Analysis of Homomorphic Filtered Remotely Sensed Imagery and Multiple Geophysical Images

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Abstract: In this study, the digital image processing with image enhancement based on homomorphic filtering was performed using geophysical imaging data such as gravity, magnetic data and sub-scenes of satellite images such as LANDSAT, IKONOS, and KOMPSAT. Windows application program for executing homomorphic filtering was designed and newly implemented. In general, homomorphic filtering is technique that is based on Fourier transform, which enhances the contrast of image by removing the low frequencies and amplifying the high frequencies in frequency domain. We can enhance the image selectively using homomorphic filtering as compared with the existing method, which enhance the image totally. Through several experiment using remotely sensed imagery and geophysical image with this program, it is concluded that homomorphic filtering is more effective to reveal distinct characteristics for some complicated and multi-associated features on image data.

Keywords: Homomorphic filtering, Geophysical image, High resolution image

1. Introduction

In these days, as the high-resolution imagery and the demand on methodologies and processing schemes using these for remote sensing application or analysis increases, it is necessary to obtain some information or characteristics exactly from these image-based data sets. Related to this, accuracy of each image-type data is also emphasized on this task. In this study, the digital image processing with image enhancement based on homomorphic filtering was performed using geophysical imaging data such as gravity, magnetic data and sub-scenes of satellite images such as LANDSAT, IKONOS, and KOMPSAT. As well, Windows-based application program for executing homomorphic filtering was designed and newly implemented. The results of homomorphic filtering are influenced by variables. We tested the difference of results according to different variables because several variables can be applied in the user interface of this program.

We also compared the result of homomorphic filtering with the results of histogram equalization and kernel-based sharpening filtering, which have been used for image enhancement. These methods can enhance features contained in the image in overall image extent. Meanwhile, frequency domain filtering approach in this study can enhance the image selectively, if we use homomorphic filtering. And then, we carried out the differencing to confirm how much pixel values changed respectively. Homomorphic filtering is effective in extracting linear feature from image and edge detection because it elevates the contrast of boundary. So, we applied to real image and geophysical data finally.

Through several experiments using remotely sensed imagery and geophysical image with this program, we investigate efficiency of homomorphic filtering in the task to reveal distinct characteristics for some complicated and multi-associated features on image data.

2. Homomorphic filtering: Overview

Homomorphic Filtering is the technique that is based on Fourier Transform, which enhances the contrast of image by removing the low frequencies and amplifying the high frequencies in frequency domain [1], [2]. [3]. Images normally consist of light reflected from objects. The basic model of the image $F(x, y)$ may be characterized by two components: the amount of source light incident on scene being viewed and the amount of light reflected by the objects in the scene. These portions of light are called the illumination and reflectance components, and are denoted $I(x, y)$ and $R(x, y)$, respectively.

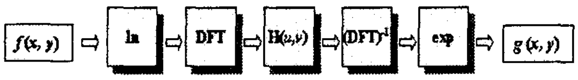


Fig. 1. Homomorphic filtering approach

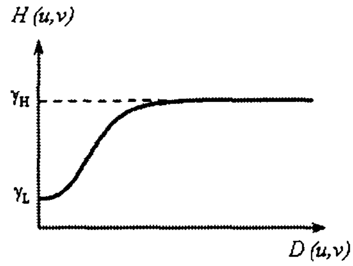


Fig. 2. Cross section of a circularly symmetric filter function.
***D(u, v)*: distance from the origin of the centered transform.**

The functions I and R combine multiplicatively to give the image function F, where 0 <I (x, y) <∞ and 0 < R (x, y) <1:

$$F(x,y) = I(x,y) + R(x,y) \qquad (1)$$

We cannot easily use the above product to operate separately on the frequency components of illumination and reflection because the Fourier transform of the product of two functions is not separable. In this case, some way converting multiplication into addition must be employed before trying to apply Fourier transform. The obvious way to do this is to take logarithms of both sides.

Then, we take the Fourier transform of both sides, and apply a suitable filter function *H (u, v)* in Figs. 1 and 2:

$$H(u,v) = (\gamma_H - \gamma_L)[1 - e^{-c(D^2(u,v)/D_0^2)}] + \gamma_L \qquad (2)$$

If we take the inverse Fourier transform and the exponential of both sides finally, the desired enhanced image *g(x, y)* can then be obtained.

The filter function, *H(u,v)* will decrease the contribution of the low frequencies (illumination) and amplify the contribution of mid- and high frequencies (reflectance).

Fig. 3 shows main user interface of implemented program in this study.

3. Results and Discussion

Illumination tends to vary slowly, or relatively so, across an image. The reflectance, on the other hand, is characterized by sharp changes, especially at boundaries or edges. So, Illumination corresponds to low frequency, whereas the reflectance corresponds to high frequency in frequency domain.

