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A Review on Application of Image Processing Techniques in Underwater Exploration Rover's Vision System

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Abstract—*Vision related issues have been always a challenging task for the underwater robotics. Various factors like scattering of light, uneven brightness, refraction at water camera interface, objects, pigments in the path of vision etc. plays a significant role during imaging. For proper working of an underwater rover the enhancement of such images are very essential. The image processing tools for automatic correction here acts as a blessing for the rovers. Different image processing techniques are improvised by the researchers for better underwater visibility and getting more information from the image. This leads to the application of visual imaging in underwater robotics for obstacle detection, object recognition and 3D mapping. In this paper we have reviewed various algorithms for tackling issues related to underwater imaging. Furthermore the efficiency of the systems have been discussed and it have been found that the results have recently improved with high efficiency.*

1. INTRODUCTION

Water covers almost 70% of the Earth's and many portion is still left to be explored. Activities like scientific research, commercial explorations, utilization of water resources etc. requires an intelligent underwater robotic platform. For an autonomous rover, a proper vision system is required but underwater vision system is a challenging task[1]. Underwater imaging systems have certain limitation in visibility. Along with the visibility, segmentation and getting errorless information from underwater images is also a difficult job. They lack in providing quantitative information about the size, shape and topography of a site etc. For such purposes image processing techniques can be a promising technology for getting high quality images and extracting more information from them [2]. In this paper we are presenting a brief study of some image acquisition techniques followed by enhancement and information extraction algorithms used for under underwater environment.

2. UNDERWATER IMAGE ACQUISITION TECHNIQUES

By using proper image acquisition technique quality of raw underwater image can be enhanced. In this section some underwater image acquisition techniques are discussed.

In 2004 Yoav Y. Schechner and Nir Karpel, developed a physics based computer vision approach to remove the degradation of underwater images. They studied the effect of physical phenomena (Polarization of light) in underwater imaging. They developed an algorithm for recovering the visibility of underwater image in natural light. This method is dependent on the distance of the object which gives a distance map of the object as a positive byproduct. They were inspired from marine animals and applied different states of polarizing filter in the path of light which results in slight photometric differences in row images. They were able get better underwater image by compensating Backscattered Light. The algorithm assumes that the effect of the signal on the measured scene polarization is insignificant relative to the backscatter, this may not hold in very close distance [3].

In 2009 Marc Levoy and Hanumant Singh, published their work on application of "Confocal Imaging" in underwater environment. They used large array of synchronous projectors and cameras to project patterns and get the simulation of single video camera. They demonstrated effect of different illumination protocols and turbidity in this system [4,5].

In 2010 Chris Roman, Gabrielle Inglis and James Rutter, used "Structured light" for high resolution mapping of underwater archaeological sites. They used camera and 532 nm sheet laser to create the profile of the bottom surface. They observed better resolution comparing to multi beam and stereo reconstructions, particularly in low contrast scenes. They integrated rover navigation data with the profile to get a 3D map of the scenes. They were able to get centimeter level precision in the 3D map [6].

In 2014 Wojciech Biegański and Andrzej Kasiński, described their image acquisition system based on capturing underwater images in two different wavelength spectrum of light (the visible light spectrum and near infrared spectrum). Two images were combined by "single-sensor image fusion" to get more information compared to any one of the images. They used "Trinocular vision" in inland water bodies and used it for navigation of Automated Underwater Vehicles. They observed VIS images contain more information about plastic, metal, rubber and patterned surfaces. But for aquatic plants contrast is high in NIR images. A weighted image fusion algorithm may extract more useful information for underwater exploration [7].

The summary of various underwater image acquisition techniques discussed above are shown in Table 1.

Table 1: Image acquisition techniques

Title	Author	Approach
Clear Underwater Vision	Yoav Y. Schechner and Nir Karpel	Using Polarization filters
Improving underwater vision using confocal imaging	Marc Levoy and Hanumant Singh	Confocal imaging with large array of camera and projectors
Application of structured light imaging for high resolution mapping of underwater archaeological sites	Chris Roman, Gabrielle Inglis and James Rutter	Structured light imaging
Image Acquisition in an Underwater Vision System with NIR and VIS Illumination	Wojciech Biegański and Andrzej Kasiński	Using two web length band of light for different ofjects

3. UNDERWATER IMAGE ENHANCEMENT TECHNIQUES

Underwater images are affected by insufficient and uneven light intensity along with other problems like scattering of light. In this section underwater image improvement algorithms are discussed.

In 2007 Kashif Iqbal, Rosalina Abdul Salam, Azam Osman and AbdullahZawawi Talib proposed Integrated Color Model approach for enhancing the underwater images. In this method color contrast is stretched in RGB domain, Saturation and Intensity is stretched in HIS domain. They also designed interactive software for the processing of images and video. This method successfully improved the color contrast also it partially solves the problem of uneven lighting [8].

In 2013 Shuai Fang, Rong Deng, Yang Cao and Chunlong Fang introduced a new single image enhancement technique based on image fusion strategy. The algorithm first generates two different images from one image by using white balance and global contrast enhancement technique in original image separately. Both the images are weighted through three weight maps (Chromatic, Luminance and Saliency) and fused in two steps. The algorithm does not involve deconvolution which reduce the execution time [9].

