Ink Dot-Oriented Differentiable Optimization for Neural Image Halftoning (Supplementary Material)

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1. Qualitative Experiments

To validate the efficacy of the proposed method, additional qualitative experimental results are presented in Figure 1 and Figure 2.

Taking Figure 2 as an example, it involves generating halftones on images with higher grayscales, such as a roof under direct sunlight. This sample necessitates the model to effectively manage subtle changes in tone. Some previous methods produce failed results in this experimental setup. For example, Atkinson Dithering generates halftones with undesirable blank holes. Alternative methods such as Sierra Lite Dithering, Floyd-Steinberg Error Diffusion, Simpler Floyd-Steinberg Error Diffusion, and Ostromoukhov's Method avoid generating blank holes but introduce streaks of regular ink dots in certain areas, diminishing the visual quality of the halftone generation. The deep learning-based method (Xia's Method) also demonstrates restricted performance in flat areas, revealing artifacts created by the dot structure that are relatively evident. Additionally, it exhibits limitations in reproducing subtle changes in light and tone shadows. In contrast, our method better preserves tonal details in flat regions and achieves superior visual results.

2. Experiments on High-Resolution Images

To validate the effectiveness of our proposed method on high-resolution images, we adopt images from the DIV2K dataset [1] and conduct experiments on them. The halftone outputs of our method are depicted in Figure 3. The top image primarily validates the halftone performance on high grayscale images with light-toned backgrounds. The generated halftones showcase a well-distributed pattern of ink dots in the bright regions, devoid of noticeable regular stripes or visual artifacts, thus achieving a satisfactory effect. The bottom image displays the high-resolution halftone outputs for medium and low gray levels. The background sky presents intricate variations in light and dark tones, and our method can simulate this scenario effectively by controlling the arrangement of ink dots. The wings of the bird in the foreground consist of pixels with various shades, and our method reproduces these details well in the generated halftones.

3. Experiments on Color Images

Apart from grayscale images, our proposed method demonstrates its ability to process color images, as illustrated in Figure 4. It can be observed that the generated color halftones exhibit visually pleasing results. It's noteworthy that our proposed algorithm does not involve any specific optimization for color halftones. Instead, we individually halftone the three color channels of the image and concatenate them to generate the color halftone. Since the primary scope of this paper centers on the halftoning process of grayscale images, we plan to explore specific optimizations of color halftoning in the future work, potentially yielding further performance improvements.

References

[1] Eirikur Agustsson and Radu Timofte. Ntire 2017 challenge on single image super-resolution: Dataset and study. In *Proceedings of the IEEE conference on computer vision and pattern recognition workshops*, pages 126–135, 2017. 1, 4, 5

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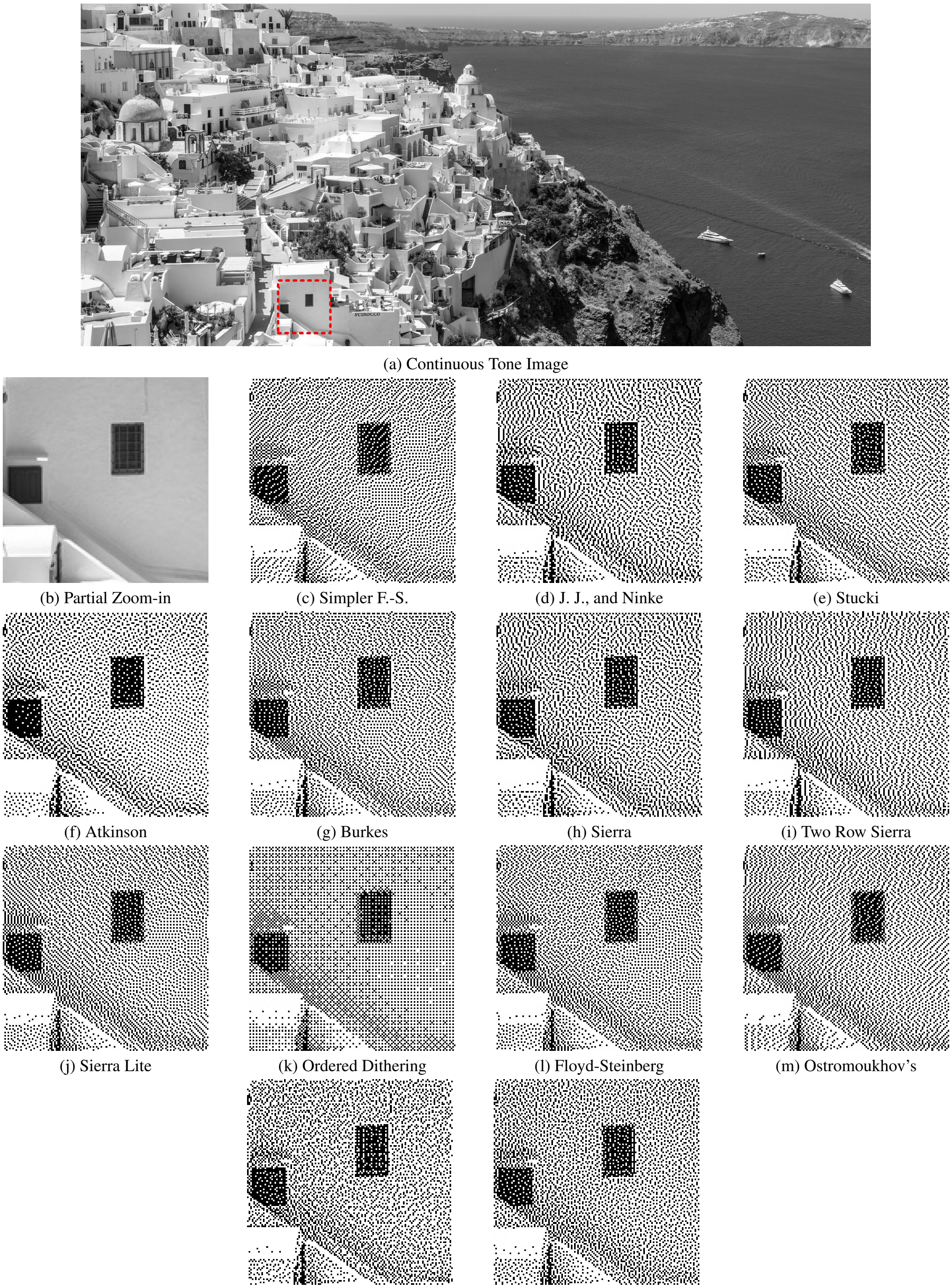


