An underwater ship fault detection method based on Sonar image processing

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Abstract. For the research of underwater ship fault detection method in conditions of sailing on the ocean especially in poor visibility muddy sea, a fault detection method under the assist of sonar image processing was proposed. Firstly, did sonar image denoising using the algorithm of pulse coupled neural network (PCNN); secondly, edge feature extraction for the image after denoising was carried out by morphological wavelet transform; Finally, interested regions Using relevant tracking method were taken, namely fault area mapping. The simulation results presented here proved the feasibility and effectiveness of the sonar image processing in underwater fault detection system.

1. Introduction
Ships may encounter unpredictable situations while its sailing on the ocean, and there may be bad weather, threat from the other ships, also the damage caused by long time operation of various equipment of the ship itself. Currently, ships fault detection and troubleshooting can be solved on the water basically, but for underwater fault, there has not yet provided a feasible solution, even the type of specific underwater failure can be determined from remote security system. It is a week line for the realization of fault real-time maintenance underwater particularly turbid waters. If this problem has not solved, the entire ship manoeuvre maintenance system will be flawed on the sea. In the turbid and low visibility waters, underwater video equipment can be seen in the visual range of 1-2 meters. Therefore, the ship's underwater fault detection and immediate repair is necessary by means of high-resolution imaging sonar to obtain high-resolution image data. High-resolution imaging sonar has important applications in the muddy waters of proximity detection. It can provide essential technical support for underwater ship maintenance program by processing and analyzing the image data obtained through high-resolution imaging sonar, and greatly improve the efficiency and reliability of the ship maintenance implementation.

2. Program design
The system flow chart in this paper is shown in Fig. 1. Taking the characteristics of sonar image itself into account: noise pollution, blurred or discontinuity edges, low contrast, non obvious target area characteristic features and so on, it is necessary to take sonar image denoising at first, which can remove the interference to acoustic imaging generated by complex underwater environments to make the image clearer and more obvious target feature. Pulse coupled neural network (PCNN) is taken in this paper to complete image denoising by adjusting the brightness of pixels, according to whether
each neuron and its neighboring neurons can inspire output pulse train or not, it can be determined and
distinguished between noise and pixel gray values, in order to take appropriate measures\cite{1}. Pulse
coupled neural network is a feedback network consists of several interconnected PCNN neurons. In
the practical application of image processing, PCNN network is a single two-dimensional network of
local connections. The number of neurons is equal to the number of pixels in the image input, and they
are correspondence. The output of each neuron has only two states, i.e. excitation (ignition) or
inhibition(no ignition). Compared with the conventional classical neural network, training process is
not required for PCNN to implement image processing, segmentation and recognition, which is
different from the traditional multi-layer network, making it ideal for real-time image processing
environment.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{system_flow_chart.png}
\caption{The system flow chart in this paper.}
\end{figure}

Secondly, feature extraction by extracting the relevant characteristics of the target area is taken to
the image after de-noising for further special tag localization and identification of workers, which can
largely reduce system complexity and running time. This paper does domain transform processing for
image by morphological wavelet transform to extract image edge feature\cite{2}.

Morphological wavelet, which is produced by making mathematical morphological combine with
wavelet analysis, can take the characteristics of non-linear filter of morphological and the
characteristics of multi-resolution of wavelet transform into account, make the various types of
wavelet analysis brought in its framework. Mathematical morphological solves a variety of image
processing problems from expansion and corrosion, and the program of morphological wavelet signal
analysis can be get by using morphological filter instead of the analysis and synthesis filter of linear
wavelet transform. The sketch map of two-dimension morphological wavelet decomposing is showed
in Fig. 2, where the detailed analysis operators are consist of a vertical direction operator $y_v(n)$, a
horizontal direction operator $y_h(n)$ and a diagonal direction operator $y_d(n)$.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{2D_MWT.png}
\caption{2-D morphological wavelet transform(2-D MWT).}
\end{figure}
Studies have shown that it has different information sensitivity characteristic of human eyes to different frequencies and in different directions. It has high sensitivity for intermediate frequency information, leading the information sensitivity is weaker above a certain frequency and the diagonal direction. Since morphological wavelet is nonlinear multi-resolution analysis, the image reconstructed from different scales of space can highlight the signal characteristics of different frequencies after appropriate treatment.

For the nonlinear multi-resolution analysis of morphological wavelet, reconstruct image from different scales of space can highlight the signal characteristics of different frequencies after appropriate treatment[3]. Combined with the characteristics of morphological wavelet, multi-channel adaptive image enhancement structure can be constructed, based on this, image edge detection can get a better result conducive to solving practical problem.

Finally, to improve efficiency of fault detection and failure exclusion for the workers, certain parts of the ship which require special mark is tagged on the image, which is called special tag localization[4]. In this paper, correlation tracking method by matching between the target template feature and various sub-regions sequences of the actual image is carried out, to identify the sub-image position most similar to target template as the current target position[5-7]. The correlation tracking system is insensitive for all other scene dissimilar with the selected tracking target image. When the resolution is good and the noise and interference are not serious, it has better tracking ability and anti-background interference, which is conducive to tag localization for interest area such as fault region.

3. Experiment

In our experiment, we selected a representative sonar image which is a 256×256 underwater hull image showed in Fig. 3(a), then noisy image can be get by adding Gaussian noise whose noise standard deviation is 0.1 showed in Fig. 3(b). It is obviously can be seen that this image has serious noisy pollution phenomenon, and the hull edge is ambiguous even some places are incomplete.

![Figure 3. The underwater hull image.](image)

The sonar image denosing result by PCNN method and some classical methods is showed in Fig. 4 and Fig. 5. Comparing with other denoising method, our method has better denoising effect, which is clearly to be seen that in the comparison curve of sonar image denoising under the different SNR in Fig. 5. In addition, it also can be seen from Fig.3 that the PCNN method not only have better performance in denoising, but also reserve the detail of the image well. To sum up, PCNN method is more suitable for sonar image denoising.
The image feature extraction results of the hull edge is showed in Fig. 6.

Figure 4. Denoising image.

Figure 5. The comparison curve of sonar image denoising under the different SNR.

The image feature extraction results of the hull edge is showed in Fig. 6.
The special markers result is showed in Fig. 7. When the resolution is good and the noise and interference are not serious, it has better tracking ability and anti-background interference, which is conducive to tag localization for interest area such as fault region.

Finally, these simulation results prove the feasibility of this paper.

4. Conclusion
For the application of sonar image processing on ship underwater fault detection, this paper has realized location markers of a particular hull by de-noising, feature extraction and special markers of hull sonar image. Applying to the actual ship underwater inspection and maintenance, setting particular location to be the fault area, it is possible to achieve the auxiliary for ship underwater maintenance and repair work on a certain extent by acquiring high-resolution sonar images. In summary, this paper provides technical support for inspection and maintenance.

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