In 2013 Ali A. Yassin, Rana M. Ghadban, Salah F. Saleh and Hikmat Z. Neima presented an active approach to solve the underwater imaging problems, based on Discrete Wavelet Transform(DWT), Hue saturation value color space (HSV), and Slide Stretching. They achieved high ratio of the image enhancement up to 98.08% [10].

In 2015 Anuradha and Harsimranjeet Kaur proposed an image enhancement technique for underwater image by using l*a*b on CLAHE. They proposed a new l*a*b color space for enhancement. Experimental result shows better mean square error (MSE) and peak signal to noise ratio (PSNR) as compared to mixed Contrast Limited Adaptive Histogram Equalization (CLAHE) algorithm [11].

The summary of various underwater image enhancement techniques discussed above are shown in Table 2.

Table 2: Image enhancement techniques

Title	Author	Approach
Underwater Image Enhancement Using an Integrated Colour Model	Kashif Iqbal, Rosalina Abdul Salam, Azam Osman and AbdullahZawawi Talib	Integrated Color Model
Effective Single Underwater Image Enhancement by Fusion	Shuai Fang, Rong Deng,Yang Cao and Chunlong Fang	Fusion of differently treated version of same image
Using Discrete Wavelet Transformation To Enhance Underwater Image	Ali A. Yassin, Rana M. Ghadban, Salah F. Saleh and Hikmat Z. Neima	Discrete Wavelet Transformation
Enriched Enhancement of Underwater Images by L*A*B on Clahe and Gradient based Smoothing	Anuradha and Harsimranjeet Kaur	L*A*B on Clahe and Gradient based Smoothing

4. COMPUTER VISION BASED UNDERWATER IMAGE PROCESSING

Goal of the computer vision is to make automated algorithm for extraction of useful information from images for use in computers or robots. In this section some computer vision applications for underwater images are discussed.

In 2000 G.L. Foresti and S. Gentili resented there work on "vision-based system for underwater object detection". They applied the concept of color compensation procedure to reduce problems connected with the light attenuation in the water and applied for automated detection of underwater pipelines and some nearby objects. They applied "Artificial Neural Networks" to classify pixels and geometric reasoning to reduce false detections. They were able to detect eadges of pipeline structure which was also used for navigation of the Autonomous Underwater Vehicle (AUV) [12].

In 2009 Muljowidodo K et.al designed a vision based distance measurement system for an Unmanned Underwater Vehicle (UUV). The system is based on camera with laser pointer for marking. Deigned system can detect the real life distance (in meters) in horizontal (front) and vertical (below) direction from wall or other rovers. The red laser point is segmented out and the degree of red is calculated. Distance between the laser dot and center of image (in pixels) is used to calculate the original distance. Effective range of the designed system is 30-150 cm with maximum error 10cm [13].

In 2010 Dr.G.Padmavathi, Mr.M.Muthukumar and Mr. Suresh Kumar Thakur proposed fuzzy c means clustering method with thresholding for underwater image segmentation. They evaluated nonlinear image region segmentation by using quantitative statistical measures like gray level energy, discrete entropy and information redundancy. The relative entropy, mutual information are also considered. The proposed method is the combination of fuzzy algorithm, data clustering and thresholding algorithm. The results of proposed methods are compared with FCM for underwater environment and found satisfactory results [14].

In 2013 Atsushi Yamashita, Toru Kaneko and Hajime Asama proposed a precise extraction process of visual information for distorted images in noisy and underwater environment. The system includes multiple camera for stereo vision which is implemented for noise removal in this case. Stationary noise was removed by comparing different images. They also proposed color registration by using multiple images to deal with light attenuation. They also experimentally verified the effectiveness of proposed methods [15].

The summary of various computer vision applications for underwater images discussed above are shown in Table 3.

Table 3: Computer vision techniques

Title	Author	Aria	Approach
A Vision Based System for Object Detection in Underwater Images	G.L. Foresti and S. Gentili	Object detection	Color compensatio n procedure
Vision based distance measurement system using laser pointer design for underwater vehicles	Muljowidodo K, Mochammad A Rasyid, Sapto ADI N and Agus Budiyono	Distance measure ment	Using laser pointer as a marker
Nonlinear Image segmentation using fuzzy c means clustering method with thresholding for underwater images	Dr.G.Padmavathi, Mr.M.Muthukum ar and Mr. Suresh Kumar Thakur.	Nonlinea r Image segmenta tion	Fuzzy logic with thresholding
Color Registration of Underwater Images for Underwater Sensing with Consideration of Light Attenuation	Atsushi Yamashita, Megumi Fujii and Toru Kaneko	Stereo vision	Color registration

5. CONCLUSION

In this paper we discussed about some image acquisition techniques, enhancement techniques and computer vision algorithms for underwater environment. As the underwater environment is different is different from aerial, some special image acquisition techniques along with some enhancement techniques can boost the vision system[16]. For robotic applications like navigation, object recognition etc. computer vision techniques are utilized. A hybrid combination of the three system may be implemented in underwater robotics. This may open the door for low cost underwater rovers.

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