

An Algorithm for Image Restoration Based on Underwater Video Series

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Abstract—The inspection for nuclear power facilities has been paid attention all the time. In underwater NP videos exit waggling water flow and much snowflake noise whose positions are undetermined. The former results from the cold-hot water with different temperatures, and the latter maybe are from high radiation. All these severely influence recognition for objective structures and flaws in the nuclear power facilities. In order to get clear images about the nuclear power facilities, in this paper we put forward an algorithm for image restoration based on underwater video series, in which, each frame is de-noised firstly, and then these images are registered and fused, finally the fused image is enhanced by histogram equalization or homomorphic filtering according to the requirement. The effectiveness of this algorithm is proved by an example in processing a series of underwater videos.

Keywords—underwater video; image restoration; image registration; B-spline transformation; histogram equalization; homomorphic filtering

I. INTRODUCTION

In NPS, the environment that the NP devices are located is complex, where there is not only high radiation, but also irregular changing water flow. In the detection for the reactor core and its components, it is necessary that the underwater video cameras shoot these objects. Since these videos are influenced by fluctuating water, random noise, and unbalancing illumination, each frame is with many speckles, and some hubble-bubbles whose positions are undetermined. Moreover, some water waves and dark zones exist in it. All these are influential to discern the structures and flaws of these facilities^[1,2].

In order to accomplish the recognition for the structures and flaws, one wants a very clear image processed by these underwater videos^[3,4]. From this image, we can see the actual condition about the components. Especially, we can determine the sizes of the flaws and know their damage level. Only this, we can adopt some effective measures to avoid NP accident.

To do this, we present an algorithm for image restoration based on a series of underwater videos, in which each frame of these video series is de-noised firstly, and then all frames are stacked (also called “fused”) after registration, and finally the fused image is enhanced by histogram equalization or homomorphic filtering according to the requirement. This paper is organized as the following: Section II introduces some fundamental methods of image processing such as de-noising, registration, B-spline transformation, video stack, histogram

equalization and homomorphic filtering; Section III introduces the main algorithm for image restoration based on a series of underwater videos; Section IV gives an example about the image restoration from a series of underwater videos; Section V gives conclusions.

II. FUNDAMENTAL METHODS OF IMAGE PROCESSING

In this section, we will give an introduction for some elementary methods used in the algorithm.

A. Image De-noising

Which de-noising method to choose depends on the model that noise obeys^[3,5]. For example, additional Gauss noise can be suppressed by mean filtering, and the pulse noise such as salt and pepper noise can be eliminated by median filtering. In order to restrain more pulse noise and reserve the detail as smoothing non-pulse noise, one can choose the adaptive median filtering (abbr. AdaMedF). The AdaMedF method is as the following^[3]:

Define the following variables in a given filter zone S_{xy} : z_{\min} is the smallest gray level in S_{xy} ; z_{\max} is the largest gray level in S_{xy} ; z_{xy} is the gray level in the coordinate (x, y) ; S_{\max} is the biggest size permitted in S_{xy} .

The algorithm works in two courses, denoting Course A and Course B.

$$\text{Course A: } A_1 = z_{\text{med}} - z_{\min}$$

$$A_2 = z_{\text{med}} - z_{\max}$$

if $A_1 > 0$ and $A_2 < 0$, turn to Course B

or enlarge the size of S_{xy}

if the size of S_{xy} is no more than that of S_{\max} ,

repeat Course A

else output z_{xy} .

$$\text{Course B: } B_1 = z_{xy} - z_{\min}$$

$$B_2 = z_{xy} - z_{\max}$$

if $B_1 > 0$ and $B_2 < 0$, output z_{xy}

else output z_{med}

B. Image Registration

Image registration can be divided into three classes of methods: template registration methods based on the gray level, registration methods based on the features and registration methods based on the relations. The template registration methods are also called correlation registration methods, and those based on the relations are built according to the semantics, while the image registration we adopt is the robust registration based on the spot features between the images^[4]. In the course of registration, we will use affine registration, and B-spline transformation. Affine transform mainly contains shift, rotation, dilate, slant and tip transformation.

