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An Underwater Optical Image Segmentation Algorithm Based on Fuzzy C-means Model

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Abstract. In the process of underwater light propagation, the distortion of light varies with wavelength. The three main causes of underwater visual quality degradation are absorption, scattering and color distortion which will bring low contrast, blurring. In order to guarantee the quality of segmentation in fast image segmentation, a segmentation algorithm based on FCM clustering of underwater images, and on the basis of effective evaluation index of underwater image segmentation and fuzzy partition. Experimental results show that this algorithm can achieve better segmentation quality and time efficiency.

1. Introduction
Autonomous Underwater Vehicles (AUV) is widely used in marine resources exploration, marine ecological monitoring, military and other fields. Most of the AUV are now equipped with optical imaging and image processing and recognition system, and the visible image is one of the main sources of AUV information. However, in the process of underwater light propagation, the distortion of light varies with wavelength. The three main causes of underwater visual quality degradation are absorption, scattering and color distortion, due to the limitation of underwater image, the underwater images have many disadvantages, such as low contrast, blurring. The decrease of visual quality will seriously affect the performance of subsequent feature extraction and target recognition. Therefore, it is of great scientific significance to improve the visual quality of underwater images by means of image processing technology. More and more researchers have paid close attention to it, and the related researches have been increasing. Currently, there are many practical applications such as X ray image, satellite, aerial and remote sensing images restoration. The noise characteristics of X ray photographs impacted by human body and the degradation of images from the atmospheric turbulence were well understood. However, for underwater images, there are no systematic quantitative results for long distance and multiple scattering light propagation, and the perturbation mechanism and noise model of different water conditions and propagation functions of different water bodies have hardly been studied.

Underwater image enhancement methods can be divided into two categories: spatial enhancement and frequency domain enhancement. Spatial enhancement is based on gray level mapping and template convolution, such as gray scale transformation, template smoothing and histogram equalization. It is directly on the gray value of the image processing in image contrast enhancement without considering the image sharp details; and frequency enhancement basic information can not only preserve the image, but also can enhance the image edge details effectively. It first performs the
Fourier transformation of the image, then operates the spectrum components, and finally obtains the desired results by inverse Fourier transform, such as low-pass filtering, high pass filtering. The low contrast of the underwater image enhancement which, TBHF method can suppress the low frequency components of image, gain high frequency components, enhance the effect of increasing some of the low contrast image under water, but the uneven illumination of underwater image processing effect is not good, not considering the influence factors of phase angle and TBHF in the suppression of low frequency and enhance high frequency, inevitably lost a part of high frequency, resulting in important details of image edges. Zhang R and Liu J [1] proposed an underwater image segmentation with maximum entropy based on particle swarm optimization. The image threshold approached with the index of entropy maximization of the grayscale histogram based on particle swarm optimization (PSO) algorithm is proposed to deal with underwater image. Experiments showed that the proposed method can get ideal segmentation result with less computation cost. Bai J, Pang Y, Zhang Y, et al.[2] proposed an underwater image segmentation method based on MCA and fuzzy clustering with variational level set. The framework uses MCA method to decompose the image into texture and cartoon parts. The segmentation algorithm utilizes the subordinate properties of the fuzzy clustering membership function to construct the new variational level set, and uses the minimization of energy functional to get the evolution equation of the level set function. Experiment results showed that the proposed algorithm can reduce the influence of the noise and obtain a better segmentation result for underwater images. Bai J, Pang Y, Zhang Q, et al.[3] proposed a new adaptive level set evolution method to obtain the weaken edges of the cartoon part. The new method combines the threshold piecewise function with variable right coefficient and halting speed function, and the new function is suit for the cartoon part image segmentation. Zhao K, Xu Y P, Peng F Y, et al.[4] proposed an underwater image segmentation combining dual-band enhancing and edge-grouping.

In this paper, a segmentation algorithm based on FCM clustering of underwater images, and on the basis of effective evaluation index of underwater image segmentation and fuzzy partition., Experimental results show that this algorithm can achieve better segmentation quality and time efficiency.

2. FUZZY C-MEAN
FCM algorithm is a kind of clustering algorithm based on division[5]. Its idea is to make the objects that are divided into the same cluster which have the highest similarity, and the similarity among different clusters is the smallest. The fuzzy C mean algorithm is an improvement of the ordinary C mean algorithm, and the ordinary C means algorithm is hard to classify the data, while FCM is a flexible fuzzy partition. The main idea of FCM clustering segmentation algorithm for underwater image is to iteratively optimize the objective function according to the weighted similarity measure between the image pixels and the clustering centers to determine the optimal clustering. For the image of M * N, according to each center image n = M * N pixels and C clustering center between weighted membership, iterative optimization of objective function, fuzzy partition matrix U and V matrix class center clustering objective function J.

