Proceedings of International Conference on Technology and Social Science 2017
Invited Paper

DeepEye: A Dedicated Camera for Deep-sea Tripod Observation Systems in the South China Sea

Huimin Lu[1, a], Yujie Li[2, b], Tomoki Uemura[1], Ryunosuke Tadoh[1], Keita Kihara[1], Seiichi Serikawa[1, c] and Hyoungseop Kim[1, d]

[1]Kyushu Institute of Technology, Japan

[2]Yangzhou University, China

[a]luhuimin@ieee.org, [b]liyujie@yzu.edu.cn, [c]serikawa@elcs.kyutech.ac.jp, [d]kim@cntl.kyutech.ac.jp

Keywords: Underwater camera; Deep-sea tripod; South China Sea.

Abstract. The deep-sea tripod systems are designed and built at the U.S. Geological Survey (USGS) Pacific Coastal and Marine Science Center (PCMSC) in Santa Cruz, California. They are recovered in late September 2014 after spending about half a year collecting data on the floor of the South China Sea. The deep-sea tripod systems are named as Free-Ascending Tripod (FAT), are deployed at 2,100 meters water depth—roughly 10 times as deep as most tripods dedicated to measuring currents and sediment movement at the seafloor. Deployment at this unusual depth was made possible by the tripod's ability to rise by itself to the surface rather than being pulled up by a line. Instruments mounted on the tripod took bottom photographs and measured such variables as water temperature, current velocity, and suspended-sediment concentration. FAT is used to better understand how and where deep-seafloor sediment moves and accumulates. Besides of this, we also use them to study the deep-sea biology. The obtained the images from the camera, the biology animals are hardly to be distinguished. In this project, we are concerned to use novel underwater imaging technologies for recovering the deep-sea scene.

Introduction

Ocean observations [1] are being developed and deployed by scientists, researchers and institutions around the world oceans for monitoring the status of ocean. Some observatories are cabled, For example, the Ocean Networks Canada Observatory [2], contains VENUS and NEPTUNE Canada cabled networks. It enables real-time interactive experiments, for measuring ocean health, ecosystems, resources, natural hazards and marine conservation. Some observatories are moored or made up of surface buoys, such as National Oceanic and Atmospheric Administration (NOAA) Ocean Climate Observation System [3]. The observations near the equator are of particular important to climate. Besides of monitoring the air-water exchange of heat and water, the moored buoys provide platforms for instrumentation to measure the air-water exchange of carbon dioxide in the tropics. Some observatories are remote sensed, such as Japanese Ocean Flux Data Sets with Use of Remote Sensing Observation [4]. It is used for monitoring the changes of heat, water and momentum with atmosphere at ocean surface.

Interestingly, there are some excellent systems for ocean observing, such as Global Ocean Observing System proposed by Henry. Stommel Woods Hole Oceanographic Institution (WHOI) [5]. More than 30 countries are joined in this program. However, until now this system also has some drawbacks. First, the system is not fully built-out because of funding issues. Second, most of subsystems are not at full operational capacity. Many of them are funded through research programs rather than operational. Third, deep ocean (under 2000 meters) is very under-sampled-issue of technology and cost.

Methods

Figure 1 shows the location of captured images by the dedicated camera. Size of the image is 5184× 3456 pixels. Fig.2 shows the free-ascending tripod for observing the bottom of the South China Sea. The image Fig. 2(b) was captured on May 5, 2014. The water depth is about 1900 m. We utilize the Housing for the dedicated CANON EOS 70D MarkII camera and take underwater blue-green LED light for imaging. The distance between the camera and sea bottom is about 1.53 m. Because of using a single blue-green deep sea LED lighting, the illumination is inhomogeneous. Meanwhile, the captured images contain some floating sediments and color distortion. Hence, we need to take the proposed descattering [6] method and pre-processing method [7, 8] to remove the haze-like objects. Furthermore, deep sea blue-green LED light has the limitation of wavelength. The real underwater scene cannot illuminate as well as on the land. Consequently, we need to use the camera spectral response function and illumination characteristics in water to recover the scene color [9, 10]. The processing steps of this camera is: firstly, we need to know the illumination characteristics and camera spectral response function. After that, we take the proposed color correction method for color reconstruction in Fig. 3.

