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Underwater image processing method for fish localization and detection in submarine environment ☆

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ABSTRACT

Object detection is an important process in image processing, it aims to detect instances of semantic objects of a certain class in digital images and videos. Object detection has applications in many areas of computer vision such as underwater fish detection. In this paper we present a method for preprocessing and fish localization in underwater images. We are based on a Poisson–Gauss theory, because it can accurately describe the noise present in a large variety of imaging systems. In the preprocessing step we denoise and restore the raw images. These images are split into regions utilizing the mean shift algorithm. For each region, statistical estimation is done independently in order to combine regions into objects. The method is tested under different underwater conditions. Experimental results show that the proposed approach outperforms state of the art methods.

1. Introduction

Oceans cover most of the surface of the planet. It cover almost one third of the surface of the earth. The field of detection in the marine environment is a hot topic since many years. Due to the proprieties of underwater and the limitation of human access in this environment. Many technologies have been developed to monitor and track the evolution of the marine environment, such as a remotely operated vehicles (ROVs), systems targeting objects (STO), autonomous underwater vehicles (AUV) [1–3].

Today, the most detection and monitoring systems underwater are based on cameras and the exploitation of the image data. The computer vision and image processing have been particularly studied in this context to develop robust and sophisticated algorithms for underwater research topics. The light absorption and scattering pose a bottleneck, because the visibility underwater is only a few meters. In [4], where clear water is considered, twenty meters visibility is shown.

Recent works try to enhance the underwater image quality, and to reduce the level of noise, in order to detect and localize the objects in it successfully. Some researchers in [5–7] propose filter based methods for reduction of undesirable noise. In [8,9] wavelet based methods are proposed.

In [8], authors combine Wavelet Decomposition and High-pass Filter in order to remove back-scattering noise. Homomorphic filtering, anisotropic filtering and wavelet-based thresholding are applied to reduce the additive noise in [9]. However, these wavelet based methods cause unsharpness in the resulting image. In [10], the authors use a median filter to remove the noise, RGB Color Level Stretching to enhance the quality of the image, and Dark channel prior to obtain the atmospheric light. This method can Only help in the case of images with minor noise. Very noisy images was treated in [11] by utilizing a Bilateral filtering, the proposed solution presents good result but the required time processing is very high.

Statistical methods are proposed in [12–14], these methods are based on the modulation of the noise as Poisson–Gauss distribution and supposing that the image is independent form the noise. The authors show promising results in different noise level.

Beside noise, the absorption, and scattering of light between the camera and the object, degrade the quality of the captured images. the non-uniform absorption of colors, for example, red color is absorbed more than blue color, that make the underwater images dominated by the blue color. This behavior enhance the difficulties of identification and detection of divers, fish and other objects in underwater images. [15–17] apply regularization methods by means of laser technologies. Color polarization methods are proposed in [18–20], the authors utilize a filter (at the front of the camera) in order to uniform the color proportions in the captured images. The combination of the laser based technology and color polarization are proposed in [21,22].

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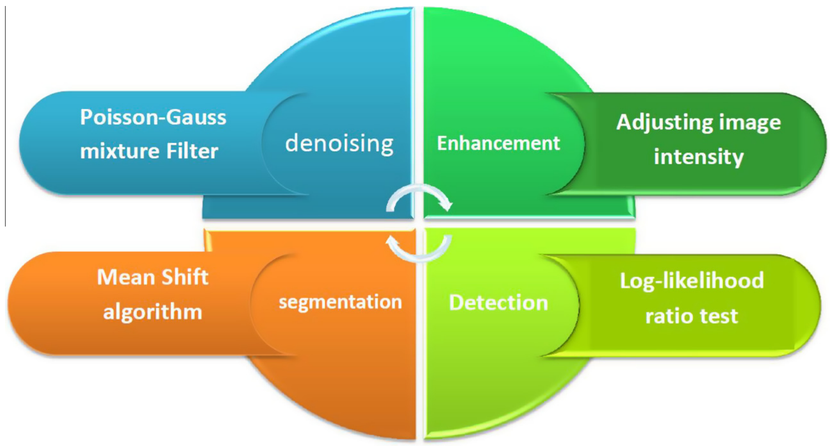

Fig. 1. Skills of the proposed approach.

