Scanning Electronic Microscopy Calibratio using a Smooth General Imaging Model

Xingjian Lui[1,*], Zhongwei Li[1], Kai Zhong[1], and Pedro Miraldo[2]

[1] *State Key Laboratory of Material Processing and Die & Mould Technology, School of Materials Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, China*

[2] *Institute for Systems and Robotics (LARSyS), Instituto Superior Técnico, Lisboa, Av. Rovisco Pais, 1 – 1049-001 Lisboa*

[*] *E-Mail:* xingjianliu@hust.edu.cn

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OCIS codes: (000.0000) General.

References and links

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1. Introduction

The Scanning Electron Microscope (SEM) can be seen as an imaging system where a focused electron beam strikes the surface of specimen [1]. It is an essential instrument to observe, analyze, and manipulate these micro and nano specimens with micro-scale and nano-scale accuracy. However, a SEM is designed for visualization, not for metrological studies. When the computation of metric information from 2D SEM images is needed, the model and its calibration becomes a crucial issue to be considered, in order to conduct vision-based applications: nano-handling, three-dimensional reconstruction, visual serving, etc.

Photogrammetric analysis of SEM has been considered by several authors [2, 3]. In earlier studies, two different projection models were used, according to the microscopes magnifications. At low magnification, since the field of view and the angular view (observed area) are larger, the perspective projection can be applied. On the other hand, at high magnification the field of view and the angular field of view are both very small and, as a result, projection rays can be considered as parallel: the center of projection is at infinity and the parallel projection is assumed. However, the magnification limit for the choice of perspective projection model and parallel projection model is not distinct. Generally, the limit is chosen between 200× and 1000× or higher (# put some references here). According to some papers (# Missing references), the magnification limit for perspective projection is about 500×. As a result, the applied law of projection should be changed at magnifications higher than 500× from central projection to parallel projection geometry. Sutton (# missing reference) claimed that the angular field of view is negligible only below 0.1 (# in degrees?? or radians??), the approximation of the general perspective projection by the parallel projection does not seem adequate lower than a magnification 20000×. Recently, a landmark-based 3D calibration strategy (# missing reference...) was proposed, which consists on the application of a 3D micrometre-sized reference structure with the shape of a cascade slope-step pyramid. However, the fabrication of this special 3D reference structure is an important and difficult issue. To model magnification-continuous parameters of the static distortion and the projection of the SEM, Malti (# missing reference here) purposed a systematic method of estimating the static distortion and the projective mapping, in a continuous range of magnification scale.

Since the imaging principle of the SEM is essentially different from the principle of an optical system, all the discrete calibration models above are a real bottleneck during micro/nano-material inspection, characterization, or manipulation especially in the magnification limit between 200 and 1000. So we consider to use the general imaging model to characterize the nature of the SEM imaging process. Grossberg and Nayar [24], [25] define a nonparametric discrete imaging model that can represent any type of camera, central or non-central (General Camera Model). Differently from the usual parametric camera models, this camera model consists of the individual mapping between pixels and rays in 3D space, accompanying with a simple ray-based calibration method. Their calibration approach requires the acquisition of two or more images of a calibration object with known structure, and knowledge of the camera or object motion between the acquisitions [19,20]. In 2003, P. Sturm and S. Ramalingam [18] developed a completely general approach, that requires taking three or more images of calibration object, from arbitrary and unknown viewing positions. All the methods mentioned above are discrete and nonparametric, using mapping arrays (raxels) to calibrate the imaging model. Miraldo modifies the general imaging model using radial basis functions to interpolate image coordinates and 3D lines allowing both an increase in resolution (due to their continuous nature) and a more compact representation. A new linear calibration procedure was developed. In this process it is only required to match one 3D point to each image pixel. Also it is not required the calibration of every image pixel. As a result the complexity of the procedure is significantly decreased.

This paper addresses the problem of building the real model of the SEM by using the general imaging model, where projection and imaging process can be regarded as a black box connecting pixels with corresponding rays thus no longer depend on the specific optical layout. To allow the simplification of the general calibration procedure and the parametric representation, the smooth general model and a linear point-based calibration method is used.

By using the smooth general model, the imaging rule of the SEM under different magnifications is revealed. Then the residual of the smooth model is analyzed and compared to the traditional projection model. To the best of our knowledge, it is the first time to establish the SEM model by using general imaging model. The paper is organized as follows. First, the imaging process of the SEM and the general imaging model are described in Section II. Section III introduces the smooth general imaging model of a SEM including the parametric representation of the model and The linear point-based calibration. The experimental results at various magnifications that validate the approach are shown in Section IV.

2. Conclusion

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