Oil Spill Image Segmentation Based on Fuzzy C-means Algorithm

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***Abstract*—Oil spill may cause serious pollution of the marine environment. Unmanned aerial vehicles remote sensing system can be used to monitor oil spill conditions. In order to identify the oil spill area on aerial image accurately, the first step is oil spill region segmentation. The paper presents an image segmentation method of oil spill area based on fuzzy C-means Algorithm. Firstly, according to the color characteristics of the oil, the paper selects YCbCr color space as the feature space. Then, the paper uses fuzzy clustering algorithm to divide the color feature space. Finally, according to oil color model, the paper selects clustering result as the segmentation results of oil spill area. Experiment show that the proposed algorithm's accuracy for oil region segmentation of calibration attain to 95 percent.**

Keywords—Oil aerial image; color model; YCbCr color space; fuzzy C-means Algorithm

I. Introduction

Oil spill is a serious disaster. Every year, there are many oil spill accidents occurred in China's coastal, oil spill accidents make serious impact to the development of marine economy [1]. Accurately oil spill monitoring can reduce the impact of accidents and economic loss.

With the development of Unmanned aerial vehicles(UAV) technology, UAV remote sensing systems are increasingly used in environmental monitoring. Compared with satellite remote sensing monitoring system, air monitoring, marine monitoring and other traditional platforms, UAV remote sensing systems have the characteristics of low cost, simple operation, fast response, efficient operation, can acquire high-resolution aerial images [2].

In the monitoring process, UAV remote sensing system will generate a lot of real-time oil spill image and video data. In order to improve the capability of automatic image recognition to deal with a lot of real-time data, we need to research the oil detection algorithm based on aerial images.

The first step of oil detection is the image segmentation to get the region contained oil spill area. In multi-spectral image analysis of oil spill, there are many segmentation methods. The basic segmentation based on multi-threshold segmentation. Some literatures use fuzzy C-means algorithm (FCM), watershed, active contour models in segmentation. Reference [3] used mixing KFCM and CV model in segmentation. Reference [4] proposed segmentation method based on level set and SFCM. Reference [5] used spectral clustering method for SAR image segmentation in the oil spill area. These methods have better effects than the threshold segmentation in oil segmentation.

Currently oil recognition of visible image is concentrated on gray zone. However, due to the UAV aerial oil image contains many objects, and the overlap of different objects in gray zone, there are not easily to distinguish the oil area in gray zone.

The paper uses fuzzy clustering method in oil color image segmentation. Select the cluster classification by oil color model to obtain segmentation results contain the oil spill area. Experiments show that the method has higher segmentation accuracy.

II. The Oil Color Characteristics

After the oil poured into the sea, with the waves, wind and other effects, it will make oil and seawater in the physical action mixed to form an emulsion. Depending on the emulsion droplet size, the droplet absorption of incident light, scattering is different and the appearance is different. Emulsion appearance as shown in Table 1.

TABLE I. MILKY OIL COLOR DESCRIPTION

Droplet size	Large drops	>1um	1-0.1um	0.1-0.05um	<0.05um
Appearance	Distinguish two phase	Milky	Blue and white	Gray translucent	Transp-arent

Table 1 show that the color of emulsion distribution is concentrated in blue-gray to white range.

III. Selection of the Color Space

Oil spill area in different color spaces exhibit different characteristics. To obtain the best segmentation result, we first need to choose the color space which is sensitive to oil color characteristics. Color space can be divided into three categories as physics-based color space, perceptual-based color space and uniform color space. Physics-based color space is defined to adapt to device, including RGB, CMY, YIQ, YUV, YCbCr. Perceptual-based color space can visually portray human color perception, including HSV, HIS. Uniform color space includes CIELAB, CIELUV.

RGB space is suitable for display systems. But the *R*, *G*, *B* three components are highly correlated, so if the change in luminance, three components will change accordingly. Thus, it is difficult to use RGB color space to describe the oil spill region with a smaller dynamic range.

HSI color space is based on human perception. Hue and

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saturation components may describe the color information. However, according to the color transformation between RGB and HSI space, hue and saturation are sensitive in perceive.

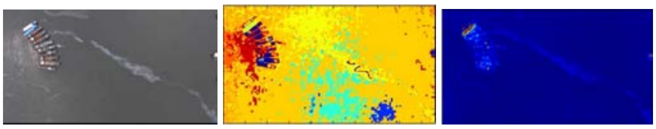
$$H=\begin{cases}\delta & B\le G\\ 360^\circ-\delta & B>G\end{cases} \tag{1}$$

$$\delta=\arccos\left\{\frac{(R-G)+(R-B)}{2\sqrt{(R-G)^2+(R-B)\times(G-B)}}\right\} \tag{2}$$

$$S=1-3\frac{\min(R,G,B)}{R+G+B} \tag{3}$$

Firstly, if the brightness is high or low, tone can't express color characteristics. Secondly, if the color saturation is weak, tone values will be unstable. Finally, if the brightness tends to extremes, saturation tends to zero. Therefore, if the image has the above characteristics, hue, saturation will not accurately describe object properties.