The challenge now is to create an efficient tool which is able to solve jointly the problem of noise, light absorption, and scattering effects. Our goal is to offer the submarine biologist to explore the underwater environment and analyze the behavior of different fish species. Several additional effects such as rain, whirlpool, current, salinity, temperature, waves, tides and many other effect make the visibility more difficult. Fig. 1 defines the skills of our approach, it is divided on four fundamental blocks: image denoising, image enhancement, estimation, and detection. without knowledge of the environment. in order to generalize the image preprocessing solution.

The next sections in this paper are organized as follows. Section 2 describes the theoretical principle of the model under investigation. In this part, denoising-enhancement process as well as statistical estimation of the desired object are derived. In Section 3, experimental results and comparison with other methods are shown. Section 4 conclude this work.

2. Theoretical principle

Notations:

Variable	Designation
v	a data vector
α_i	the mixture weights $(1 \leqslant i \leqslant m)$
μ, μ_i	mean element(s)
x, y	a strictly positive numbers
η	a real number
C_i	covariance matrix
z_k	the realization of Z
Z	series of observations
m	number of Gaussians
k	the mean of the PGM distribution
$R_{I,t}$	the observed random variable] at time t and location I
$Q_{I,t}$	the signal-dependent Poisson component
$\mathbb{N}_{I,t}$	signal independent Gaussian component
$\gamma(z_{ji})$	defines the posterior probabilities for the jth observation and the ith Gaussian
s_l	the lth region
I_l	the lth region from the image I
L	number of regions in the image
N_i	the effective number of pixels assigned to the ith Gaussian
j	number of observations $(1 \leqslant j \leqslant N)$

The goal of the proposed approach is to reduce the noise level extremely in order to enhance the quality of the images in submarine environment. There are principally two sources of noise: The first one is coming from the capture. Its usually depends on the capture settings and the power of the device. The second is caused in the transmission, a typical example is the information loss due to image compression. Otherwise, without compression, we would have to consume several temporal and material resources for the transmission of images (Fig. 2).

The Gaussian mixture is among the most popular model applied in statistics ([23,24]). It is a parametric probability density function represented as a weighted sum of Gaussian component densities. A Gaussian mixture model is a weighted sum of m component Gaussian densities as given by the equation,

$$p(v/C_i, \mu_i) = \alpha_i \sum_{i=0}^{m} (v, C_i, \mu_i), \tag{2.0.1}$$

where v is a data vector, and α_i are the mixture weights $(1 \leqslant i \leqslant m)$. Given the component Gaussian densities. Each component density as:

$$f(v, C_i, \mu_i) = \sum_{i=0}^{m} \frac{1}{\sqrt{2\pi}\sigma} \exp\left\{-\frac{1}{2}(v-\mu_i)^T C_i^{-1}(v-\mu_i)\right\}, \tag{2.0.2}$$

with mean elements μ_i, and covariance matrix C_i, The mixture weights satisfy the constraint that

$$\sum_{i=0}^{m} \alpha_i = 1.$$

In [25] the authors create a statistical model based on a mixture of projected Gaussian distribution and wavelet based algorithms, in which they use the expectation maximization algorithm to accelerate the processing time of the algorithm. This method implicitly segments the image into regions of similar content.

Poisson–Gaussian distribution is a statistical model formed by the combination of a Poisson distribution and a Gaussian distribution. In [12] the authors show that the noise produced in the imaging devices can be modeled as Poisson–Gaussian distribution. This combination generates a method of noise removal. The aim of the method is to benefit from the property of each distribution in image denoising. The Poisson component accounts for the signal-dependent uncertainty, while the Gaussian mixture component accounts for the other signal-independent noise sources. The Poisson–Gaussian can use generalized Anscombe transform to stabilize the variance [12], and to ensuring the precision of the denoising process. The authors use this technique to treat pictures with low intensity.