Through Water Image by Using Continuous Photos

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KEY WORDS: Through Water Image, Shallow Water, Underwater Feature

Abstract

Underwater features at shallow depth (~ 40 cm) are difficult to be observed and monitored. The water surface disturbed by flow and wind action prevents the direct observation from above water. Water-proofed camera or video are also hard to maneuver in such situations. In this study, we tackle this problem by using continuous photos (~2000 photos per site) taken from above water and setup on a tripod. We employed a Nikon D200 camera, which takes about 3 - 12 minutes for each site. A grey card of photogrammetric grade is used to adjust the temporal change of illumination condition. Test sites include two flow types, i.e., no perceptible flow and smooth. A mode-based filter scheme is developed to filter the pixels that are disturbed by wave actions. The results show that the proposed filter is most effective for both flow types, where the water surface is mostly flat.

1. Introduction

Due to the wave and wind action, the water surface is disturbed, which hampers direct observation of underwater features, such as substrate and geomorphology of the river bottom, from above the water. For deeper water (approximately greater than 40 cm), the camera can be enclosed in an underwater housing and operated by a diver to collect underwater images. For the case of shallower water (approximately less than 40 cm), maneuvering the underwater housing becomes difficult.

However, many of the instream habitats are of shallow depth. And most of the field observation is conducted by trained personnel with visual judgment (Scottish Environment Protection Agency, 2003).

The slope statistics of the wave facets for open ocean has been reported to be a function of wind speed and wind direction by Cox and Munk (1954) and Shaw and Churnside (1997). The probability density function (PDF) of the slope statistics for open ocean is Gaussian distribution with zero mean and the variance is a function of wind speed and wind direction. Figure 1 shows the PDF of sea surface slope obtained by Shaw and Churnside (1997). Although the slope statistics of the river water surface is not reported in any references, we assume it to be similar to that of the open ocean. If continuously multiple images can be collected, one can expect to see though the water surface when the water surface is flat (zero slope) for most of the time.

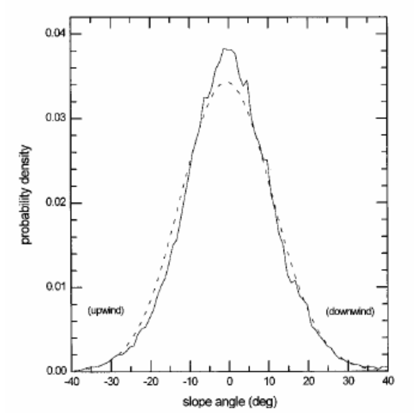


Figure 1. Sea surface slope PDF (Shaw and Churnside, 1997)

Professional grade camera becomes affordable in recent years, and more advanced features, such as taking continuous photos of more than 40 shots and controllable by a notebook through universal serial bus (USB) connection, are added. In this study, we exploit the capability of a professional camera, Nikon D200 for the observation of underwater feature from above the water.

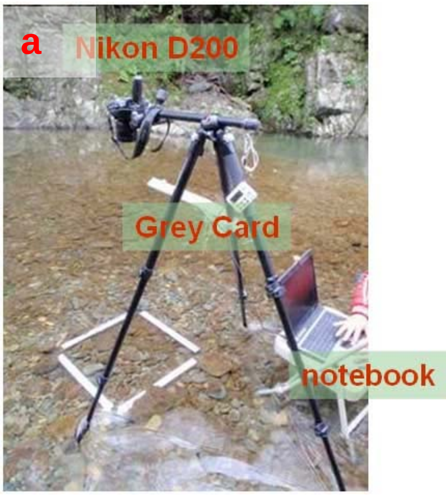
2. Experiment and methodology

2.1 Equipments

The professional grade Nikon D200 camera is able to take continuous photos. However, the number of photo can be taken by D200 is limited by the memory size of the compact flash card onboard D200 as a data storage media. In addition, the temporal interval between individual photo increases as more photos are taken, which is unfavorable for image collection.

All the above mentioned problems can be solved by controlling the D200 from a notebook via a USB cable by Nikon Camera Control Pro (version 2.0). The image can be transferred to and stored on the hard drive of the notebook. Considering the time required for transfer before another photo can be taken and to minimize the field time, ten 10 photos are taken at every 4.8 seconds for a period of 3 (a total of 200 photos are collected) or 12 (a total of 2000 photos are collected) minutes. The setup for photo collection can be seen in Figure 1a. A rectangular reference frame shown in Figure 1b is placed in the water as a reference for geometric distortion. MTF codes are also added for future assessment of the image quality.