RGB components of oil spill area have smaller interval, and the saturation is low. By the impact of lower saturation, tone value's change is not stable. Therefore, HSI color space can't effectively describe the color characteristics of emulsified oil, as shown in Fig.1.



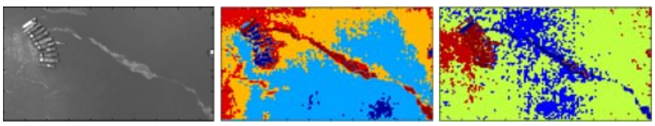
(a)Original color image (b)Hue component (c)Saturation component

Fig. 1. Each component of the HSI color space dimension

In YCbCr color space, the two chrominance information components *Cb*, *Cr* describe blue and red color offsets, and have less relevance with luminance. Thus, the components reduce the impact of non-uniform illumination [6]. YCbCr color space can be transformed from RGB color space.

$$\begin{bmatrix}Y\\C_b\\C_r\end{bmatrix}=\frac{1}{256}\begin{bmatrix}65.738 & 129.057 & 25.064\\ -37.945 & -74.494 & 112.439\\ 112.439 & -94.154 & -18.285\end{bmatrix}\bullet\begin{bmatrix}R\\G\\B\end{bmatrix}+\begin{bmatrix}16\\128\\128\end{bmatrix} \tag{4}$$

YCbCr color space separates luminance and color segments. The luminance component has less relevance with blue offset and red offset. This character may reduce the influence of non-uniform illumination. Oil image component of YCbCr space is shown in Fig.2.



(a) Luminance component (b) Cb component (c) Cr component

Fig. 2. Each component of the YCbCr color space dimension

The emulsified oil's color is white, blue and gray translucent. In further analysis, the brightness and blue offset components have obvious color characteristics in YCbCr color space. Therefore, the paper chose *Y* component and *Cb* component to constitute the emulsified oil's color model.

IV. Fuzzy Clustering Segmentation

Fuzzy clustering algorithm use fuzzy partition matrix to describe the degree of uncertainty of each category and reflect the influence of fuzziness. Thus, fuzzy clustering classification is better than the threshold classification, so fuzzy clustering often used in medical image noise image segmentation [7] [8] [9].

The collection $X=\{x_1,x_2,\ldots,x_n\}\subset R^s$ is a collection with *S* dimension in feature space *R*. Divide *R* into *C* parts ($c\in[2,n]$). Assume that cluster centers are $V=\{v_1,v_2,\ldots,v_n\}$. The fuzzy partition matrix *U* which can let function $J(U,V)=\sum_{j=1}^{n}\sum_{i=1}^{c}(u_{ij})^m(d_{ij})^2$ obtain the minimum value is ideal classification results. *Uij* is the membership of sample *Xj* for cluster centers *Vi*, $U=(u_{ij})_{cxn}$ is a fuzzy partition matrix, m is a fuzzy weighted index, *dij* is the distance between sample *Xj* and cluster centers *Vi*. Thus, the fuzzy clustering algorithm can be expressed as a mathematical programming problem as shown in (6).

$$\min J_m(U,V)=\sum_{j=1}^{n}\sum_{i=1}^{c}(u_{ij})^m(d_{ij})^2 \tag{6}$$

Equation (6) satisfies $\sum_{i=1}^{c}u_{ij}=1$ .we can use lagrange operator to solve the issue, and *U*, *V* can be described as shown in (7), (8).

$$u_{ij}=\frac{(d_{ij}{}^2)^{-1/(m-1)}}{\sum_{k=1}^{c}(d_{kj}{}^2)^{-1/(m-1)}} \tag{7}$$

$$v_i=\frac{\sum_{j=1}^{n}(u_{ij})^m\cdot x_j}{\sum_{j=1}^{n}(u_{ij})^m}(1\le i\le c) \tag{8}$$

When using the clustering algorithm for image segmentation, we should consider the selection of clustering results.

In order to determine the clustering results, the paper extracts 400 emulsified oil region, and analysis the *Y* and *Cb* component distribution. Then establish the oil color model. As shown in (9).

$$\begin{cases}Y\in[15,120]\\ Cb\in[128,140]\end{cases} \tag{9}$$

The color model is based on statistical sampling results of oil color distribution. It describes the mainly oil distribution range in color space. Therefore, according to the color model, we can select the clustering results with the cluster center located in threshold model color range as the result of segmentation.

V. The Segmentation Algorithm Analysis

The flow chart of segmentation algorithm based on fuzzy clustering is shown in Fig.3.

