Scene Restoration and Object Removal through Exemplar-based Inpainting

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***Abstract*—This proposal presents a brief overview of the application of object removal in the general field of image reconstruction. It will also cover introductory explanation to the various techniques currently adopted in the academic papers, with particular emphasis on exemplar-based inpainting. Project overview and tentative schedule are discussed in the following sections.**

I. Motivation

IN the world of photography, a perfect shot can be attributed to aesthetics factors such as scene composition and artist's vision, as well as technical standard such as lens capabilities and sensor resolution. However, an image can still occasionally be flawed by random intruders or undesirable objects that are unexpectedly presented in the scene. There are also scenarios where we wish to preserve the quality of worn-out old photographs, which may have debris, fold marks, or blurred surface. A possible way is to apply computational imaging techniques on the digital version of the photo. In either of the cases discussed above, a post-processing step is necessary in order to restore the desired scene or photo effects. Thus we would like to examine the techniques for object removal and scene restoration as the focus of this course project.

Fig. 1: Contrast of pre/post removal processing.

II. Related Works

There has been recent development of image reconstruction algorithms in the past 20 years that pay particular attention to the topic of object removal. Desired effect of such scene restoration and object removal technique is shown in Fig 1. Existing methodologies generally fall into the following two categories. The first algorithm is the "texture synthesis" technique, which repairs targeted region from sample textures, working particularly well for scenes with repetitive textures. It can be viewed as a heuristic approach that utilize the repetition of two-dimensional textural patterns to edge-stitch the missing cut-out zone. Based on researches on texture-synthesis, this method seeks to replicate texture with moderate stochasticity, given a small source sample of the pure texture. The works of Ashikhim et al, de Bonet et al, and Efros et al., pushed the boundary of this approach.

Another commonly-referred technique is "inpainting", which takes other patterns/contours/edges in the scene that's similar to the ones near the cut-out edge region, and stitches the pattern to fill the object-removed zone. It specifically tackles the difficulty of filling holes in photographs of real-world scenes. This algorithm was proposed by Alexandru Talea in 2004, and is based on a mathematical model - the Fast Marching Method. The algorithm starts from the exterior of the to-be-inpainted cut-out zone and graduates towards the interior, crossing through the boundary edge, and fill the region along the way. Each pixel in the inpainting zone is filled with a normalized weighted sum of the known pixels in its neighborhood. Pixels locating near the targeted inpaint pixel are given more weight, and so are the pixels near the normal of the boundary and lying on the boundary contours.[1] Such filling method takes into consideration every direction from the center of the cut-out zone, producing a relatively coherent visual effect on the cut-out zone.

Based on the naive inpainting method, Criminisi, Perez, and Toyama came up with a more advanced version of inpainting called exemplar-based inpainting. It is essentially a hybrid design aggregating the advantages of the two previous approaches, namely the texture synthesis and inpainting. Their paper presents a best-first algorithm in which the confidence in the synthesized pixel values is propagated in a manner similar to the propagation of information in inpainting.[2] The actual color values are computed using exemplar-based synthesis.

Furthermore, Dr. Marcelo Bertalmo and his colleagues proposed another algorithm based on fluid dynamics and the use of partial differential equations. This algorithm simulates a traversal along the edges from known regions to the unknowns. As edges of objects are meant to be contiguous, we may continue the isophotes while matching gradient vectors at the boundary of the targeted inpainting region (with reference to methods used in fluid dynamics). Once the contours are reconstructed, colors can be filled to reduce minimum variance in that region.[3] Note that experimentation of this method combining with the exemplar-based inpainting can also be found in Wu and Ruan's paper on cross isophotes exemplar-based inpainting.[4]

III. Project Overview

The ultimate goal for this project is to implement a refined and advanced object removal algorithm through MATLAB. The overall goal can be separated in to three major sub-steps, shown in the image processing pipeline in Fig 2. After the regular denoising and tone-mapping, the second action required is to detect the foreground object region and the targeted inpaint area (or the filling region). For the detection process, we plan to implement the Viola and Jones object detector through MATLAB Computer Vision Toolbox.[5] Once the detection step is complete and cropped out from the image, we'd move on to the reconstruction process. We plan to design an algorithm that is a well-balanced hybrid of the texture synthesis and exemplar-based inpainting, and experiment on photos with real-life scenes.

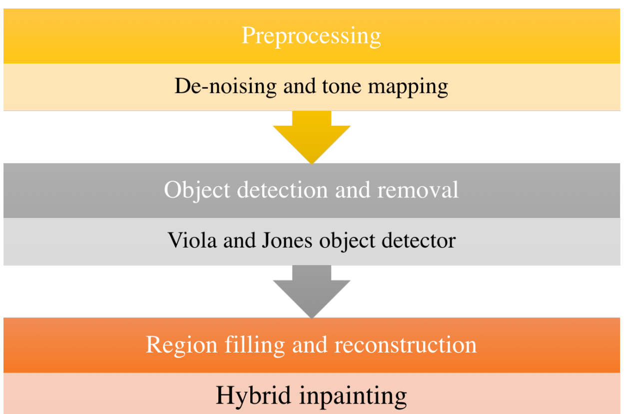

Fig. 2: Processing pipeline.

In order to evaluate the quality of our processed images, we plan to compare the resulting image with Adobes Photoshop CS5 background completion processed image. The results will be ailgned side to side for visual contrasting purpose.

IV. Milestones and Plans

A. *Tentative Schedule*

Time period	Goals
Week of 2/13	Examine the mathematical models behind algorithms;
Week of 2/13	Select suitable images
Week of 2/13	from image library for pre-processing
Week of 2/20	Implement Viola and Jones object detector
Week of 2/27	Implement reconstruction algorithm (texture/inpainting)
Week of 3/13	Design advanced reconstruction algorithms
Day of 3/15	Work on poster presentation and report
Day of 3/17	Finalize project deliverables

TABLE I: Tentative schedule for the project

V. Optional Work

If time permits, we would like to advance further to improve the algorithm in terms of both restoration quality as well as computational efficiency. We might also proceed to incorporate this image processing feature to an Android/iOS app.

References

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