AUTOMATIC MONITORING OF WASTE-WATER IN INDUSTRIAL PLANTS BASINS

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ABSTRACT

We describe an algorithm for the analysis of color images of basins which gather dirty water, with the objective of detecting and estimate the presence of exceeding combustible oil. The algorithm first detects most of the pixel corresponding to the combustible oil applying a thresholding method based on the entropy of the image's histogram. Then it treats the images differently according to the first order statistics of the image's hue; we distinguished two cases in which the algorithm has a different behavior: in the first case, it applies a clustering method in the HSV color space, whereas in the second case it operates in the CIE-L*a*b* color space. Finally it estimates the percentage of the present oil.

1. INTRODUCTION

The industrial processes can be responsible of oil spills in rivers, lakes or seas and, consequentially, a continuous control has to be carried out. Nowadays several techniques are available for the oil analysis in water: gravimetry, infra-red spectrum-photometry, spectra-fluorometry, UV absorption, surface reflection, In the past CESI has patented a method and an apparatus for continuum measuring of concentration of the mineral oil in water by a spectrum-photometric detector. Later CESI patented a floating platform mounted device for oil detecting on water surfaces based on a electro-optical technique (laser diode). However, all the above mentioned techniques give a localized picture of the pollutants in water. In this paper we describe a non-localized oil detection system based on image processing techniques. Such system has been built in order to automatically monitoring the basins which gather waste-water of industrial plants, where the nature of the pollutants is well known. The system is able to detect and estimate the possible presence of combustible oil in the basin and to signal to the remote control room operators the presence of excessive oil quantities which indicate a probable leakage or failure in oil's pipes and which could create some problem at the purification devices. Such system consists of a video camera and a hardware platform devoted to the frame grabbing, the image processing and the transmission of the possible alarm signal and the related images. Here we will focus on the algorithm developed to process the images.

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2. PROPOSED METHOD FOR THE ANALYSIS OF THE IMAGES

Considering the oil's spots don't have a specific shape that we can look for, we based the method on the information linked with the color which characterize better the oil.

We selected forty sample images such that they were representative of very different situations for the oil's dilution and for the illumination [Fig.1]. We used twenty of them to set the algorithm parameters, and the other twenty for the testing.

In order to detect the presence of oil independently of the ways it looks, we differentiated the behavior of the procedure according to the situation to catch [1]. We can divide the procedure into two main steps:

1. Identification of thick dark oil.
2. Identification of "other form" of oil.

2.1. Identification of thick dark oil

Starting from the consideration that most of the thick oil is much darker than the rest of the image, we considered appropriate to apply to all the images acquired a low-cost thresholding method which gives a first rough estimate of the present oil.

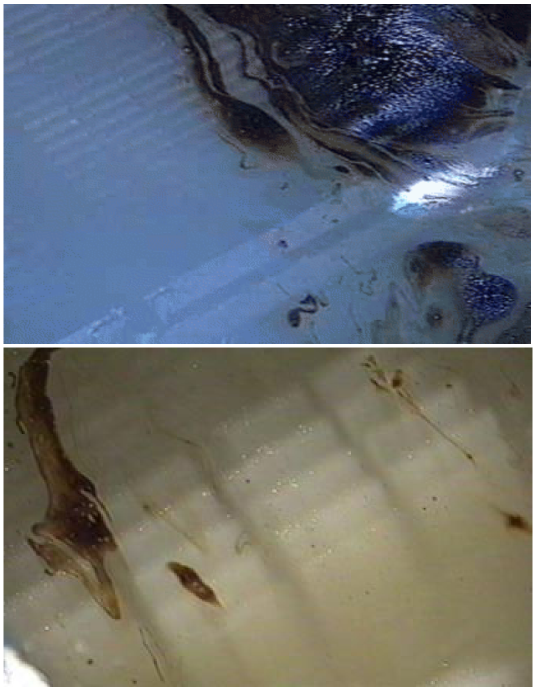

Fig. 1. Sample images.

The method we implemented processes gray-level images and is based on the entropy of the image's histogram [2].

In order to reduce the computational cost of the algorithm, the next steps are not applied to all the pixels classified as ”oil” by this method.

2.2. Identification of ”other form” of oil

The aim of this step is to refine the result obtained in the previous step analyzing the images more accurately and taking into account the information linked with the color. In particular we identified two main situations in which the thresholding method fails:

a) identification of diluted oil,

b) identification of thick oil passed through by beams.

The images belonging to these two classes are fairly different in color: as regards the first case, the predominant hue is brownish, whereas in the second case there are more blueish pixels. Therefore, in order to distinguish these two classes, we adopted the hue average as discriminating criterion: images with diluted oil have an average of hue lower than 75, while the images with thick oil passed through by beams have an average of hue greater than 75. In both cases we applied a clustering method [3], but, depending on the classification obtained, we considered different color spaces and we looked for clusters with different characteristics.

2.2.1. Identification of diluted oil

The color space which gives the best characterization to the images in this case is the HSV [4].

A further distinction has to be done according to the value of the hue variance: when it is lower than 0.002 just the Saturation plane is clustered. This is enough because the spots of diluted oil have the purest colors (i.e. the most saturated) in the images. We experimentally determined that the number of clusters necessary and sufficient to identify the spots of oil is four. On the contrary, when the hue variance is greater than 0.002, it is necessary to cluster both the Saturation (still with 4 clusters) and the Value planes (with 10 clusters).

