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Performance of Improving Image Quality using DAE Algorithm in Underwater Fading Channel

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1. Introduction

Underwater communication is used in various fields such as ocean resource development, marine enviroment, AUV and so on. Underwater acoustic communication uses sound waves, unlike wireless communication that uses terrestrial radio waves. Sound waves are very slow in underwater at about 1500 m/s and have multipaths over time and reflections from the sea level and the bottom. In addition, signal distortion and loss occur due to water temperature, salinity, water pressure, ocean currents and seabed topography. Therefore, it is difficult for underwater acoustic communication to transmit and receive accurate information compared to communication using radio waves on the ground[1-4].

Various papers suggest methods to improve underwater acoustic communication. However, the underwater communication environment is highly variable and is a time-varying fading channel. Therefore, it can only be improved in certain ways in certain enviroment. In this paper, we propose a DAE algorithm for image quality improvement in an underwater fading channel regardless of any underwater environment.

2. DAE algorithm

DAE(Denoising Auto-Encoder) is an evolution of the AE learning method. It is mainly used to restore the noised image to the original image as much as possible. It can be seen as a solution to improve the image quality that has been degraded by underwater fading channel[5)].

Here is the DAE algorithm in **Fig. 1**. The input of the hidden layer which is called encoder can be expressed by **Eq. (1)** and the output of the hidden layer which is called decoder can be expressed by **Eq. (2)**. The principle of the DAE algorithm is to remove unnecessary data from noised image through the encoding process, and to restore it as close to the original image as possible through the decoding process.

encoder : $$y = f_\theta(\tilde{x}) = s(W\tilde{x} + b) \qquad (1)$$

decoder : $$z = g_{\theta'}(y) \qquad (2)$$

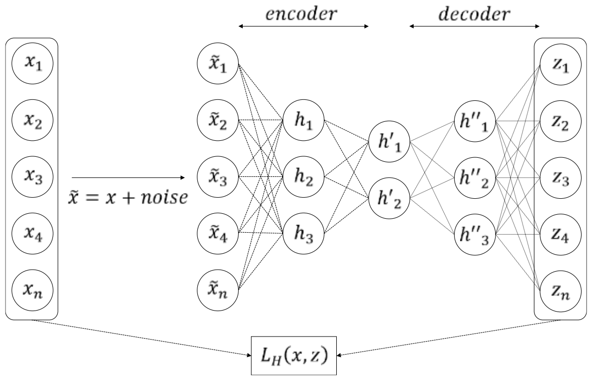

Fig. 1 DAE algorithm

The difference between input data and output data which is reconstructed through learning process is called reconstruction loss. By minimizing the reconstruction loss, the original image can be reconstructed and can be expressed as **Eq. (3)**. We use DAE algorithm to improve image quality created by underwater fading channel.

$$L_H = \frac{1}{n}\sum_{i=1}^{n}(x_i - f_\theta(g_{\theta'}(\tilde{x}_i)))^2 \qquad (3)$$

3. Experimental conditions and results

The experimental conditions for the simulation in underwater are shown in **Table 1**. Each image data was collected by changing the depth of the receiver and the range between the transmitter and receiver. In order to implement an underwater fading channel, we assumed that channel response had only 7 delayed impulse signals which include direct, bottom, surface, bottom-surface, surface-bottom, bottom-surface-bottom and surface-bottom-surface paths. The channel impulse responses when the signal is received are shown as **Eq. (4)**. In this case, α_i denotes the magnitude of the ith multipath signal and τ_i denotes the delay time of the ith multipath signal.

$$h(t) = \sum_{i=0}^{N}\alpha_i\delta(t-\tau_i) \qquad (4)$$

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Table 1. Experimental conditions

Modulation	QPSK
Carrier Freq.	16kHz
Sampling rate	128kHz
Bit rate	200bps
Tx and Rx range	100m/400m
Tx depth	7m
Rx depth	10m/11m/12m
Data	64x64 image (32,768 bits)

Fig. 2 shows discrete time impulse response and its frequency spectrum for six cases. Noised images caused by frequency fading in underwater communication were used as experimental data. We learned one hundred noise images generated in various cases.

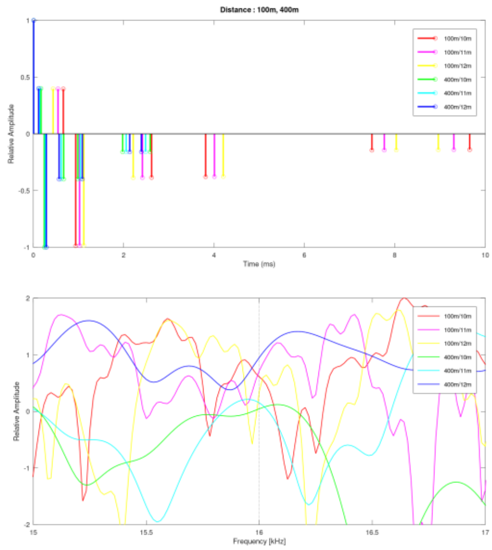
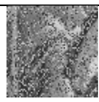
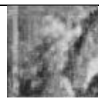


Fig. 2 Discrete time impulse response and its frequency spectrum for six cases

The conditions of DAE is as follows. To prevent overfitting, batch normalization is added to the encoder and decoder respectively. The encoder part goes through the convolution layer and the max pooling layer, and the decoder part goes through the convolution layer and the up sampling layer. The ReLu function was applied to the encoder and the sigmoid function was applied to the decoder, and the loss was minimized by training the model for 50 epochs. The value of the loss after 50 epochs converges to 0.0015. We improved the quality of the noised image with the DAE algorithm created through previous learning, and the expermimental results are shown in **Table 2**.

In order to objectively confirm whether the image quality is improved, the PSNR and SSIM index are used. When PSNR index is close to 50dB or SSIM index is close to 1, it is evaluated as quantitatively similar to the original image. Even visually, it can be seen that the noise caused by underwater fading channel has been removed. The average PSNR was 31.22dB which was improved by about 1.62dB when the DAE algorithm was applied. Also, SSIM was 0.6839 which was improved by about 0.2411

Table 2. Experimental results

Range/ Depth	Before	PSNR /SSIM	After	PSNR /SSIM
100m/10m		29.01/ 0.2771		30.65/ 0.5370
100m/11m		29.06/ 0.2757		30.69/ 0.5673
100m/12m		29.07/ 0.2885		30.97/ 0.5584
400m/10m		30.08/ 0.5909		31.70/ 0.8116
400m/11m		30.14/ 0.6048		31.94/ 0.8191
400m/12m		30.22/ 0.6199		31.37/ 0.8102

4. Conclusion

As a result of the experiment, we found that the proposed DAE algorithm helps to improve the quality of the noised images in underwater fading channel.

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