Comparative Analysis of Inverse Halftoning Techniques

University of Toronto CSC2529 Final Project Proposal
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Overview and Motivation

Halftoning, or dithering, is an imaging technique that has long been used in the print industry to reproduce tone with limited colours (e.g. black and white) via the distribution of halftone dots [7, 8]. Dithering is also an effective technique for image compression, due to the smaller amount of storage needed for a reduced colour palette. Today, environmentally conscious web designers are also turning to dithering to radically reduce the energy consumption associated with accessing online content [2]. Inverse halftoning, on the other hand, looks to retrieve continuous-tone images from halftoned images. Reverting halftone images to continuous-tone images is useful not only for the recovery and preservation of historical printed media, but for various image editing and processing that is not possible on halftone images [9]. However, these inverse processes can be energy intensive. It is therefore desirable to find inverse halftoning techniques which generate high quality reconstructed images that are also computationally efficient. In this project, we explore various techniques for restoring dithered images to a continuous-tone image. In particular, we will evaluate the effectiveness of these techniques given different levels of compression (the number of tones used in our dithered images) as well as the computational cost. This will allow us to determine a standard of quality for inverse halftoning algorithms that also takes into account energy use.

Related Work

Extensive work has been done on inverse halftoning over the last 30 years [1, 4, 5, 8, 9]. Dither can be removed with a low-pass filter, but this causes edge information to be lost [4]. More complex techniques for inverse halftoning have also been proposed [1, 4, 5, 8, 9]. One of the most promising techniques is Mese and Vaidyanathan's use of a pre-computed look-up table (LUT) which improved both reconstruction accuracy and efficiency in comparison to previous implementations using iterative filtering or projection onto a convex set (POCS) [4]. More recently, neural networks and deep learning have been applied to the problem of inverse halftoning, with Xia and Wong achieving a state-of-the-art performance using progressive residual learning [8].

Xia et al. have also implemented a technique for reversible halftoning — via encoding information about the colour and fine details of the original image in the distribution of the halftone dots in the dithered image — which permits for the restorability of the original colour image from a dithered image [9]. However, because the images we wish to un-dither are typically not produced using reversible halftoning, our focus in this project remains on methods for retrieving images from traditional, non-reversible dithering.

Project Overview

In this project, we will examine the effectiveness of different dithering techniques in terms of both visual results and computational cost. In particular, we will compare results for inverse halftoning using (1) a low-pass filter, (2) Mese and Vaidyanathan's look-up table technique, (3) Xia et al.'s deep learning technique, and Alternating Direction Method of Multipliers (ADMM) with (4) Total Variation (TV) and the (5) denoising convolutional neural network (DnCNN). We will start by generating a dataset of continuous-tone and halftone image pairs using the most popular image halftoning algorithm, Floyd-Steinberg error diffusion [9]. We will then restore the image using the techniques mentioned above. For our quantitative evaluation, we will report the average peak signal-to-noise ratio (PSNR) and Structural Similarity Index (SSIM) for each technique across three different levels of compression. We will also offer a qualitative assessment of our results. Finally, we will assess the computational cost by tracing the number of floating point operations required for each technique, and draw conclusions on which techniques offer the best results given their computational cost (and energy use).

Milestones, Timeline, & Goals:

1. [Week 1]
    a. Obtain a dataset of ~300 images, and generate 3 sets of continuous-tone and halftoned image pairs using Floyd-Steinberg for 3 different compression levels.
    b. Implement low-pass filter, ADMM-TV, and ADMM-DnCNN.
2. [Week 2]
    a. Implement Mese and Vaidyanathan's look-up table technique, (3) Xia et al.'s deep learning technique
    b. Report the average PSNR, SSIM, and number of floating point operations for each technique
3. [Week 3]
    a. Generate plot of performance of each technique for different compression levels.
    b. Generate plot of PSNR and SSIM vs. computational efficiency.
    c. Write paper
    d. If time allows, test on CNN with non-local means, other techniques.
    e. If time allows, train on additional dithering methods.

References:

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