If the low-frequency (illumination) components could be decreased, while increasing the high-frequency (reflectance) components, we can get enhanced imagery.

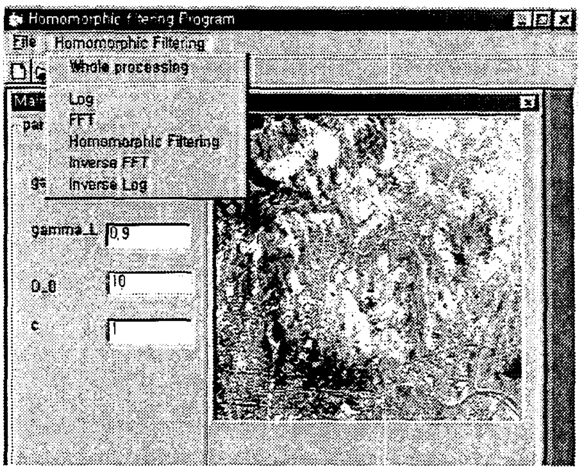


Fig. 3. Implementation result for homomorphic filtering.

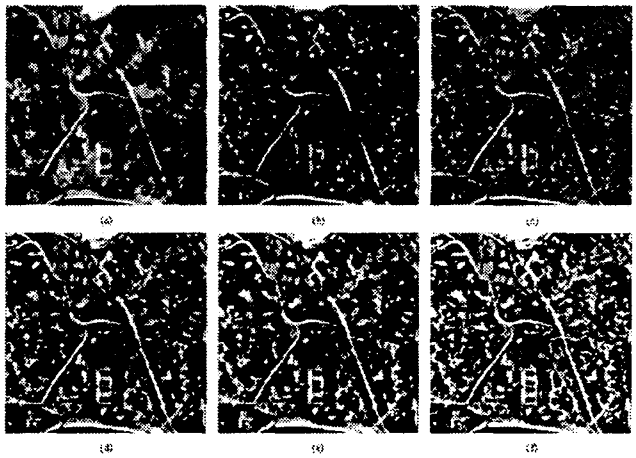


Fig. 4. The results of homomorphic filtering with respect to KOMPSAT EOC.

This is the key of homomorphic filtering. The results of homomorphic filtering are influenced by variables such as γ_H, γ_L, c and D_0. γ_H, γ_L, c and D_0 mean how much high frequencies are emphasized, how much low frequencies are decreased, the slope of the frequency from low to high and the limitation of low frequency respectively.

Figure 4 shows the difference of results according to the change of variables. This image is the KOMPSAT-EOC image, which was acquired in the Namyangju area, nearby Seoul, Korea. Fig. 4(a) is the original image of KOMPSAT EOC sub-image. Fig. 4 (b) is the homomorphic filtering result where γ_H=2, γ_L=0.8, c=0.5 and D_0=20. Fig. 4 (c), (d), (e) and (f) is the image where γ_H=2, γ_L=0.9, c=0.5 and D_0=20, where γ_H=2, γ_L=0.9, c=0.5 and D_0=10, where γ_H=2, γ_L=0.9, c=1 and D_0=10, and where γ_H=3, γ_L=0.9, c=0.5 and D_0=10 respectively. We can find the difference of results according to variables and see detailed feature characteristics contained in the original image. We compared the result of homomorphic filtering with the results of histogram equalization and kernel-based spatial filtering, as popular image enhancement method, to examine what is more effective.

Fig. 5 represents each result of image enhancement. This image is the IKONOS PAN image and shows the high way intersection and the ramp, located in the Guri-city, nearby Seoul, Korea. Fig. 5 (a) and (b) represent the original image and the result of kernel-base spatial filtering, respectively. General 3×3 sharpening filter was used for this method. Fig. 5 (c) is the result of histogram equalization. And (d) shows the effect of homomorphic filtering (γ_H=2, γ_L=0.9, c=1 and D_0=10).

In case of kernel-based sharpening filtering, the road edges became clearer than the original image. But dark part is similar to original image. It also might make the locations of edges change in process of using kernels, because DNs were assigned as new ones using the operation with neighbor pixels. Meantime, Histogram equalization improves contrast totally. In case of homomorphic filtering, some parts became darker. But, other parts became brighter. Road boundary and features' edge were enhanced specially, when we used homomorphic filtering. So, we can find that lanes, road boundary and vehicles are shown clearly in comparison with other methods.

We practiced the edge detection to certify whether the location of edge changed or not and compared it with the extracted edge from original image. Fig.6 shows each result of edge detection. Fig. 6 (a) and (b) show the original image and the extracted edge from sharpening image, respectively. Fig. 6 (c) is the result of histogram equalization. Fig. 6(d) shows the effect of homomorphic filtering.

