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WEATHER SATELLITE IMAGE ENHANCEMENT USING HOMOMORPHIC FILTERING

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Abstract:
This paper presents an enhancement method for weather satellite images using a homomorphic filtering procedure. Homomorphic filtering is a technique applied in the frequency domain that enhances images by compressing their intensity range and simultaneously improving their contrast. Prior to applying homomorphic filtering, a median filter is used to remove noise from the input image. The results demonstrate that the proposed procedure successfully improves the visibility of weather satellite images.

Keywords: *Image processing, Homomorphic filtering, Median filtering, Image enhancement.*

Introduction

Meteorological satellite imagery provides significant information for meteorologists and scientists [1-2]. Recently, due to rapid climate changes, the obtained weather maps have become crucial data for monitoring and analyzing atmospheric movements and changes [3-4]. These weather maps are acquired from operational weather satellites, which gather data for weather forecasting and monitoring the Earth's climate system, such as NOAA satellites (National Oceanic and Atmospheric Administration) [5]. The images are received and recorded via the Automatic Picture Transmission (APT) system, specially developed for image transmission from weather satellites [6], using a software-defined radio (SDR) system [7]. After reception, the data is converted from a waveform audio file format to an image format, as the transmitted signal from the NOAA satellites is not originally in an image format [7].

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Satellite connections are highly susceptible to various interferences, which can result in noisy signals. Consequently, the resulting images often contain various artifacts, such as spots, glare, shadows, and blur. Therefore, it is necessary to eliminate these artifacts before observation and analysis. Various image processing methods can adequately improve the resulting satellite images [8]. In this paper, a weather map image enhancement method using homomorphic filtering is presented. The homomorphic filtering process is preceded by median filtering. Experiments show that the proposed method can significantly improve the quality of the weather map images.

1. Image Enhancement using Homomorphic Filtering

Homomorphic filtering is a frequency domain procedure used to enhance the appearance of an image by simultaneously compressing the intensity range and improving contrast, based on the illumination-reflectance image model [8]. The aim of this approach is to separate the illumination and reflectance components before applying the filter's transfer function using the logarithmic operation. Essentially, this procedure is a frequency domain filtering technique, as shown in Figure 1.

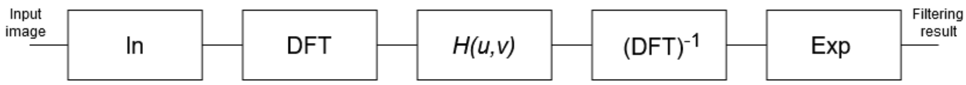


Figure 1. *Homomorphic filtering procedure* [8]

Based on the illumination-reflectance image model, the image can be defined as [8]:

$$f(x,y) = f_i(x,y)f_r(x,y) \tag{1}$$

where f represents the image, f_i and f_r are the illumination and reflectance components respectivelly, and x and y are the spatial coordinates. Since the Fourier transform of a product is not the product of the individual transforms, equation (1) cannot be used directly for frequency domain filtering [8]:

$$F[f(x,y)] \neq F[f_i(x,y)]F[f_r(x,y)] \tag{2}$$

Therefore, suppose that the logarithm operation is applied to the input image:

$$t(x,y) = \ln[f(x,y)] = \ln[f_i(x,y)] + \ln[f_r(x,y)] \tag{3}$$

Further, the Fourier transform is applied to the expression (3):

$$F\{t(x,y)\} = F\{\log[f(x,y)]\} = F\{\log[f_i(x,y)\}] + F\{\log[f_r(x,y)]\} \tag{4}$$

Equation (4) can be written as [8]:

$$T(u,v) = T_i(u,v) + T_r(u,v) \tag{5}$$

where T_i and T_r the Fourier transforms of the illumination and reflectance components respectively, and u and v are the spatial frequencies.

Finaly, the filtering is done using the $H(u,v)$ transfer function of the highpass filter [8]:

$$G(u,v) = H(u,v)T(u,v) = H(u,v)T_i(u,v) + H(u,v)T_r(u,v) \tag{6}$$

where G denotes the filtering result in frequency domain.