2.1 Fuzzy Sets
The membership function is a function of the degree of object X belonging to the set A, usually denoted A(x), the variable range is all belongs to the set A (i.e. a collection of A spaces in all points), the range is [0,1], namely 0<=μA(x)<=1,μA(x)=1 x said completely belonging to the set A, the equivalent of the traditional concept of the X and A set. A membership function defined on the space X={x} defines a fuzzy set A, or a fuzzy subset defined on the domain X={x}. For finite objects x1, x2, ......xn, the fuzzy set can be represented as

\[ A = \{ (\mu_A(x_i), x_i) \mid x_i \in X \} \]

, in the problem of clustering, clustering can put the generated clusters as fuzzy sets, therefore, each data point belonging to the cluster membership is [0, 1].
2.2 C Means Clustering Method

K means clustering, that is known as C means clustering, has been applied to various fields. Its core idea is as follows: the algorithm takes n vectors XJ (1, 2, ..., n) divided into C groups Gi (i=1, 2, ..., C), and seek the clustering centers of each group, so that the value function (or objective function) of the non-similarity (or distance) index is minimum. When the Euclidean distance is chosen as the non-similarity index between the vector XK and the corresponding cluster center CI in group J, the value function can be defined as:

\[ J = \sum_{i=1}^{C} J_i = \sum_{i=1}^{C} \left( \sum_{k, x_k \in G_i} \| x_k - c_i \|^2 \right) \]  

(1)

In general, a common distance function d(xk, ci) can be used instead of the vector xk in group I, and the corresponding total value function can be expressed as:

\[ J = \sum_{i=1}^{C} J_i = \sum_{i=1}^{C} \left( \sum_{k, x_k \in G_i} d(x_k - c_i) \right) \]  

(2)

2.3 FCM

Fuzzy C means clustering (FCM), is a clustering algorithm that uses the degree of membership to determine the degree to which each data point belongs to a certain cluster. [6] In 1973, Bezdek proposed the algorithm as an improvement on the early hard C means clustering (HCM) method. FCM takes the N vector Xi (i=1, 2, ..., n) is divided into C fuzzy sets, and the clustering centers of each group are obtained, so that the value function of the non-similarity index is minimum. The main difference between FCM and HCM is that FCM uses fuzzy partitioning so that each given data point is determined by its membership value between 0 and 1 to determine the extent to which it belongs to each group. In conjunction with the introduction of fuzzy partitions, the membership matrix U allows elements with values between 0 and 1. With the normalization rule, the membership degree of a data set is always equal to 1:

\[ \sum_{i=1}^{C} u_{ij} = 1, \forall j = 1, ..., n \]  

(3)

Then, the value function (or objective function) of FCM is the general form of formula:

\[ J(U, c_1, ..., c_c) = \sum_{i=1}^{C} J_i = \sum_{i=1}^{C} \sum_{j=1}^{n} u_{ij}^m d_{ij}^2 \]  

(4)

Here, Uij is between 0 and 1; Ci is the clustering center of the fuzzy group I; \( d_{ij} = \| c_i - x_j \| \) is the Euclidean distance between the ith cluster center and the j data points; and \( m \in [1, \infty) \) it is a weighted index. The new objective function is constructed, and the necessary condition for the minimum value of (6.10) is obtained:

\[ J(U, c_1, ..., c_c, \lambda_1, ..., \lambda_n) = J(U, c_1, ..., c_c) + \sum_{j=1}^{n} \lambda_j (\sum_{i=1}^{C} u_{ij} - 1) \]  

\[ = \sum_{j=1}^{n} \sum_{i=1}^{C} u_{ij}^m d_{ij}^2 + \sum_{j=1}^{n} \lambda_j (\sum_{i=1}^{C} u_{ij} - 1) \]  

(5)

The minimum necessary condition for (5) is

\[ c_i = \frac{\sum_{j=1}^{n} u_{ij}^m x_j}{\sum_{j=1}^{n} u_{ij}^m}, \quad u_{ij} = \frac{1}{\sum_{k=1}^{C} \left( \frac{d_{ij}}{d_{kj}} \right)^{2/(m-1)}} \]  

(6)
3. Simulation
Through a large number of experiments, it is proved that when the number of cluster C is 5, the time consumption has been great, if it has to be satisfied. The efficiency of the underwater robot is very important, and the segmentation effect is obvious when the C takes 4 from the actual segmentation effect.

Fig.1 original image

Fig.2 Image preprocessing
As shown in Fig3, for the three prism image serious uneven illumination, blurred edge, clustering characteristics using the new algorithm after segmentation algorithm has better effect than the traditional segmentation, the extracted object details are more prominent and complete.

4. Conclusion

Through the research on the FCM algorithm, using the gradient information of the image, relative to the loss of image information as the constraints, make full use of resampling data of the original image information compression. The experimental results show that the FCM algorithm is improved a lot, at the same time, the segmentation quality did not decrease to a certain extent, the methods the target region extraction more complete. According to the special requirements of the underwater work and mission, the method based on the segmentation quality, improve real-time and practical operation, and provide reliable data for further target recognition and tracking.

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