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Optimal Image Blending for Underwater Mosaics

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Introduction

In the recent years, mosaics created from individual images acquired underwater are attracting more and more attention from marine geologists and biologists. Applications can be divided into three categories:

a. Targeting extraction of quantitative information (distances, sizes, shapes, etc.)

b. Attempting to create a consistent continuous image, possibly at the expense of minor local distortions.

c. Aiming at accurate recovery of three-dimensional information about the seafloor, is capable of achieving both goals, but requires principally different approach, and has substantially higher level of complexity.

In reality, most underwater images are fuzzy and difficult to process. Problems can be classified in to three aspects:

a. Limited visibility underwater
b. Artificial spatially inhomogeneous illumination
c. Parallax issues

In this poster, we are not concerned with the ability to measure distances and sizes as accurately as possible. Algorithms for object recognition and shape extraction are typically tolerant to scaling and insignificant distortions, but can be easily confused by feature doubling and rapid changes in illumination. Our goal is:

a. Diminishing the effects of inhomogeneous illumination, which are almost always present in the case of artificial lighting.

b. Combine individual image frames into a single mosaic in some optimal way.

Note: "Optimal" may have different meanings depending on intended consumer: scientist, trying to deduce large-scale interrelationships; computer program, extracting shapes according to some specific rule; or a high-school student learning about a deep-sea environment.

Our Method

The method proposed here based on the graph-cut in the gradient domain is to overcome the defects of the single graph-cut technique, which would have apparent seam when two images have inhomogeneous illumination, and the single gradient domain stitching, which can still cause blurring in a misaligned case. In addition, it reduces the artifacts when combining these two methods directly (Fig. 10).

The procedure is as follows, assuming that two images have already been aligned and we take only one color channel for illustration (Fig. 5):

1) Calculate the gradient values of two images

2) According to the overlapping area (which in general is an irregular polygon), a boundary box is obtained (Fig. 6), which is composed of three parts: overlapping area, and parts that have contributions from only one of the images.

3) Within the boundary box, execute the graph-cut technique and get the graph-cut mask (Fig. 7), using weighting function to smooth the boundary cut and obtaining the final gradient domain mask (Fig. 8).

4) Fill in the boundary box with gradient values according to the mask matrix, and use it as a source term of the Poisson equation. Boundary values of the boundary box are from the original pixel values of two images given the boundary of the mask.

5) Reconstruct the spatial values of the boundary box by solving the Poisson equation with Dirichlet boundary conditions.

6) Put the corresponding reconstructed values back in the final mosaic (Fig. 9).

In practice, the images are part of a sequence, for example, captured from a video tape. Transformations relating consecutive images are either deduced from the navigation data, or estimated from the imagery. Frames are added sequentially to already existing mosaics.

Previous Methods

Current blending techniques can be divided in two main categories, assuming that the images have already been aligned:

a. Optimal seam algorithm:

By searching for a curve in the overlap region on which the differences between two overlapping images are minimal, each image is copied to the corresponding side of the seam. One simple and commonly used method is the minimum cut method which employs dynamic programming, but it works well only when two images are involved. As opposed to this "memoryless" approach, the graph-cut method (Fig. 1) was proposed that can be applied when more than two images are needed to be mosaiced. However, the seam may still be visible where brightness of neighboring original images differs dramatically.

b. Transition smoothing algorithm:

By manipulating the images in transition region, two images are blended to release the illumination difference. Most common blending techniques employ simple averaging of images in the overlapping regions (Fig. 2). This results in ghosting artifacts, blurring, and visible seams that degrade the mosaic. Some improvement of this method were proposed, such as feathering or alpha blending (Fig. 3) which employs the special weighting functions, multi-resolution blending which takes advantage of the characteristics of different sub-bands, and gradient domain stitching (Fig. 4), which is designed to remove sharp changes of brightness across the frame boundaries. However, blurring and ghosting effects could not be avoided due to misalignment of the underwater imagery.