The formula on shift transformation is

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & a_{13} \\ 0 & 1 & a_{23} \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \quad (1)$$

where (x, y) and (x', y') are the spots before and after transformation, a_{13} and a_{23} are the shift magnitudes along X axis and Y axis.

The formula on rotation transformation is

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos \alpha & -\sin \alpha \\ \sin \alpha & \cos \alpha \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \quad (2)$$

where α is the rotation angle anticlockwise, its unit is rad.

The formula on dilate transformation is

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} a_{11} & 0 \\ 0 & a_{22} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \quad (3)$$

where a_{11} and a_{22} are the dilate factors along X axis and Y axis.

The formula on slant transformation is

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} 1 & a_{12} \\ a_{21} & 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \quad (4)$$

where a_{12} and a_{21} are the slant factors deviating from x and y .

The formula on tip transformation is

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \pm 1 & 0 \\ 0 & \mp 1 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \quad (5)$$

where the symbol “ \pm ” means two cases of plus and minus.

In B-spline transformation, the B-spline basis function utilized is the same to that in the literature^[4]

$$\begin{cases} B_0(t) = (1-t)^3 / 6 \\ B_1(t) = (3t^3 - 6t^2 + 4) / 6 \\ B_2(t) = (-3t^3 + 3t^2 + 3t + 1) / 6 \\ B_3(t) = t^3 / 6 \end{cases} \quad (6)$$

How to register the characteristic spots refers the literature [4] and Image Registration and Alignment in Image Processing Toolbox in MatlabR2009b.

By registration, the control spots and intervals that B-spline transformation needs are obtained.

C. Video Stack after Registration

High radiation and hot turbulence lead to noise and water-flow waggling. After registration, by video stack the noise and the water-flow waggling on the appearance can be suppressed effectively.

D. Image Enhancement

Here we introduce the histogram equalization and homomorphic filtering used in image enhancement.

Histogram equalization can elevate the contrast between the pixels by extending the range with the distribution of gray level. One can use the function “histeq” in Image Processing Toolbox in MatlabR2009b to realize the equalization. Since the technology is very mature, we don’t state any more. In the algorithm in Section III, we firstly transform the RGB image into an HSI image, and then, process the intensity image in the HSI image, at last transform the changed HSI image into a RGB image.

Sometimes, one wants to stand out the information in dark zone. At this time, we can use the homomorphic filtering.

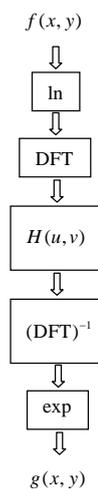


FIGURE I. THE FLOW OF HOMOMORPHIC FILTERING

According to the literature [3], an image $f(x, y)$ can be denoted as the product of its illumination $i(x, y)$ and

reflect $r(x, y)$. And the illumination is characterized by slow change in space domain, while the reflect is characterized by quick change. Fig.1 is the flow of the homomorphic filtering. The aim of the “ln” operation is to change the product of $i(x, y)$ and $r(x, y)$ into the sum of their logarithms. DFT means filtering in frequency domain. The filter is

$$H(u, v) = (\gamma_H - \gamma_L) \left[1 - e^{-c(D^2(u, v)/D_0^2)} \right] + \gamma_L \quad (7)$$

where $\gamma_H \geq 1$, $\gamma_L < 1$, $D(u, v)$ is the distance from the frequency position (u, v) to the center. D_0 is the cut-off frequency, c is the sharpening rate of the filter.

III. MAIN ALGORITHM ON IMAGE RESTORATION BASED ON UNDERWATER VIDEO SERIES

For convenient to invoke in program, the sequence files of the underwater videos are numbered by time series. Since each frame is influenced by sunlight, temperature and radiation, we will suppress the noise in preprocessing, and then register every video image to find the registered images and their control spots and intervals needed in B-spline transformation, next get an image by B-spline transform, and finally enhance the image by histogram equalization or homomorphic filtering according to the requirement.