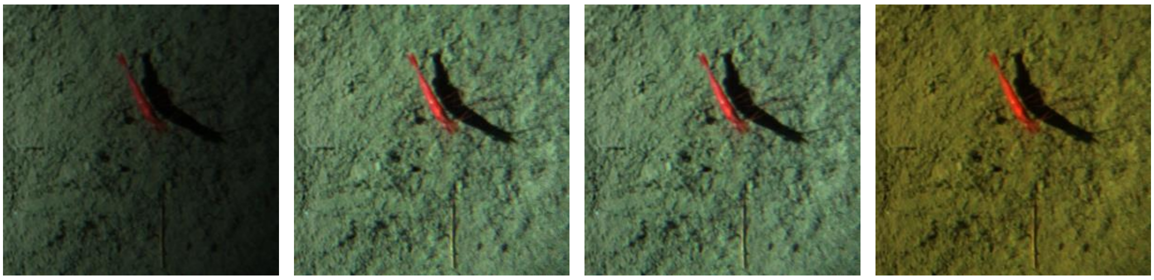
Fig. 1 Captured image at the northeastern South China Sea of China.

(a) (b)

Fig.2 Free-ascending tripod for the seafloor observation in the South China Sea. (a) Loading the equipment. (b) Captured deep sea image.

Results

We also test the proposed method with the images of real-world, deep-sea observation systems. The image used was captured by the Free-Ascending Tripod (FAT), which was built at the U.S. Geological Survey (USGS) Pacific Coastal and Marine Science Center (PCMSC) in Santa Cruz, California and is used to monitor in-situ sediment movement. FAT was recovered in late September 2014 after spending about half a year collecting data on the floor of the northeastern South China Sea (SCS). The enhanced images are characterized by a reduced noised level with better exposure in dark regions and improved global contrast, by which the finest details and edges are significantly enhanced, demonstrating the effectiveness of proposed method.



(a) (b) (c) (d)

Fig. 3 Summary of the proposed approach for recovering the color of deepsea image. (a) Cropped initial image (1122×1106p). (b) Result after descattering. (c) Result after BM3D denoising. (d) Result after color correction.

Conclusion

In this paper, we built a dedicated camera and a corresponding image processing technologies for in-suit deep sea observing in the South China Sea. The proposed device can improve the quality of deep-sea images well. It can remove the unwanted particles, can correct the non-uniform illumination as well as recover the real scene color, and super resolving the images. Water tank experiments and sea water experiments demonstrate that the proposed system performs better. The proposed methods are suitable for ocean observing.

Acknowledgements

This work was supported by JSPS KAKENHI (No.15F15077), Leading Initiative for Excellent Young Researcher (LEADER) of Ministry of Education, Culture, Sports, Science and Technology-Japan (16809746), Research Fund of Chinese Academy of Sciences (No.MGE2015KG02), Research Fund of State Key Laboratory of Marine Geology in Tongji University (MGK1608), and Research Fund of State Key Laboratory of Ocean Engineering in Shanghai Jiaotong University (1315; 1510).

References

[1] Ocean Observations, http://en.wikipedia.org/wiki/ocean_observations

[2] Ocean Networks Canada, http://www.oceannetworks.ca/

[3] NOAA Ocean Climate Observation Program, http://www.oco.noaa.gov/

[4] Japanese Ocean Flux Data Sets with Use of Remote Sensing Observation, http://dtsv.scc.u-tokai.ac.jp/j-ofuro/

[5] Woods Hole Oceanographic Institution, http://www.whoi.edu/

[6] S. Serikawa, H. Lu, "Underwater image dehazing using joint trilateral filter," Computers and Electrical Engineering, vol.40, no.1, pp.41-50, 2014.

[7] H. Lu, Y. Li, X. Xu, J. Li, Z. Liu, X. Li, J. Yang, S. Serikawa, "Underwater image enhancement method using weighted guided trigonometric filtering and artificial light correction," Journal of Visual Communication and Image Representation, vol.38, pp.504-516, 2016.

[8] H. Lu, Y. Li, L. Zhang, S. Serikawa, "Contrast enhancement for images enhancement in turbid water," Journal of the Optical Society of America A, vol.32, no.5, pp.886-893, 2015.

[9] H. Lu, Y. Li, S. Nakashima, H. Kim, S. Serikawa, "Underwater Image Super-resolution by Descattering and Fusion," IEEE Access, vol.5, no.2, doi: 10.1109/ACCESS.2017.2648845, 2017.

[10] H. Lu, Y. Li, X. Xu, L. He, Y. Li, D. Dansereau, S. Serikawa, "Underwater image descattering and quality assessment," In Proceedings of 2016 IEEE International Conference on Image Processing, pp.1998-2002, 2016.