Because it takes about 3 - 12 minutes for each site, a grey card of photogrammetric grade is used to adjust the temporal change of illumination condition to avoid the change of brightness in the photo (Figure 1a).



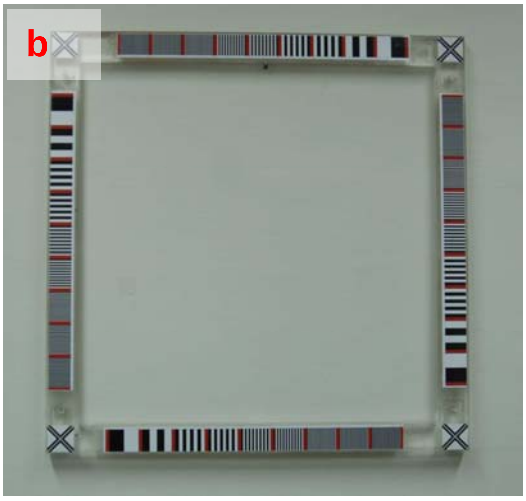


Figure 2. (a) Experiment setup. (b) The rectangular reference frame.

2.2 Study sites

The study site of no perceptible flow (NP) is a water tank with the dimension of 2 m (L) x 2m (W) x 0.5 m (H) located in National Cheng Kung University. That of smooth (SM) is located in Nan-Shih River, Taipei. The number of photo collected for NP is 200 which take about 3 minutes; the number of photo collected for SM is 2000, which takes about 12 minutes.

2.3 Mode-based filter

According to Cox and Munk (1954) and Shaw and Churnside (1997), the PDF of the water surface slope of open ocean is a Gaussian distribution with mean zero and the variance is a function of wind speed and wind direction. Although water surface slope statistics of river is absent, we assume it to be similar to that of the open ocean. This suggests the elimination of the disturbance of the water surface caused by the flow and wind action can be accomplished by taking continuous photos, where the underwater feature can be seen from above water when the water surface is flat for most of the time. In other words, by searching the most probable brightness value for each pixel in the continuous photos, a mode operation on each pixel location, one can obtain an undisturbed photo. The flowchart of the mode-based filter is shown in Figure 3.

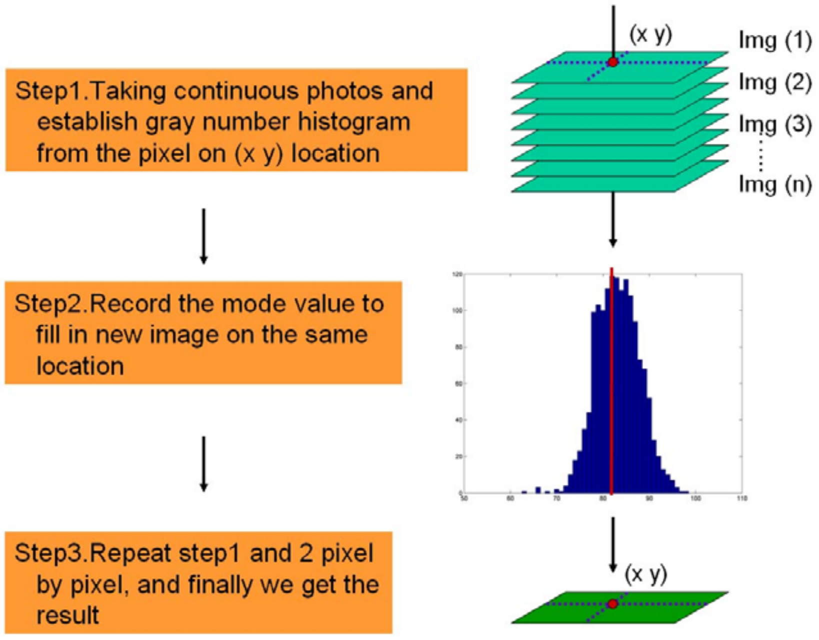


Figure 3. The flowchart of the mode-based filter.