Now we give the main algorithm for image restoration based on underwater video series (abbr. IRUVS).

Step 1. Add the functions and the files' paths in program, and read these video files;

Step 2. Use the names *frames*, *imgr*, *imgy* and *imgb* to express as the gray and the RED, YELLOW and BLUE in each color image;

Step 3. Find the mean of the intensity of the *frames* to denote as *Means(:, :, 1)*;

Step 4. Conduct adaptive median filtering for *frames*, *imgr*, *imgy* and *imgb*, the result after filtering *frames* is denoted as *ImovingBL*, the other three still denoted by original names;

Step 5. Input *ImovingBL* and *Means(:, :, 1)* to image registration function, Output the registered image *Ireg*, the control spot *O_trans* and the interval *spacing*;

Step 6. Make B-spline transformation for *imgr*, *imgy*, and *imgb* using the control spot *O_trans* and the interval *spacing*, the output is a color image denoted as *mst*;

Step 7. Enhance the color image *mst* by histogram equalization or homomorphic filtering according to the requirement;

Step 8. Show the original and processed color images and compare them.

The flow of this algorithm can be expressed by Fig.2 simply.

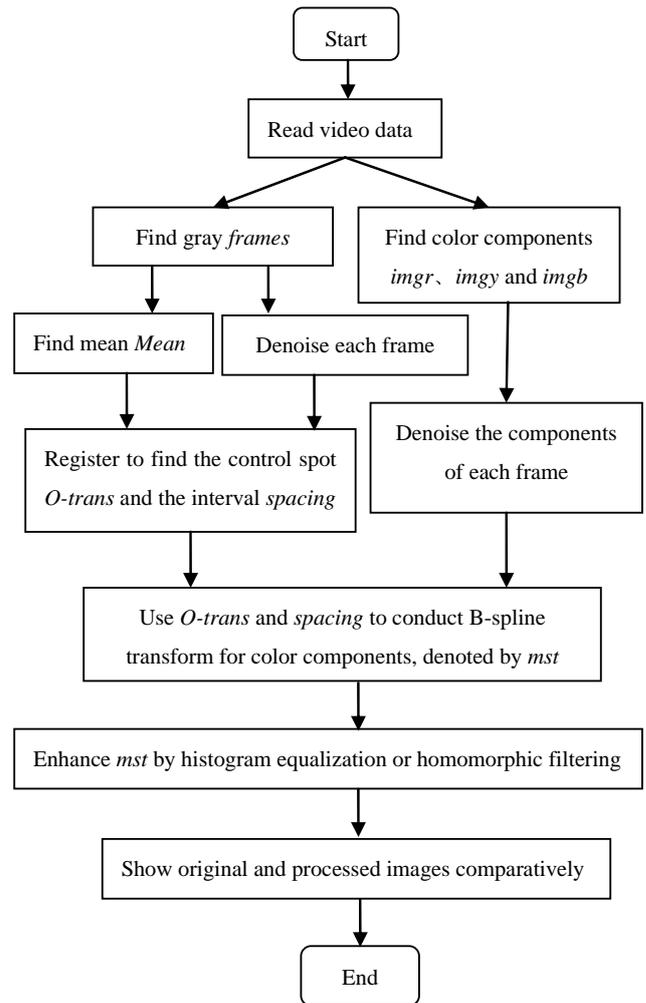


FIGURE II. THE FLOW OF UNDERWATER VIDEO IMAGE RESTORATION

IV. EXPERIMENTS

In Fig.3, four frames come from those videos that underwater cameras shoot in some NPS (SN: No.1~No.4). Observing carefully, we can see that each frame is with inhomogeneous illumination, snowflake noise and turbulent flow.

