HOMOMORPHIC FILTERING

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INTRODUCTION

Homomorphic filters are a generalized image processing technique which are used for image enhancement and noise removal. It can be described a non-linear mapping from on one specific domain to another, where it will allow for a linear filter techniques to be applied. The concept was first introduced by Thomas Stockham, Alan V. Oppenheim, and Ronald W. Schafer at MIT.

METHODOLOGY

As been described in the introduction, Homomorphic filters are use for image enhancement and noise removal. Image enhancement, in general,is the process of improving the quality of an input digital image using filters.The principal objective of image enhancement is to modify attributes of an image to make it more suitable for a given task [1].
Image enhancement can be applied on the spatial domain of an input image and the frequency domain.
Multiplicative noise removal is one of the techniques used for image enhancement. It happens when a random signal affects another real and wanted signal(the random signal multiplied with the real one). Homomorphic filters is used to remove this type of noise.

0.0.1 Illumination-Reflectance Model

An important concept needs to be introduced which is the illumination-reflectance model. A 2d image can be described as a combination of its illumination and reflectance functions.

$$S(x,y) = R(x,y)L(x,y) \tag{1}$$

Where S is the input image. R is the reflectance function which is the amount of light reflected from different objects in the scene(the real signal(image)). L is the illumination function which is the amount of light illuminating on the objects within the scene(shows the spatial variations, The multiplicative noise).
This model is used to deal with the problems related to improving the quality of the images that suffers from poor illumination, got acquired under poor illumination conditions. For example, shady images, blurry images. Homomorphic filters can be used to remove the shading and blurring effects and images with non-uniform illumination.

0.0.2 How Homomorphic filters works

- Remove the illumination factor, L(x,y), in the image model (1) while keeping the reflectance factor, R(x,y). because L(x,y) is considered the multiplicative noise. So, the first step is to convert the model components multiplication into summation which is done using the log function.

$$ln(S(x,y)) = ln(R(x,y)L(x,y)) \tag{2}$$

$$ln(S(x,y)) = ln(R(x,y)) + ln(L(x,y)) \tag{3}$$

- Remove the low frequency illumination parameters Using a high-pass filter on the model after applying the log function. And keep the high frequency reflectance parameters.

- Convert the image model to the frequency domain, then apply one of the High pass filters like Gaussian or Butterworth filtes.

$$F[ln(S(x,y))] = F[ln(R(x,y))] + F[ln(L(x,y))] \tag{4}$$

$$Z(u,v) = F_R(u,v) + F_I(u,v) \tag{5}$$

Where $F_R(u,v)$ is $F[ln(R(x,y))]$ and $F_I(u,v)$ is $F[ln(L(x,y))$.
After Applying the H.P filter we have :

$$O(u,v) = H(u,v).Z(u,v) = H(u,v).F_R(u,v) + H(u,v).F_I(u,v) \tag{6}$$

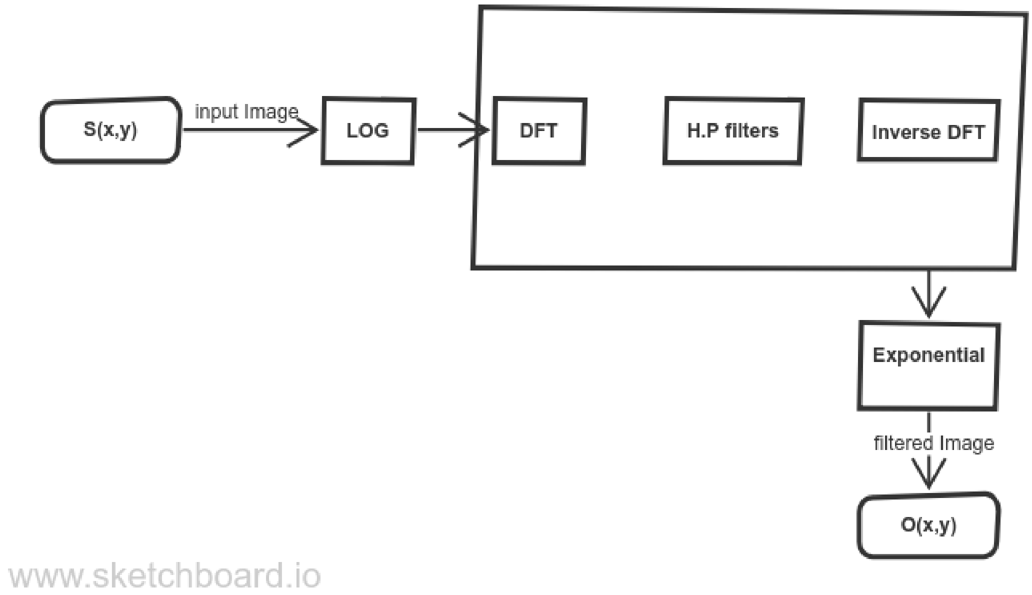
Where $H(u,v)$ is a High Pass Filter in the frequency domain.

- Take the inverse of the Fourier Transform.

$$O(x,y) = F^{-1}[O(u,v)] = F^{-1}[H(u,v).F_R(u,v) + H(u,v).F_I(u,v)] \tag{7}$$

- After that, to get the homomorphic filtered image we apply the exponential function.

$$O(x,y) = exp[O(x,y)] \tag{8}$$



0.0.3 High Pass Filters

We apply high pass filters on the log transformed image, to provide to remove the low frequencies in the image as been described before. let's describe two of the high pass filters used in the homomorphic filtering algorithm.

- Gaussian High-pass Filter [2]

$$H(u,v) = 1 - exp^{\frac{(u-\frac{M}{2})^2+(v-\frac{N}{2})^2}{2\times\sigma^2}} \tag{9}$$

  Where u,v are the pixel coordinates in the image, M,N are the shape of the image(Width,Height) and σ is the Gaussian parameter

- Butterworth High-pass Filter [2]
  It controls the sharpness of the filter based on its order. The function is given by

$$H(u,v) = \frac{1}{1+\frac{\sigma}{(u-\frac{M}{2})^2+(v-\frac{N}{2})^2)^{2n}}} \tag{10}$$

  Where n is the filter order, and σ is the filter parameter, u and v are the pixel coordinates, M and N are the image shape.

Implementation

Data: Image, Segma

Result: Gaussian Filtered Image

Algorithm 1: Gaussian High-pass Filter

REFERENCES

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