Noise Analysis and Removal
in 3D Electron Microscopy

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Abstract. Recent research in several fields such as Biotechnology and Healthcare has uncovered a vast number of applications where 3D Electron Microscopy (EM) is useful. However, images produced by 3D EM are in most cases severely degraded. These degradations arise due to a multitude of reasons, e.g. the complex electronics in the system, magnetic lens aberration, heating and motion stability, charging, etc. Although the raw, degraded images are currently used for analysis, their usefulness is limited because the degradations make visual distinction and automated analysis of biological features very difficult. In this work, we give an analysis of noise, as one of the most important degradations in 3D EM imaging. Next, we propose a Non-Local Means image restoration algorithm that exploits the derived noise characteristics. The proposed algorithm yields significant improvements compared to other state-of-the-art image restoration algorithms.

1 Introduction

Microscopy has been a crucial subject within fields such as biological and medical research. Where Light Microscopy (LM) is able to magnify up to a factor of 2.000, recent Electron Microscopes (EM) allow us to increase this factor up to 2.000.000. Therefore, it is possible to image biological samples up to nanometer resolution.

However, acquired EM images are severely degraded with various artifacts such as noise (Fig. 1), making it sometimes difficult for field experts to visually distinct biological structures. Current methods used in EM for dealing with these obstacles involve low-pass filtering techniques resulting into low-quality image restorations. Further automated processing such as e.g. segmentation will, as a consequence, become less accurate.

Image restoration requires a detailed description of the image artifacts. For example, taking into account for noise correlation yields significant improvements in several existing techniques \cite{1, 2, 3, 4}. We will therefore perform an analysis of EM noise, which is one of the most notable artifacts in EM images.

The derived noise characteristics will be used in a Non-Local Means (NLMS) framework. NLMS \cite{5} is a state-of-the-art denoising algorithm exploiting non-local
repetitive structures in images. In order to do this, it assumes white, Gaussian noise in the corrupted image, an assumption which is not always satisfied. We will therefore extend this algorithm in order to remove correlated, signal-dependent noise.

The structure of this paper is as follows: in Sect. 2 we will discuss the image acquisition process and noise sources in 3D EM. Furthermore, a noise analysis within degraded EM images is derived. Next, the proposed NLMS-based algorithm will be discussed in Sect. 3. We evaluate the proposed algorithm in Sect. 4. Finally, Sect. 5 recapitulates this paper.

2 EM Image Acquisition and Degradation

Image artifacts such as noise are caused by a variety of sources: complex electronics, heating, signal amplification, etc. A study of how these artifacts are introduced in the resulting EM images will allow us to suppress them more effectively.

2.1 Image Acquisition and Noise Sources

In general, two types of EM can be distinguished: Transmission and Scanning EM (respectively TEM and SEM). Both types focus a beam of electrons (using a magnetic lens system) on the specimen’s surface. The difference between TEM and SEM lies in the type of detected electrons. Where TEM detects electrons passing through the specimen, SEM detects backscattered electrons. In 3D SEM, a diamond knife makes a next slice after every acquired image in order to capture the next image. This way, a 3D stack of 2D images is obtained. This is called serial block face (SBF) SEM. As the name specifies, SEM scans the image in a grid, cell by cell. Fig. 2 shows the workflow of this type of EM and the most important noise sources it contains.

1 Not in the biological sense, but cells within the grid.