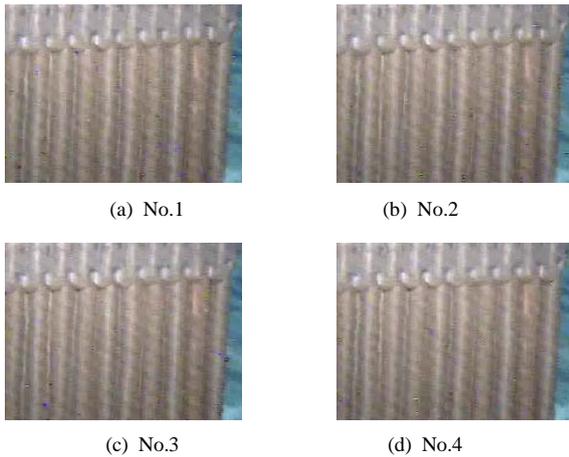


FIGURE III. FOUR UNDERWATER VIDEO IMAGES (NO.1~NO.4)

It is not rational that the condition of the equipment is judged by some frame among these images, because the turbulent water flow, noise and inhomogeneous illumination will lead to difficulty in seeing it clearly. Fig.4 is a video image whose SN is No.9. Clearly, the image is very dim, and with some hubble-bubbles.

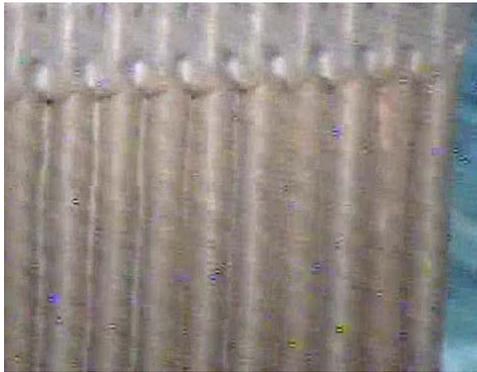


FIGURE IV. THE NINTH UNDERWATER VIDEO IMAGE (NO.9)

Applying the algorithm presented in this paper to these underwater videos, we get the following two images, seeing Fig.5. It is worth mentioning that the parameters are selected properly, in homomorphic filtering $\gamma_H = 1.1$, $\gamma_L = 0.5$.



(a) Histogram equalization in IRUVS



(b) Homomorphic filtering in IRUVS

FIGURE V. TWO IMAGES OBTAINED BY IRUVS

It is seen that the original noise and water waves are eliminated thoroughly in Fig 5. Regardless of the light zone and the dark zone, the facility can be seen clearly.

V. CONCLUSIONS

In allusion to the video traits of underwater NP facilities, in this paper we present an algorithm for image restoration based on underwater video series, in which, each frame is de-noised firstly, and then these images are registered and stacked to be meant (also called fused), finally the fused image is enhanced by histogram equalization or homomorphic filtering according to the requirement. This algorithm can eliminate the snowflake noise and turbulent water waves, stand out the information in the light zone or in the dark zone, which makes us see these underwater facilities clearly. Its effectiveness is proved by the experiments in processing a series of underwater videos.

REFERENCES

- [1] K. Shi, Advanced Techniques of nondestructive testing and evaluation. Beijing: Qinghua University Press, 2007.
- [2] Nondestructive testing and evaluation association (Japan), Ultrasonic wave detecting flaw (A). Jiangsu: Jiangsu Science & Technology Press, 1980.
- [3] Rafael C. Gonzalez, Richard E. Woods(translator: Q. Ruan, Y. Ruan), Digital image processing(second edition). Beijing: Electronics Industry Press, 2004.
- [4] Omar Oreifej, Guang Shu, Teresa Pace and Mubarak Shah, A two-stage reconstruction approach for seeing through water. <http://doi.ieeecomputersociety.org/10.1109/CVPR.2011.5995428>.

- [5] W. Wei, S. Yan, X. Huang, Nonlinear approximation and radar signal processing. Beijing: National Defense Industry Press, 2016.