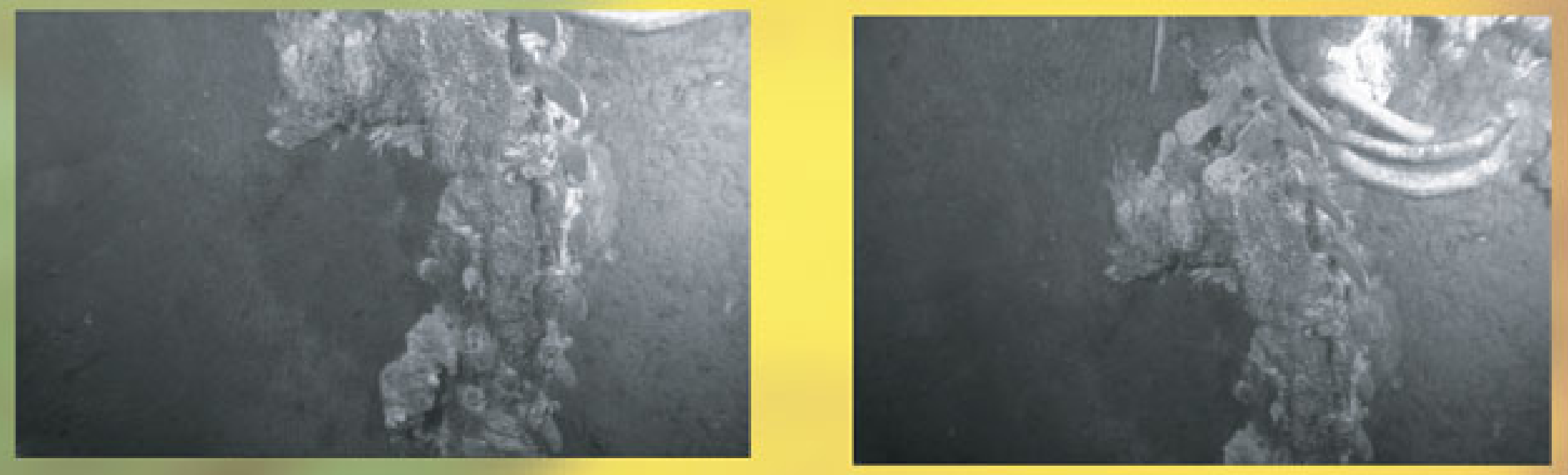


Fig. 5


Fig. 6

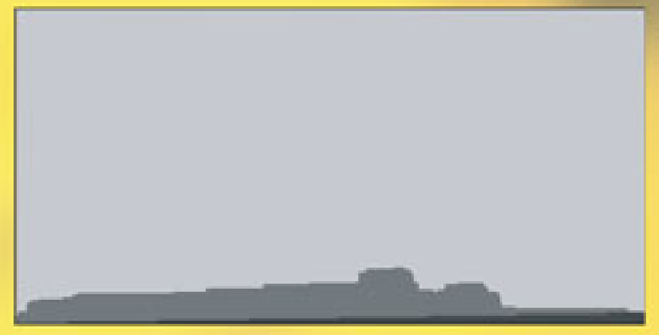
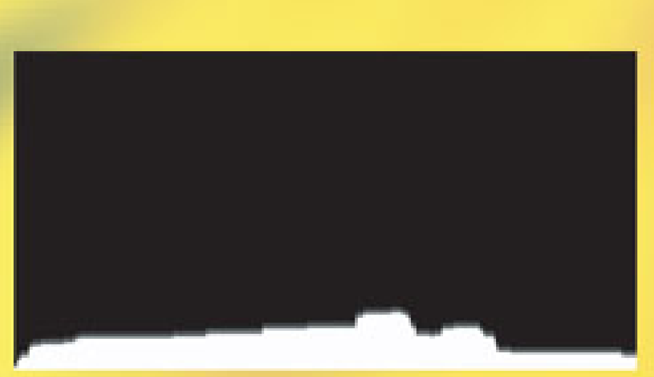


