Vision Science II

Lab 5 - Fourier transformation of images

Fourier analysis is a powerful tool that allows us to break down functions into its basic sinusoidal components. One-dimensional functions are curves that show how values (plotted on the y-axis) change as a function of another variable such as time or distance (plotted on the x-axis). Two- dimensional functions are numerical values that vary as a function of position within a two-dimensional area. Images are two-dimensional functions in which the luminance value varies depending on its location on the two-dimensional surface. Fourier analysis can be applied to both one and two- dimensional functions, but we'll begin our study with one-dimensional functions, since they are easier to understand.

Excel FFT workbook

A. Sine wave parameters

- Notice how the sine wave changes with changes ΔI (magnitude), f (frequency) and phase.
- How would changes in ΔI (amplitude), f (frequency) affect the appearance of a sine wave grating?

Decreasing amplitude would decrease contrast. Increasing frequency would cause more, and narrower stripes to fit into the pattern. Low frequency would cause broader stripes.

B. Sum sine waves

- Start with a single sine wave with a f=1 and contrast=1.0 (lower curve).
- Create a square wave by adding sine waves. Note the sum in the upper curve.
- You can see how this is approaching a square wave. How could you perfect its appearance?

By continuing the pattern with higher frequencies.

- What happens to the sum if you modify some parameters? What does this show?

The appearance of the sum will change. The component sine waves must have the proper frequencies, amplitudes, phase and mean values to add up to the correct function.

C. FFT of sine waves

- Explain the spatial domain table, its parameters (in yellow) and the graph.

They have the x and y data that is plotted in the graph, showing the sine wave. It is the function to be analyzed.

- Explain Fourier transformation, the frequency spectrum table and its graph. The Fourier transformation operation compute the frequency spectrum, which tell you the frequency and amplitudes (contrast) in the original sine wave.
- What is the connection between the Fourier spectrum values (x and y) and the sine curve? The position of the values (x axis) tells you the frequency; the y-axis values correlate with the amplitude.
- Perform a Fourier transformation of a single sine wave and notice the result.
- The Fourier transform of a function is known as its **frequency spectrum.**
- ~~What is the relationship between the middle value in the magnitude spectrum and the original function? In the raw Fourier transform data, it is equal to the sum of the input data values.~~

D. FFT of summed sine waves

- Explain the top function. It is the sum of the five sine waves that were added to make the square wave.
- Compute the FFT and explain what the values mean in the graph as well as in the data table. The position of the values in the output table indicates which frequencies were included and their values indicate the relative amplitudes of the sine waves.

E. FFT of an arbitrary function

- Explain the function (x, y values) then perform an FFT on the data. It's an arbitrary function.
- What does the graph show about the original data? The frequencies and amplitudes contained in the arbitrary function.

Transform notebooks

A. MakeGrating notebook

- Vary the basic parameters and make one or two vertical sine wave gratings
- Look at a line graph of the luminance profile.

- Compute the Fourier spectrum and explain how the values in the spectrum relate to the grating image. The position out from the center indicates the spatial frequency; location indicates orientation and value indicates contrast.

B. Spectrum2Grating notebook

- Enter values to make high contrast vertical, horizontal and oblique gratings.
- Combine several gratings with different contrasts.

C. SpatialFilteringDemo notebook

- Open the image and note characteristics of the image.
- Compute the Fourier spectrum graph and note where the high values are. Why there? Higher values, indicated by darker pixels indicate higher contrast gratings. The highest values are along the horizontal and vertical midlines, indicating rstrong representation in the original image, features that would be created, respectively, by vertical and horizontal sine wave gratings.
- Filter high and low spatial frequencies and learn what they contribute to the image. Low spatial frequencies make up the large, broad features; high frequencies give the edges and details.
- Discuss how refractive errors create low-pass filtered images. Refractive errors filter out high spatial frequencies and this leads to a blurry image.
- Filter an unknown image. Who can identify it with the fewest spatial frequencies?