Topic 11: Optical Processing

Aim

These two lectures cover coherent optical processing using the the Fourier Transform property of lenses. The operations considered are amplitude filtering, phase contrast filtering, Fourier matched filtering and optical tracking.

References

Reference are difficult here, they are either over-detailed, such as Goodman or rather superficial such as Guenther or Hecht.

- Goodman, **Chapter 8** (More detail that is needed)

- Guenther Chapter 10-B, (Very nice examples, including phase filtering).

- Guenther Chapter 12-B, (Good examples of Fourier holography).

- Hecht Chapter 14.1 (Excellent examples of simple filtering)

11   Optical Processing

11.1   Focus of a Laser Beam

A collimated He-Ne laser beam (633 nm) with a Gaussian amplitude of

$$u_0(x,y) = A \exp\left(-\frac{r^2}{r_0^2}\right)$$

is focused by a $\times 40$ microscope objective. Calculate an expression for the amplitude, and intensity distribution in the back focal plane of the objective.

Hint: Assume that the pupil function of the microscope objective is much larger that the laser beam.

If $r_0 = 0.4$ mm calculate the diameter of the input beam and the spot in the back focal plane. For a Gaussian beam the "diameter" is defined by the points that the *intensity* drops to e^{-2}.

11.2   Fourier Properties of a Lens

Show that if a slide of amplitude transmission $f_a(x,y)$ is illiminated with a coherent collimated beam in the front focal plane of a lens of focal length f, then in the back focal plane the amputide distribution is the scaled Fourier Trasnform of the object.

Hint: First calculate this for the general case of the slide being a distance z in-front of the lens, and then look at the special case of $z = f$.

11.3   Optical Processing

An 4-f optical processing system with 500 mm focal length lenses is used de-stripe lunar photographs as shown in page 472 of *Optics* by Hecht. If the stripes periodic with spacing 0.3 mm sketch the modulus of the Fourier transform of a typical slide and calculate the location of the spots associated with the stripping.

11.4   Computer Optical Filtering

Experiment with the program optical_processing available on the CP laboratory machines to simulate the optical processing of images using a range of filters $H(u, v)$. The programme is located in:

> wjh/mo4/examples/optical_processing

and is supplied with a selection of images in the same directory. These images are taken as the input *intensity* transmittance, from which the input *amplitude* transmittance is calculated by taking the square root. You can view the initial images with

> xv <imagefile>

The supplied images are:

toucan.pgm	Image of Toucan
grating.pgm	Horizontal grating
fringe.pgm	Fringe pattern
fan.pgm	Fan image used in defocus dems.

The program will ask you for:

1. *Input image:*

2. *Filter Type:* The options are:

lowpass	Lowpass filter
highpass	Highpass filter
bandpass	Combination of low and high
guassianlow	Gaussian lowpass
gaussianhigh	Guassian highlass

3. The program will then perform the calculateion and display the output *intensity* via xv.

Note: To get sensible images after highpass filtering you may have to use the "Color Edit" window in xv to modify the gamma of the output (try 3) which reduces the contrast.

11.5   Computer Phase Filtering

Experiment with the program phase_filtering available on the CP laboratory machines to simulate the optical processing of images using a range of filters $H(u, v)$. The programme is located in:

wjh/mo4/examples/phase_filtering

and is supplied with a selection of images in the same directory as listed above.

These images are used to make the "phase only" objects with a user specified maximum phase depth. The resultant phase image is then reconstrcted under either *Darkfield* of *Zernike Phase Contrast* imaging and the *intensity* of the ouput image displayed using xv.

The program will ask you for:

1. *Input image:*

2. *Maxiumum phase depth in Wavelengths* (try numbers in the range $0.1 \rightarrow 3$.

3. The type of reconstruction. The options are

darkfield or zernike

4. The program will then perform the calculation and display the output *intensity* via xv.

Again you may have to use the "Color Edit" option to get clear images due to dynamic range problems.

Note: while phase range is small things behave as "expected". However for larger phase ranges things start of go "very wrong" especially for the Zernike reconstructions. Details of this are beyond this course.

11.6   Expanding a laser beam

A collimated laser beam can be expanded into a diverging beam with a short focal length lens, typically a microscope objective. However inperfections in the glass of the objective and dust particles on the lenses result in additional high frequency patterns being superimposed on the exmanding beam. Suggest a scheme for removing this high fequency patterns to give a clean expanding beam.

11.7   Fourier Holograms

Explain the use of off-axis Fourier holograms in optical correlator system, and derive an expression for the **three** term in the output plane of the system with an input $g(x, y)$ and a hologram recording $F(u, v)$ with a carrier frequency at angle θ.

Calculate the maximum size of input field to prevent overlapping occurring in the output. (Hint: to do this properly is rather difficult since you must consider the extent of the input, correlated with the extent of the object encoded in the Fourier hologram.)