The subsequent processing consists on the binarization of the clusters obtained. As regards the Saturation plane, we select the cluster with the highest Saturation value, providing that it is higher than a minimum acceptable value (0.4). As regards the Value plane, we select the cluster whose representative is the closest to the threshold obtained in the section 2.1.

We observe that, in the case we clustered the two planes S and V, the final result is the conjunction (Logic OR) of the regions found in the two planes.

2.2.2. Identification of thick oil passed through by beams

When beams hit thick oil, they can either fade the colors or cause iridescence. Moreover it is probable that in the basin, besides thick oil, there is also diluted oil. To catch all these forms of oil, we applied two times the clustering method in the CIE-L*a*b* color space setting differently the parameters and the conditions for the binarization.

First, we sought the possible diluted oil. It is necessary to fix the number of clusters in which to divide the image's colors. This choice depends on the image's hue variance: the greater it is the higher the number of clusters is (See the table below).

Hue Variance	N. of Clusters
LT 0.004	4
0.004-0.008	5
0.008-0.03	6
0.03-0.05	8
GT 0.05	10

Once we have clustered the image's colors, we can proceed to the binarization. The selection's criteria are based on the values of the clusters' representatives in the HSV color space: we classify as corresponding to oil all the pixels whose representatives verify this description:

$$H \notin [170 - 240]$$

$$V \leq 0.4$$

$$S \neq 0$$

The first condition rules out the pixels whose hue is between cyan and blue considering we are seeking yellow-brownish colors; the second condition imposes that pixels corresponding to the diluted oil have a low Value; the third condition requires that the Saturation is different from zero.

At this point what remains to be done is the detection of the pixels corresponding to thick oil passed through by beams. A second clustering in the CIE-L*a*b* color space is applied to those pixels not yet classified as corresponding to oil. This allows to reduce the computational cost and to obtain more precise results.

Also in this case the selection's criteria are based on the values of the clusters' representatives in the HSV color space: in order to detect the pixels corresponding to oil with faded colors, we select the clusters whose representatives verify this description:

$$H \in [170 - 240]$$

$$V \leq 0.4$$

As regards the iridescences, we observed that they have the highest Values. We therefore selected the clusters with Value greater than 230. Only a partial detection has been obtained. At the end of this procedure we have three binary images which are joint by means of the logic OR.

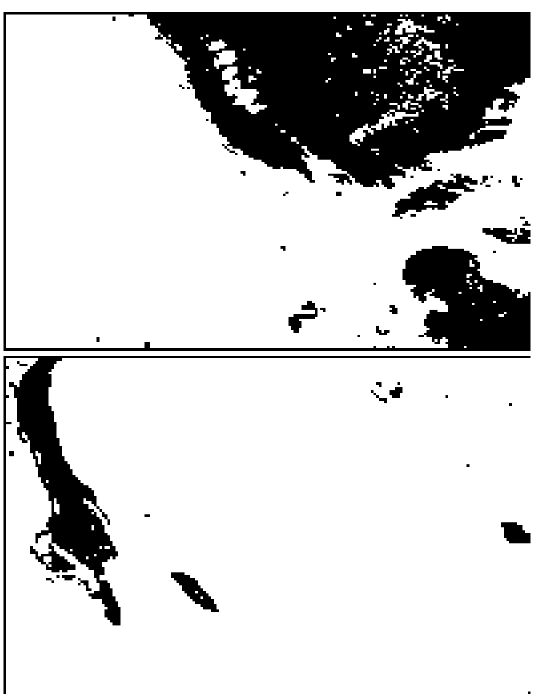

Fig. 2. Results obtained processing the images in Fig. 1

2.3. Estimation of the percentage of area occupied by the oil.

The binary images obtained present two defects: a high number of thin "filaments" and little holes inside the regions. These defects have been eliminated respectively applying the opening and the closing operators [5] with an 8-metric disk of radius 3 as structuring element. The result is more homogeneous regions.

The last step consists on calculating the percentage of pixels determined to correspond to the oil on the total number of pixels in the image. This value constitutes the final element on which it is decided whether to send the alarm signal or not.

3. RESULTS AND CONCLUSIONS

We have tested our method on the testing set of images obtaining generally good results: it automatically detects an average of 90% of the pixels corresponding to the oil. The problems we observed are due to the bad illumination's conditions: first the method fails in detecting the oil which is neighbor to some reflection; this happens because in these areas the oil assumes a bluish color which is classified by the clustering method as "water". The second problem occurs in correspondence to the oil's areas passed through by beams which sometimes make the oil appears too faded to be considered significant. Finally the third problem is due to the shadow of the grid which are over the basins. The shadows are sometimes very dark and so misclassified as "oil".

Better results can be obtained improving the acquisition conditions.

A final consideration has to be done about the computational cost of the algorithm. The time necessary to process one image on a Pentium 200 MHz with 64Mb of RAM, varies between 1 and 2 minutes. This result is acceptable because the water's flow is relatively slow. Moreover the program has been implemented with an interpreted language. The computational cost can be reduced developing the algorithm in a compiled language and optimizing the code.

4. REFERENCES

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