3. Results and Discussion

The results from the smooth flow type are used as an example to show the histogram characteristics of a single pixel in the continuous photos set. Figure 4a shows on single photo from a set of 2000 continuous photos. Although the surface is visually flat, the reflection of the tripod which holds the D200 camera indicates surface disturbance and alteration of the geometry of the underwater features in the photo. A subset of eight continuous photos corresponding to the red rectangle shown in Figure 4a is shown in Figure 4b. The overall presence of tripod reflection and underwater grains are not very different from one image to the other, however, no distinct boundary can be identified in one photo. After the mode-based filter is applied to the 2000 continuous photos, shown in Figure 4c, both the reflection of the tripod and boundaries of the underwater grains are discernible. Further inspection of the histogram of the pixel location indicated by red dot shown in Figure 4c reveals the probability distribution of the intensity value for each pixel. For those outside the shadow (Figure 4d and 4e), the distribution is close to Gaussian and skewed to lower value. For those inside the shadow (Figure 4f and 4g), the distribution is bimodal and the mode-based filter extracts the intensity value with the highest probability indicated by the red lines in Figure 4f and 4g.

One single photo from a set of 200 continuous photos for NP is shown in Figure 5a. A subset of eight continuous photos showing the red rectangle region in Figure 5a is shown in Figure 5b. The experiment is conducted in a tank; hence, the only disturbance is by wind action upon water surface. Figure 5c shows the mode-based results. And, the most noticeable feature is the reflection of the building boundary indicated by the yellow arrows in Figure 5b and 5c. The boundary is broken and jacking in single photos in Figure 5b, while the boundary becomes distinct in Figure 5c.