(a) Continuous Tone Image

(b) Partial Zoom-in

(c) Simpler F.-S.

(d) J. J., and Ninke

(e) Stucki

(f) Atkinson

(g) Burkes

(h) Sierra

(i) Two Row Sierra

(j) Sierra Lite

(k) Ordered Dithering

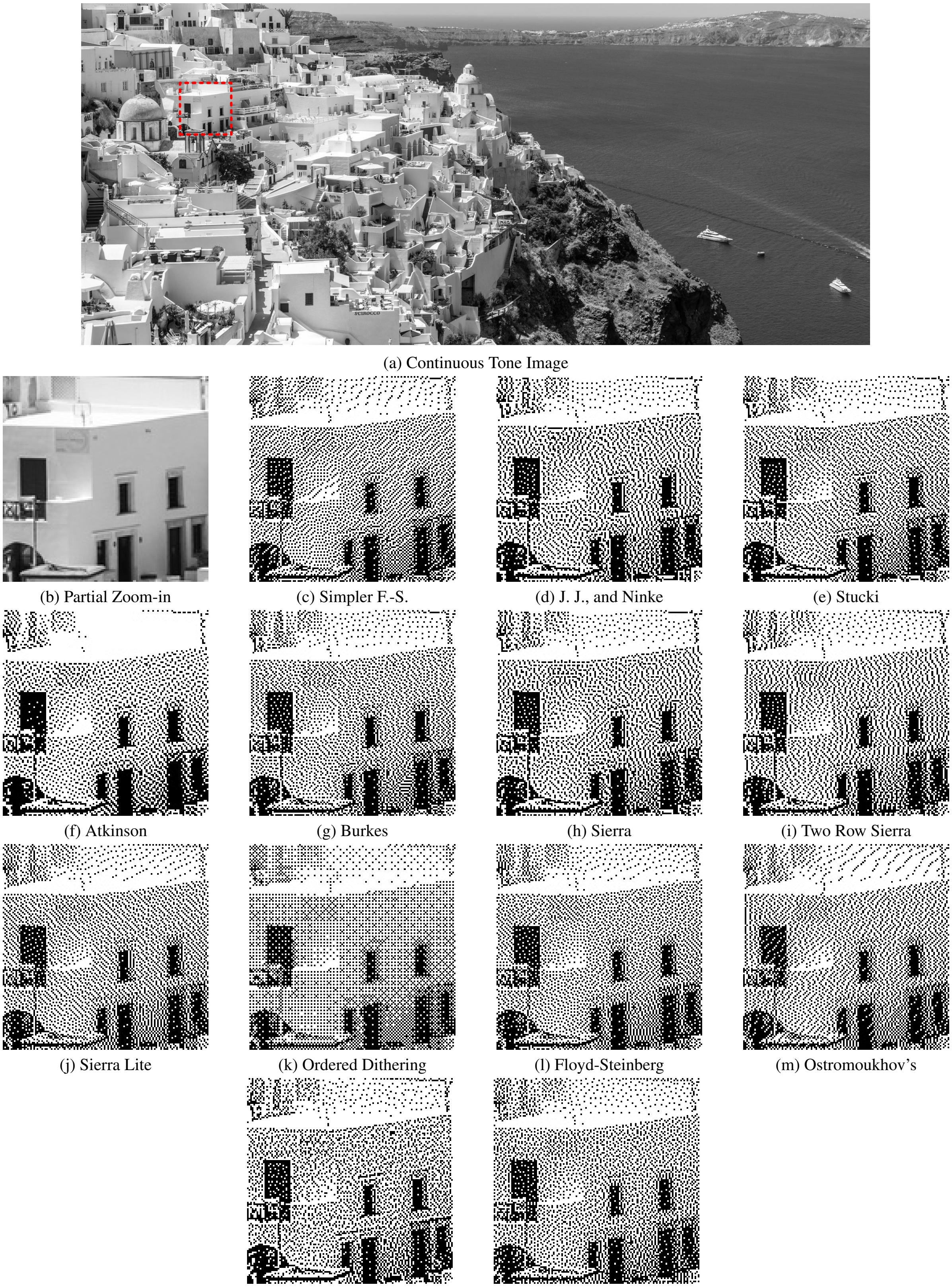
(l) Floyd-Steinberg

(m) Ostromoukhov's

(n) Xia' Method

(o) Ours

Figure 1. Qualitative experimental results. PSNR: (c): 39.79; (d): 37.01; (e): 37.91; (f): 25.22; (g): 39.80; (h): 37.59; (i): 39.43; (j): 43.60; (k): 36.87; (l): 42.50; (m): 42.21; (n): 36.52; (o): 44.10.



(a) Continuous Tone Image

(b) Partial Zoom-in, (c) Simpler F.-S., (d) J. J., and Ninke, (e) Stucki

(f) Atkinson, (g) Burkes, (h) Sierra, (i) Two Row Sierra