Fig. 7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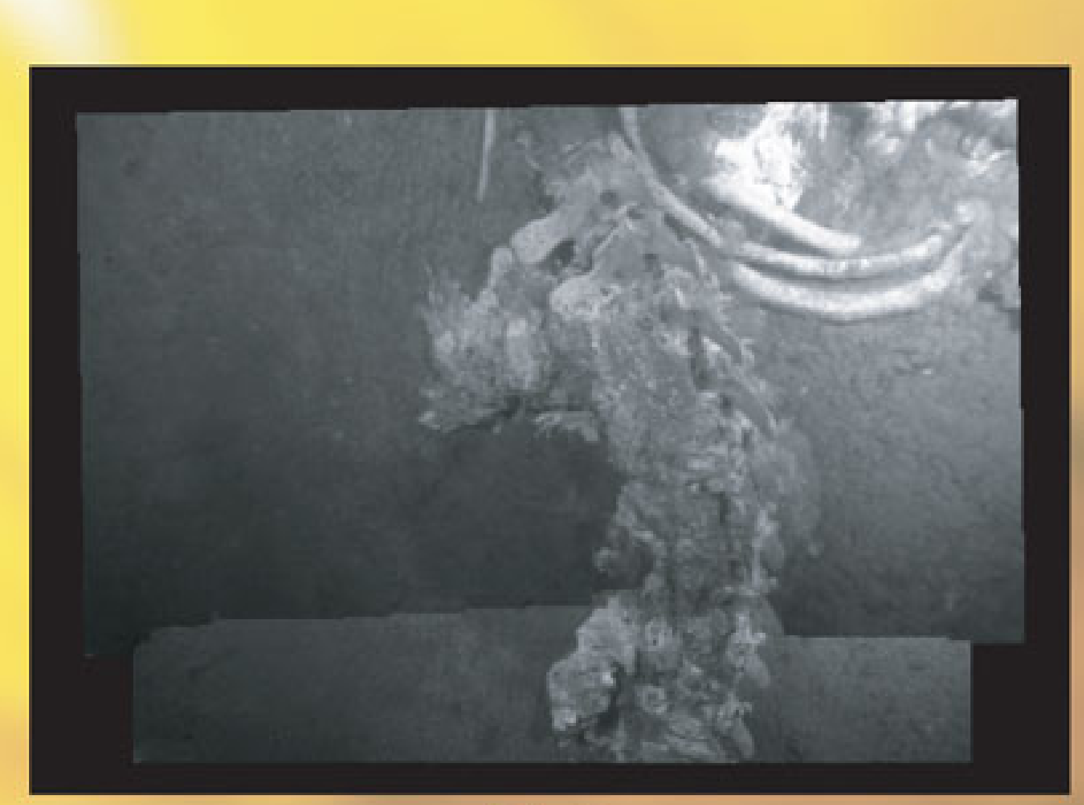
Fig. 1


