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Notice of the Final Oral Examination for the Degree of Doctor of Philosophy

of

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"Mesh Models of Images, Their Generation, and Their Application in Image Scaling"

Department of Electrical and Computer Engineering

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Room 468

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Abstract

Triangle-mesh modeling, as one of the approaches for representing images based on nonuniform sampling, has become quite popular and beneficial in many applications. In this thesis, image representation using triangle-mesh models and its application in image scaling are studied. Consequently, two new methods, namely, the SEMMG and MIS methods are proposed, where each solves a different problem. In particular, the SEMMG method is proposed to address the problem of image representation by producing effective mesh models that are used for representing grayscale images, by minimizing squared error. The MIS method is proposed to address the image scaling problem for grayscale images that are approximately piecewise-smooth, using triangle-mesh models.

The SEMMG method, which is proposed for addressing the mesh-generation problem, is developed based on an earlier work, which uses a greedy-point-insertion (GPI) approach to generate a mesh model with explicit representation of discontinuities (ERD). After in-depth analyses of two existing methods for generating the ERD models, several weaknesses are identified and specifically addressed to improve the quality of the generated models, leading to the proposal of the SEMMG method. The performance of the SEMMG method is then evaluated by comparing the quality of the meshes it produces with those obtained by eight other competing methods, namely, the error-diffusion (ED) method of Yang, the modified Garland-Heckbert (MGH) method, the ERDED and ERDGPI methods of Tu and Adams, the Garcia- Vintimilla-Sappa (GVS) method, the hybrid wavelet triangulation (HWT) method of Phichet, the binary space partition (BSP) method of Sarkis, and the adaptive triangular meshes (ATM) method of Liu. For this evaluation, the error between the original and reconstructed images, obtained from each method under comparison, is measured in terms of the PSNR. Moreover, in the case of the competing methods whose implementations are available, the subjective quality is compared in addition to the PSNR. Evaluation results show that the reconstructed images obtained from the SEMMG method are better than those obtained by the competing methods in terms of both PSNR and subjective quality. More specifically, in the case of the methods with implementations, the results collected from 350 test cases show that the SEMMG method outperforms the ED, MGH, ERDED, and ERDGPI schemes in approximately 100%, 89%, 99%, and 85% of cases, respectively. Moreover, in the case of the methods without implementations, we show that the PSNR of the reconstructed images produced by the SEMMG method are on average 3.85, 0.75, 2, and 1.10 dB higher than those obtained by the GVS, HWT, BSP, and ATM methods, respectively. Furthermore, for a given PSNR, the SEMMG method is shown to produce much smaller meshes compared to those obtained by the GVS and BSP methods, with approximately 65% to 80% fewer vertices and 10% to 60% fewer triangles, respectively. Therefore, the SEMMG method is shown to be capable of producing triangular meshes of higher quality and smaller sizes (i.e., number of vertices or triangles) which can be effectively used for image representation.

Besides the superior image approximations achieved with the SEMMG method, this work also makes contributions by addressing the problem of image scaling. For this purpose, the application of triangle-mesh mesh models in image scaling is studied. Some of the mesh-based image-scaling approaches proposed to date employ mesh models that are associated with an approximating function that is continuous everywhere, which inevitably yields edge blurring in the process of image scaling. Moreover, other mesh-based image-scaling approaches that employ approximating functions with discontinuities are often based on mesh simplification where the method starts with an extremely large initial mesh, leading to a very slow mesh generation with high memory cost. In this thesis, however, we propose a new mesh-based image-scaling (MIS) method which firstly employs an approximating function with selected discontinuities to better maintain the sharpness at the edges. Secondly, unlike most of other discontinuity-preserving mesh-based methods, the proposed MIS method is not based on mesh simplification. Instead, our MIS method employs a mesh-refinement scheme, where it starts from a very simple mesh and iteratively refines the mesh to reach a desirable size. For developing the MIS method, the performance of our SEMMG method, which is proposed for image representation, is examined in the application of image scaling. Although the SEMMG method is not designed for solving the problem of image scaling, examining its performance in this application helps to better understand potential shortcomings of using a mesh generator in image scaling. Through this examination, several shortcomings are found and different techniques are devised to address them. By applying these techniques, a new effective mesh-generation method called MISMG is developed that can be used for image scaling. The MISMG method is then combined with a scaling transformation and a subdivision-based model-rasterization algorithm, yielding the proposed MIS method for scaling grayscale images that are approximately piecewise-smooth. The performance of our MIS method is then evaluated by comparing the quality of the scaled images it produces with those obtained from five well-known rasterbased methods, namely, bilinear interpolation, bicubic interpolation of Keys, the directional cubic convolution interpolation (DCCI) method of Zhou et al., the new edge-directed image interpolation (NEDI) method of Li and Orchard, and the recent method of super-resolution using convolutional neural networks (SRCNN) by Dong et al.. Since our main goal is to produce scaled images of higher subjective quality with the least amount of edge blurring, the quality of the scaled images are first compared through a subjective evaluation followed by some objective evaluations. The results of the subjective evaluation show that the proposed MIS method was ranked best overall in almost 67% of the cases, with the best average rank of 2 out of 6, among 380 collected rankings with 20 images and 19 participants. Moreover, visual inspections on the scaled images obtained with different methods show that the proposed MIS method produces scaled images of better quality with more accurate and sharper edges. Furthermore, in the case of the mesh-based image-scaling methods, where no implementation is available, the MIS method is conceptually compared, using theoretical analysis, to two mesh-based methods, namely, the subdivision-based image-representation (SBIR) method of Liao et al. and the curvilinear feature driven image-representation (CFDIR) method of Zhou et al..