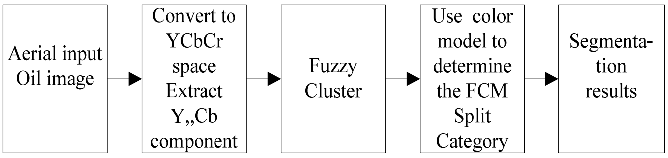
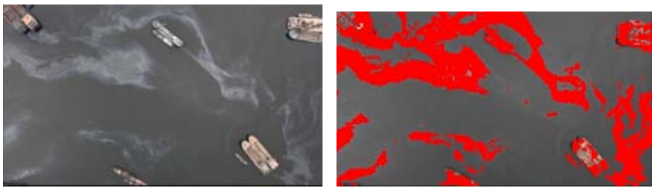


Fig. 3. flow chart of oil segmentation algorithm based on fuzzy clustering

The segmentation result is shown in Fig.4.



(a) Original color image (b) Segmentation results

Fig. 4. Result of segmentation

Reference [11], [12], [13] summarized the evaluation of a variety of image segmentation techniques. Since the oil boundary is ambiguity and uncertainty, we use the target count consistency (Object count agreement) as a measure of evaluation of segmentation algorithms. Target count consistency expressed as follows: the number of targets S obtained by segmentation in one image and actually existing target number T segmentation results maybe imperfect and different, this difference reflects the segmentation algorithm performance. Using probabilistic methods can take advantage of this difference in the definition of a target count measure to evaluate the consistency of segmentation. According to segmentation and calibration results, the relationship between the two sets can be drawn on the Venn diagram, as shown in Fig.5.

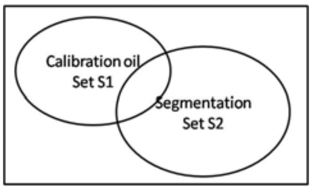


Fig. 5. Venn diagram about Segmentation Set and Calibration Set

The number of elements in the set *S*1 is *m*1. The number of elements in the set *S*2 is *m*2. The number of elements in the set $S_1 \cap S_2$ is *m*3. According to the concept of counting consistency, based on the machine learning evaluation, we use the accuracy and false alarm rate as the measure of segmentation, in which the accuracy of the segmentation result reflects the real oil region accounts for the proportion of actual area, and the false alarm rate reflects the non-oil accounts for dividing the total number of regions divided region of proportion. Accuracy, false alarm rate is defined in (10), (11).

$$P = \frac{m_3}{m_1} \times 100\% \tag{10}$$

$$FA = \left(1 - \frac{m_3}{m_2}\right) \times 100\% \tag{11}$$

Test image's shooting conditions are as follows: the image size is 1920x1080 pixels with 24 bit color. The scene length is approximately 450 meters and the scene width is approximately 300 meters. Calibration oil minimum diameter is 15 meters. We use accuracy and false alarm rate to evaluate the effect of segmentation based on fuzzy clustering segmentation algorithm. The evaluation results are shown in Table 2.

TABLE II. FCM SEGMENTATION AND COLOR MODEL SEGMENTATION EVALUATION

Calibration oil region	Split area	Split oil region	Accuracy (%)	False Alarm Rate (%)	Time Consuming （s）
850	1406	814	95.76	42.11	178.81

Experimental results show that the fuzzy clustering algorithm can reach 95 percent on accuracy for segmentation of calibration oil regions, so the missing rate is low. On the other hand, despite higher accuracy, the false alarm rate also reach to 42.11 percent. We consider that the color segmentation is intended to provide the possible oil region of interest for feature recognition, the subsequent processing such as feature recognition entirely depends on the segmentation results, thus requiring segmentation algorithm may have some over-segmentation (false alarm rate), but the leak detection segmentation algorithm will directly lead to rate decline, so the dividing leak rate (leakage alarm rate) should be controlled at a lower level. The leak rate of the proposed segmentation algorithm is less than 5 percent. Therefore, the algorithm has high accuracy. Although the algorithm takes nearly 180 seconds to get the result, which is due to the fuzzy clustering algorithm uses an iterative process to get the optimal solution generated by the algorithm, so the algorithm is unsuitable for real-time requirements, but for some less demanding real-time applications, the algorithm may obtains segmentation results with higher precision.

VI. CONCLUSION

In this paper, we proposed an oil spill region segmentation algorithm based on fuzzy clustering methods in oil detection. We first select *Y*, *Cb* components in YCbCr color space to construct the oil color model. Then use fuzzy clustering method to classify the color vector. Finally, according to the color model, we choose the cluster centers in the model range from clustering results as the result of segmentation. Experiments show that the segmentation algorithm may provide higher precision oil segmentation results for aerial images in low speed requirement.

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