Enhancement Based on An Image Model

The digital images we process are created from optical images. Optical images consist of two primary components, the lighting component and the reflectance component.

We have that an image *f(x,y)* can be expressed in terms of its illumination and reflectance components by means of the relation:

$$f(x,y) = i(x,y)\, r(x,y) \qquad 0 < i < \infty \quad , \quad 0 < r < 1$$

This equation can not be used directly in order to operate separately on the frequency components of illumination and reflectance because the fourier transform of the product of two functions is not separable in other words.

$$\Im\{f(x,y)\} \neq \Im\{i(x,y)\}\Im\{r(x,y)\}$$

suppose, however, that we let

$$z(x,y) = \ln f(x,y)$$
$$= \ln i(x,y) + \ln r(x,y)$$

Then , it follows that :

$$\Im\{z(x,y)\} = \Im\{\ln f(x,y)\}$$
$$= \Im\{\ln i(x,y)\} + \Im\{\ln r(x,y)\}$$
$$Z(u,v) = I(u,v) + R(u,v)$$

Where *I(u,v)* and *R(u,v)* are the fourier transform of *ln{i(x,y)}* and *ln{r(x,y)}*, respectively.

If we process *Z(u,v)* by means of a filter function *H(u,v)*.

$$S(u,v) = H(u,v)\, Z(u,v)$$
$$= H(u,v)\, I(u,v) + H(u,v)\, R(u,v)$$

where *S(u,v)* is the fourier transform of the result. In the spatial domain we have the relation:

$$s = \Im^{-1}\{S(u,v)\}$$
$$= \Im^{-1}\{H(u,v)\, I(u,v)\} + \Im^{-1}\{H(u,v)\, R(u,v)\} \quad \ldots\ldots 1$$

by letting :

$$i'(x,y) = \Im^{-1}\{H(u,v)\, I(u,v)\}$$
$$r'(x,y) = \Im^{-1}\{H(u,v)\, R(u,v)\}$$

we can express equation *(1)* in the form

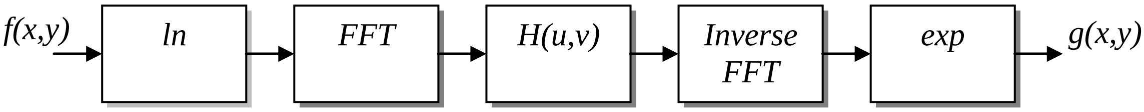
$$s(x,y) = i'(x,y) + r'(x,y)$$

finally, since *z(x,y)* was formed by taking the logarithm of the original image *f(x,y),* we now perform the inverse operation to obtain the desired enhanced image *g(x,y)*; that is:

$$g(x,y) = \exp\{s(x,y)\}$$
$$= \exp\{i'(x,y)\}.\ \exp\{r'(x,y)\}$$
$$= i_o(x,y)\, r_o(x,y)$$

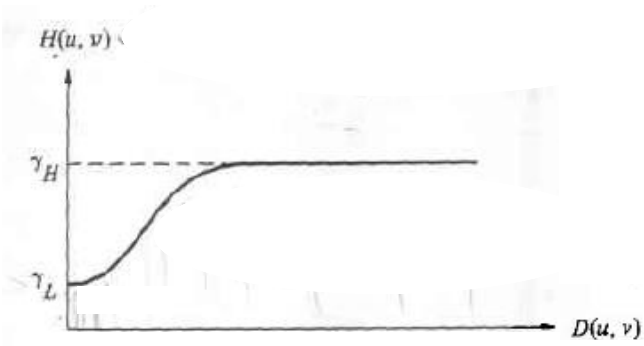
are the illumination and reflectance components of the output image.

The enhancement approach using the foregoing concepts is summarized in the following figure. This method is based on a special case of a class of systems known as homomorphic systems. In this particular application, the key to the approach is the fact that separation of the illumination and reflectance components is achieved in the form shown above. It is then possible for the homomorphic filter function *H(u,v)* to operate on these components, separately .

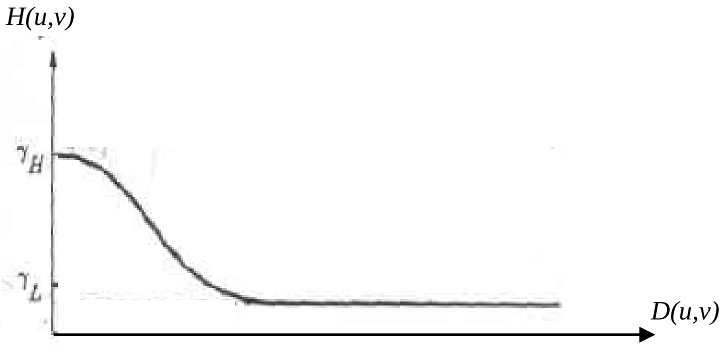


Homomorphic filtering approach for image enhancement

The typical filter for the homomorphic filtering process is shown in the following figure. Here we see that we can specify three parameters the high frequency gain, the low frequency gain, and the cut off frequency. Typically the high frequency gain is greater than *1* and the low frequency gain is less than *1*.



Cross section of homomorphic filter H(u,v)



Cross section of homomorphic filter H(u,v)

(a) (b) (c)

Homomorphic filtering: (a) homomorphic filter response, (b) input image, (c) result of homomorphic filtering.

(a) Original image (b) After homomorphic filtering