(j) Sierra Lite, (k) Ordered Dithering, (l) Floyd-Steinberg, (m) Ostromoukhov's

(n) Xia' Method, (o) Ours

Figure 2. Qualitative experimental results. PSNR: (c): 36.61; (d): 34.15; (e): 34.51; (f): 25.25; (g): 36.16; (h): 34.50; (i): 35.46; (j): 40.62; (k): 34.84; (l): 39.72; (m): 38.56; (n): 35.57; (o): 43.18.

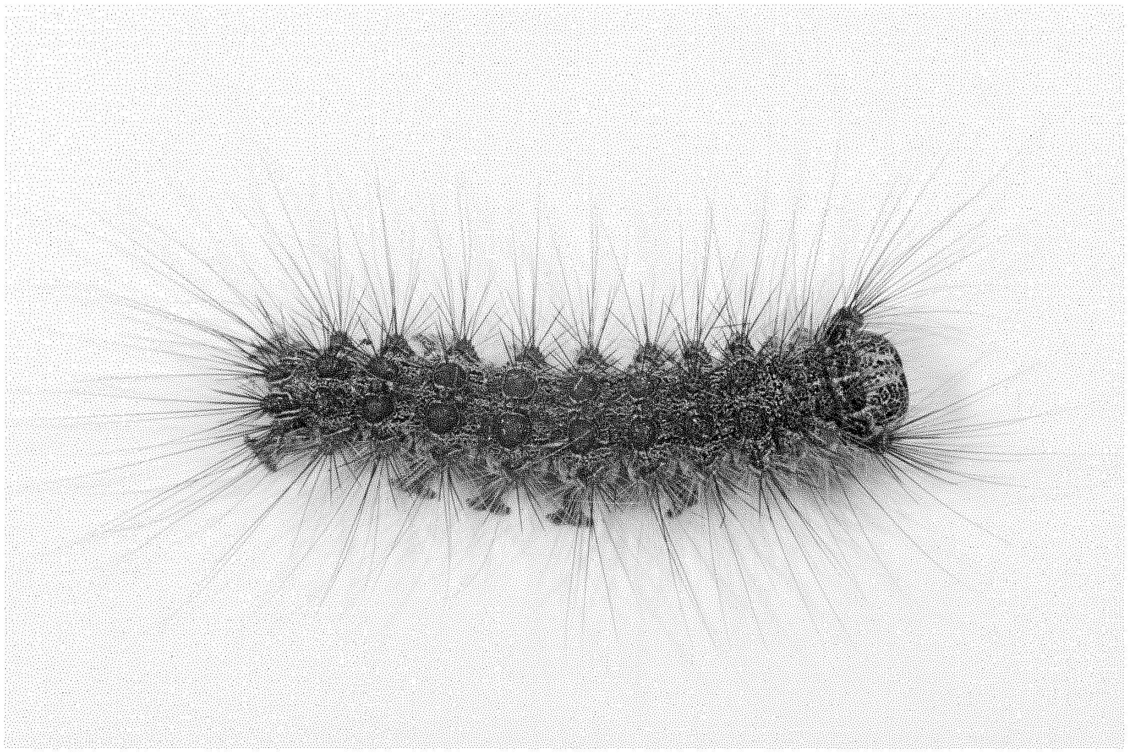


Figure 3. *Top*: Halftone results for high-resolution image with high grayscales. Image resolution is 2040×1356. *Bottom*: Halftone results for high-resolution image with medium and low grayscales. Image resolution is 2040×1356. Images are from the DIV2K dataset [1].

Figure 4. Halftone results on the color image, and the image resolution is 2040×1536. Image is from the DIV2K dataset [1].