) Original infrared image.

(b) Approximation p_1.

(c) Approximation p_2.

(d) Approximation p_3.

(e) Enhanced infrared image.

(f) Edge map of original image.

(g) Edge map of enhanced image.

Figure 3. Results of the second experiment.

For the purpose of evaluation, we use the edge map of both the original infrared image and the enhanced one as an assistance tool with the visual evaluation. Part (f) of Fig. 2 gives the edge map of the original image before processing and part (g) of the same figure gives the edge map of the enhanced image. It is clear that the proposed enhancement algorithm has enhanced the visual quality of the processed image as well as its edge map.

A similar experiment is carried out on another infrared image and the results are given in Fig. 3. From these results, it's clear that the proposed approach has succeeded in the enhancement of the visual quality of that infrared image and more details have been obtained.

6. CONCLUSION

The paper presents a new approach for infrared image enhancement. This approach combines the additive wavelet transform and the homomorphic enhancement features. The homomorphic processing is applied to the infrared image subbands, separately. Then, these subbands are merged again to reconstruct an enhanced image. The results obtained using this algorithm reveal its ability to enhance infrared images.

REFERENCES

1. Qi, H. and J. F. Head, "Asymmetry analysis using automatic segmentation and classification for breast cancer detection in thermograms," *Proceedings of the Second Joint EMBS/BMES Conference*, USA, 2002.
2. Kuruganti, P. T. and H. Qi, "Asymmetry analysis in breast cancer detection using thermal infrared images," *Proceedings of the Second Joint EMBS/BMES Conference*, USA, 2002.
3. Scales, N., C. Herry, and M. Frize, "Automated image segmentation for breast analysis using infrared images," *Proceedings of the 26th Annual International Conference of the IEEE EMBS*, San Francisco, CA, USA, 2004.
4. Zhang, C. J., F. Yang, X. D. Wang, and H. R. Zhang, "An efficient non-linear algorithmfor contrast enhancement of infrared image," *Proceedings of the Fourth International Conference on Machine Learning and Cybernetics*, Guangzhou, 2005.
5. Qil, H., W. E. Snyder, J. F. Head, and R. L. Elliott, "Detecting breast cancer from infrared images by asymmetry analysis,"

Proceedings of the 22nd Annual EMBS International Conference, USA, 2000.

6. Andreone, L., P. C. Antonello, M. Bertozzi, A. Broggi, A. Fascioli, and D. Ranzato, "Vehicle detection and localization in infra-red images," *The IEEE 5th International Conference on Intelligent Transportation Systems*, Singapore, 2002.
7. Zhang, C., X. Wang, H. Zhang, G. Lv, and H. Wei, "A reducing multi-noise contrast enhancement algorithm for infrared image," *Proceedings of the First International Conference on Innovative Computing, Information and Control (ICICIC'06)*, 2006.
8. Nunez, J., X. Otazu, O. Fors, A. Prades, V. Pala, and R. Arbiol, "Multiresolution-based image fusion with additive wavelet decomposition," *IEEE Trans. Geosci. Remote Sensing*, Vol. 37, No. 3, 1204–1211, May 1999.
9. Lim, J. S., *Two-Dimensional Signal and Image Processing*, Prentice Hall Inc., 1990.