Universidad Autónoma de Madrid

Computer Science Department

Biomedical Image Processing
Assignment - 2

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Contents

1 Goal

To better understand the contrast transfer function in electron microscopy.

2 Introduction

The contrast transfer function describes how an object examined in a transmission electron microscope is imaged, essentially providing a description of distortions due to imperfect image formation by the microscope. By considering the recorded image as a CTF-degraded true object, describing the CTF allows the true object to be reverse-engineered.

In the following we introduce a first order approximation used to describe the CTF.

$$
\begin{aligned}
CTF(\mathbf{R}) &= w\cos(\gamma(\mathbf{R})) - \sqrt{1-w^2}\sin(\gamma(\mathbf{R})) \\
\gamma(\mathbf{R}) &= 180\lambda(-\Delta Z\|\mathbf{R}\|^2 + \frac{Cs10^6\|\mathbf{R}\|^4\lambda^2}{2}) \; \textit{in degrees}
\end{aligned}
$$

where $\mathbf{R}$ is the spatial frequency, ΔZ denotes defocus in nm., w is the percentage of amplitude contrast and Cs is the spherical aberration in mm. Finally, the factor 10^6 converts Cs from mm to nm. and $\gamma(\mathbf{R})$ is termed in the specialized literature as wave aberration function.

Questions 1:

- Using matlab plot the CTF using the following two sets of values:
  - Cs=0.6 mm. accelerating voltage 300keV (λ=1.97 pm), ΔZ = 39.7 nm.
  - Cs=0.6 mm. accelerating voltage 300keV (λ=1.97 pm), ΔZ = 90 nm.
- For which frequencies the contrast is inverted?

Questions 2:

- Simulate the aberrations introduced by the microscope by convolving the Einstein image with the above CTF.
- restore partially the image by multiplying (in Fourier space) it by the sign of the CTF
- restore partially the image by multiplying (in Fourier space) it by the $\frac{1}{CTF+\epsilon}$ where ϵ is a small number that avoid division by zero

Questions 3:

- Create a uniform noise image and convolve it with the CTF. Plot the magnitude of the Fourier transform, the rings you see are the so-called Thon rings. (Fourier transform the image, multiply it by the CTF, plot the Fourier transform magnitude)
- What happen if you increase ΔZ? Does the distance between rings increase or decrease with a defocus increment?