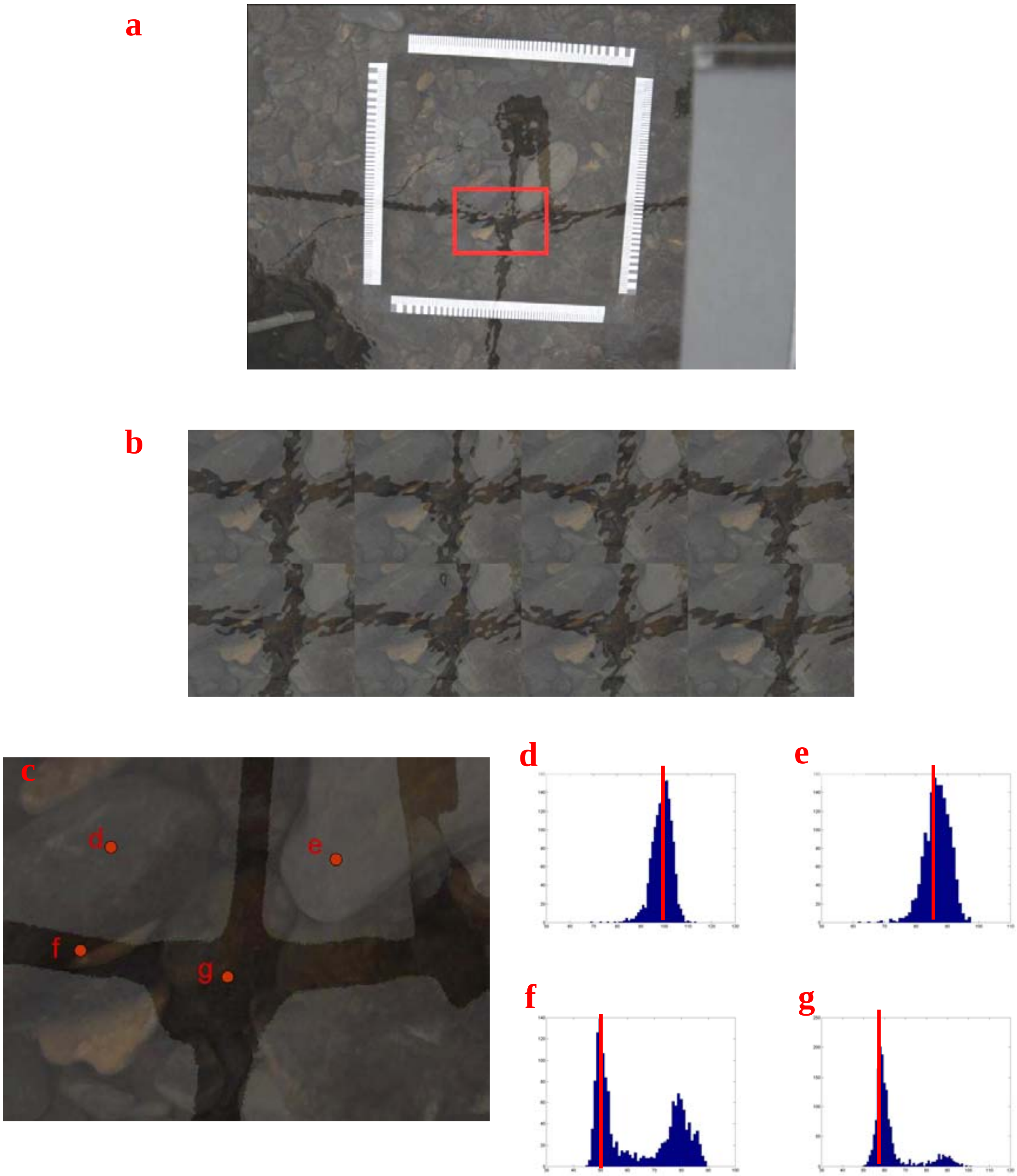


Figure 4. Results for SM: (a) One single photo from a set of 2000 continuous photos; (b) Eight continuous photos extracted from the red rectangle in (a); (c) The resultant photo after mode-based filter; (d-g) The histogram of the corresponding single pixels shown in (c).

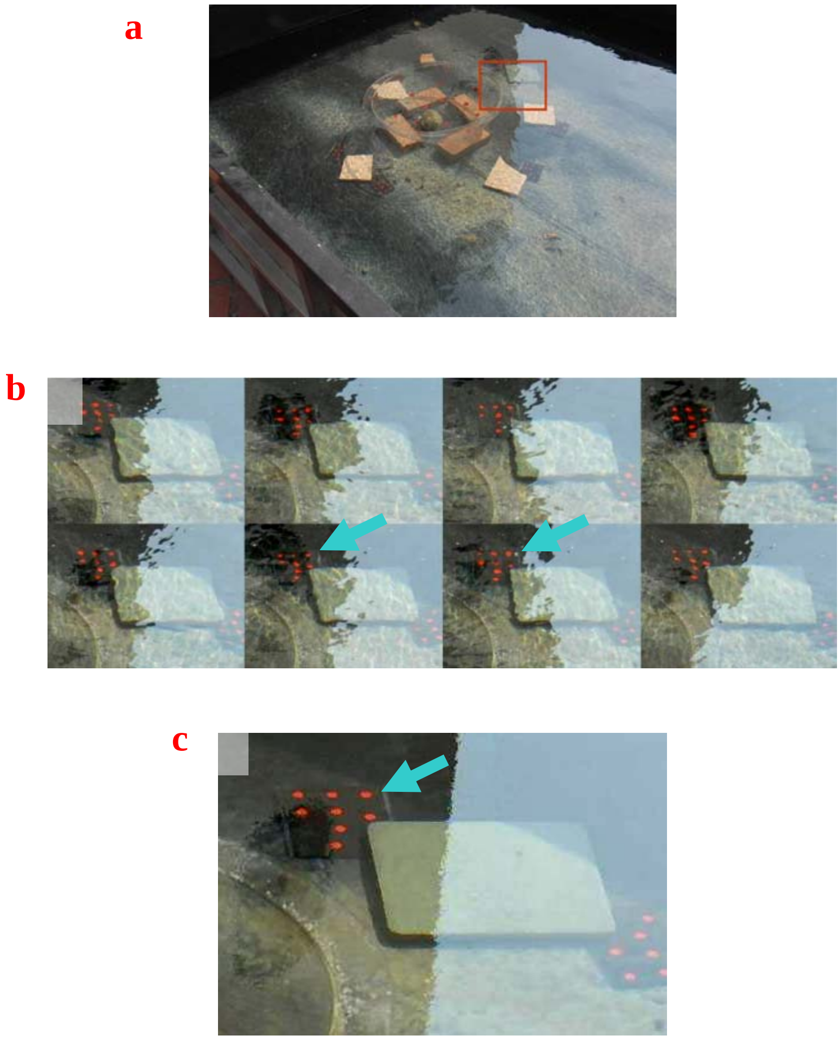


Figure 5. Results for NP: (a) One single photo from a set of 200 continuous photos; (b) Eight continuous photos extracted from the red rectangle in (a); (c) The resultant photo after mode-based filter corresponding to the red rectangle.

4. Conclusion

A mode-based filter is developed and applied to continuous photos for the collection of through water image. The results shows that the surface disturbance cased by wave and wind actions can be eliminated efficiently.

5. References

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