Next, the filtering result is transformed in the spatial domain:

$$g(x,y) = F^{-1}[G(u,v)] = F^{-1}[H(u,v)F_i(u,v)] + F^{-1}[H(u,v)F_r(u,v)] \tag{7}$$

and the next expressions are defined:

$$g_i(x,y) = F^{-1}[H(u,v)T_i(u,v)] \tag{8}$$

$$g_r(x,y) = F^{-1}[H(u,v)T_r(u,v)] \tag{9}$$

$$g(x,y) = g_i(x,y) + g_r(x,y) \tag{10}$$

where g, g_i and g_r are the filtering result, and its illumination and reflectance components in spatial domain respectively.

Finally, since the $t(x,y)$ was formed taking the natural logarithm of the input image, hence the reverse process is done using the exponential operation [8]:

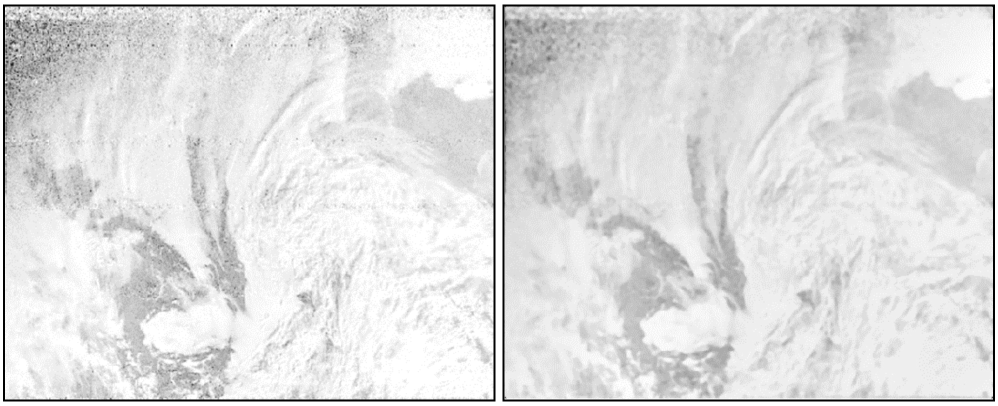
$$s(x,y) = e^{g(x,y)} = e^{g_i(x,y)}e^{g_r(x,y)} = s_i(x,y)s_r(x,y) \tag{11}$$

where s, s_i and s_r are the final result of the homomorphing filtering, and its illumination and reflectance components respectively.

This is an important fact, as the *H(u,v)* homomorphic filter transfer function can operate separately on image components, significantly simplifying the filtering procedure.

2. Experiments and Results

Next, the experiments and results will be presented. As mentioned earlier, the weather map images were obtained from NOAA satellites using APT and SDR systems. The received data was converted from waveform audio file format to image format before the filtering procedure [7]. The resulting weather map images were first filtered with a well-known median filter to reduce noise [8]. Then, the homomorphic filtering procedure was applied.



(***a***) (***b***)

Figure 2. *Result of the homomorphic filtering procedure: (a) input image; (b) filtering result*

As can be seen, the input image in Figure 2(a) contains various artifacts, such as noise and glare. These artifacts are the result of satellite connections and various interferences. First, the noise is reduced using median filtering, followed by homomorphic filtering. The final result is shown in Figure 2(b). It can be observed that the obtained image contains less noise and glare, leading to enhanced visibility of the weather map.

Finally, it should be noted that this pre-processing procedure is one of many steps involved in improving weather map images. Today, fuzzy logic, neural networks, and deep learning methods are also used in the processing of satellite images [8].

3. Conclusions

This paper presents an enhancement method for weather satellite images using homomorphic filtering. Homomorphic filtering is a frequency-domain technique based on the illumination-reflectance image model. Before applying homomorphic filtering, median filtering is used to reduce noise in the input image. The results show that the proposed approach effectively enhances the visibility of weather satellite images.

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