Fig. 2


Fig. 3


Fig. 4

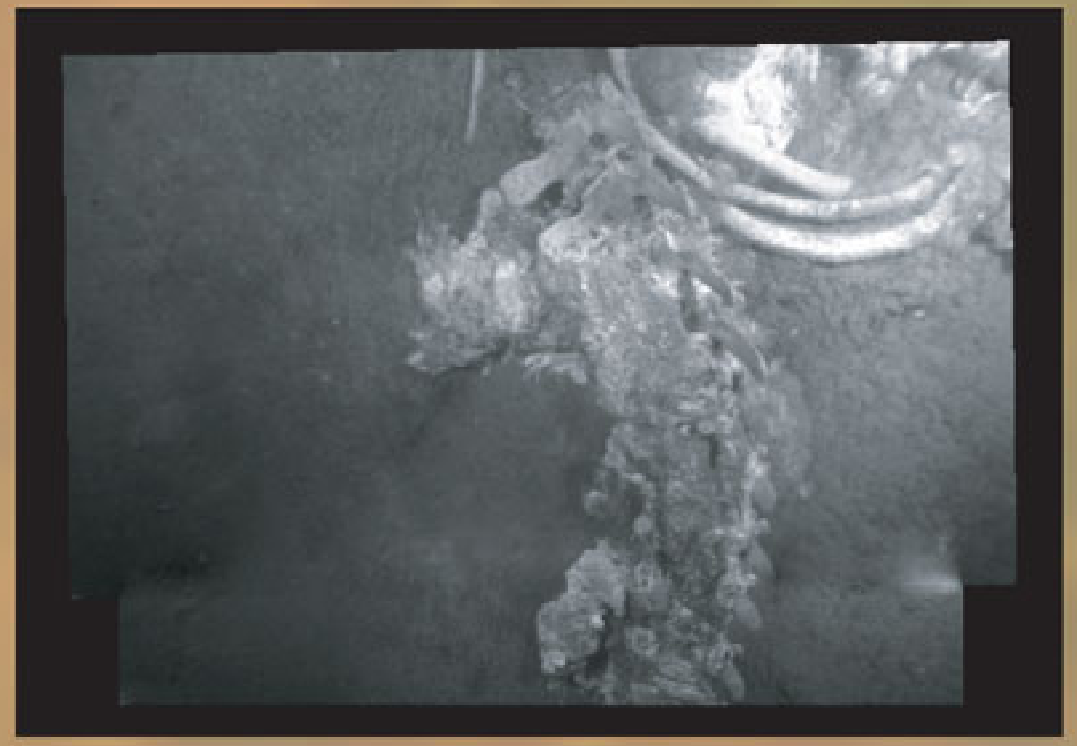
Fig. 9

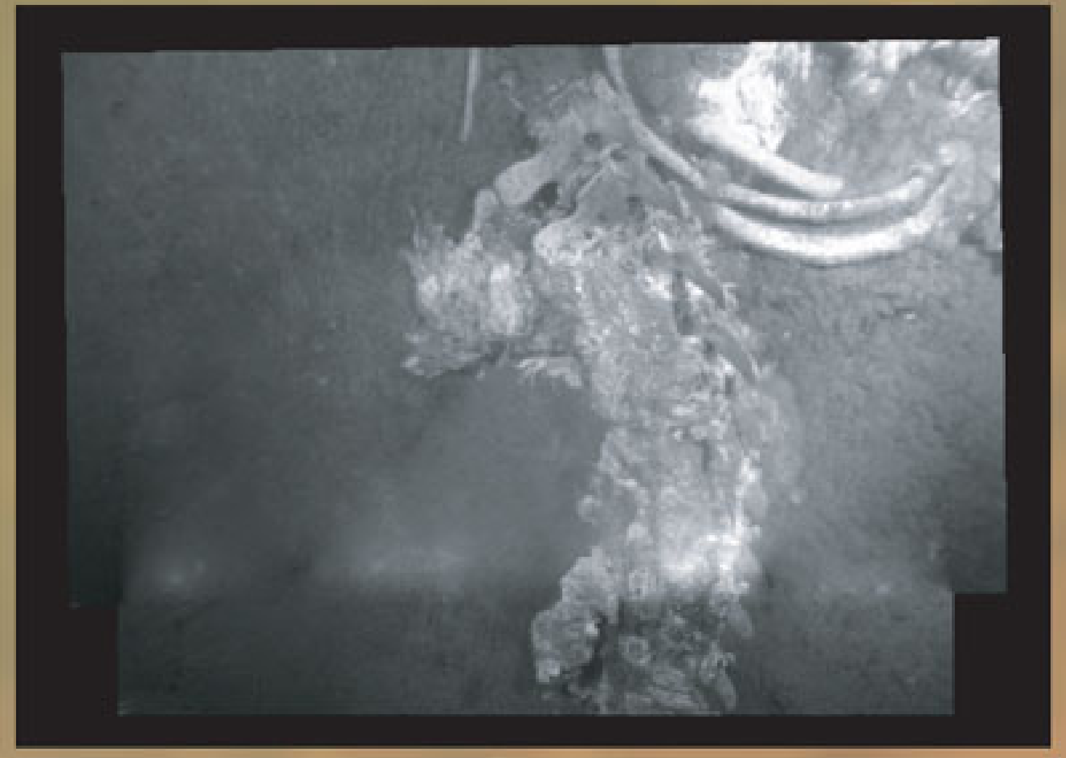
Fig. 10

Comclution

Due to the artificial lighting and 3D content of imaged terrain, imagery taken underwater almost always suffers from inhomogeneous illumination and feature misalignment, when mosaiced. This causes degradation of the final product and makes it more difficult to post-process. Often used mean value averaging blending technique can hardly satisfy the demand of post processing such as feature extraction or human view leisure. These days, a lot of blending techniques were explored in the area of image processing. Most of them fail when it comes to the underwater images, which have different specifics. We reviewed the existing popular methods and combined them in a way to facilitate in post-processing of underwater mosaics. Experimental results show the effectiveness of the proposed methods, comparing with other existing methods. The reason for artifacts, occasionally occurring in the reconstructed process, requires further investigation.