In case of histogram equalization and homomorphic filtering, the edge of original image was covered over 99 percent. But the result of sharpening showed accordance by 93 percent. It means that the location of edge changed by using sharpening filter.

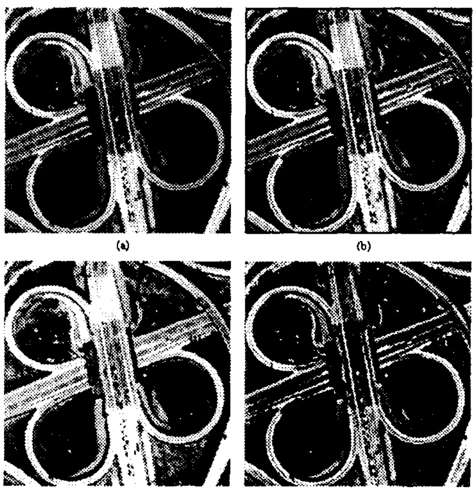


Fig. 5. The results of homomorphic filtering with respect to IKONOS PAN sub image.

As shown before, homomorphic filtering is effective technique in extracting linear feature from image and edge detection because it elevates the contrast of boundary. So, we applied to real image and geophysical data. Fig. 7 shows the extraction of linear feature from satellite image. This image is the Landsat 7 ETM+ image and shows mountainous regions, which are located in Jung-sun, Kangwon-do. Homomorphic filtering made the difference of pixel values amplified and boundary. So, the continuity becomes better in comparison sharpening when we extract linear features. Meanwhile, extracting unnecessary features is prevented because the effect of unnecessary part is decreased.

We applied this scheme in finding potential anomaly from geophysical data. Using homomorphic filtering, which amplify differences, for geophysical data might be effective. This method can be applied to other potential data, such as gravity data, as well as magnetic data. Fig. 8 shows the enhanced image of actual magnetic data, which were obtained by ground investigation, in the Jeju island, using homomorphic filtering.

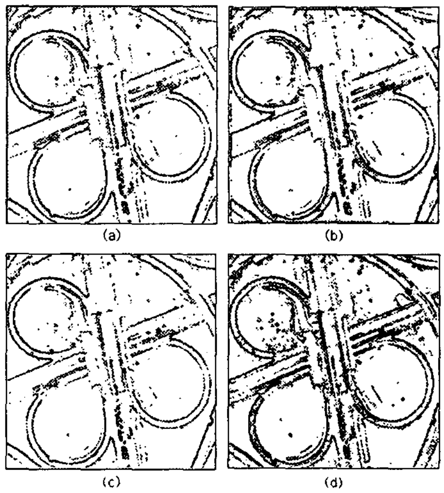


Fig. 6. Cases of Edge detection with several image enhancement schemes.

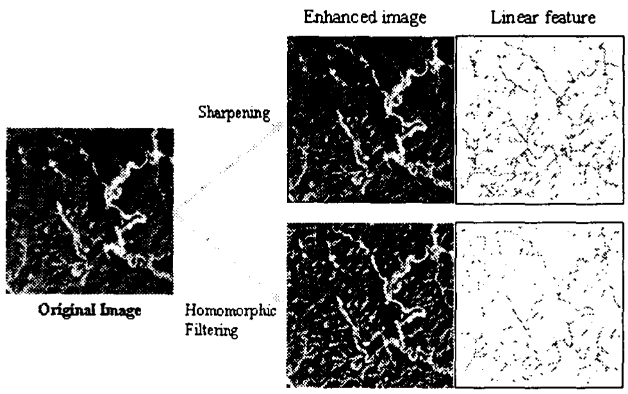
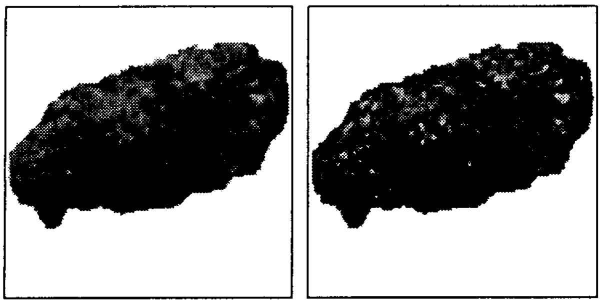


Fig. 7. Comparison results of linear feature extraction without/with homomorphic filtering.



(a) (b)

Fig. 8. Homomorphic filtered result with respect to ground magnetic data

4. Conclusion

The homomorphic filtering is an effective non-linear mapping function in spatial frequency domain. It functions that the illumination that tends to vary slowly across an image could be decreased, whereas the reflectance that is characterized by sharp changes could be increased.

Especially, this approach can be applied to extract edge and find anomaly because of amplifying contrast. Thus, homomorphic filtering can be applied to other geophysical imaging data such as gravity data and magnetic data, as well as space-borne imageries.

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