CS117

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# Edge detection algorithm based on threshold function de-noising and wavelet neural network


## ABSTRACT

In this paper, threshold function denoising algorithm and wavelet neural network edge detection algorithm are combined to apply to image edge detection. Firstly, an improved threshold function is constructed in this paper, compared with the traditional soft and hard threshold functions and some existing improved threshold functions, the improved threshold function is adjustable and differentiable everywhere. It approximates the soft threshold function and the image at the threshold point is smoother. It can retain more true information and have an obvious effect in image de-noising. Finally, this paper presents wavelet neural network edge detection algorithm. Selecting the modulation Gaussian function wavelet as its excitation function, which is applied to extract the edge of the image after threshold de-noising. Thus, a new edge detection algorithm is proposed, which combines threshold function de-noising algorithm and wavelet neural network edge detection algorithm. The simulation results show that the edges detected by the new algorithm are clearer, contain less noise, and the continuity and accuracy are also improved.


## THEORY

A class of improved threshold functions is constructed in this paper:

$$\hat{\omega}_{i,k}=\begin{cases}\omega_{i,k}-\mathrm{sign}(\omega_{i,k})\cdot T, & |\omega_{i,k}|>\beta T\\ \mathrm{sign}(\omega_{i,k})P(|\omega_{i,k}|)\cdot V(|\omega_{i,k}|), & \gamma T<|\omega_{i,k}|\le\beta T\\ 0, & |\omega_{i,k}|\le\gamma T\end{cases}$$

Where, $\gamma$ and $\beta$ are adjustment parameters and $\gamma+\beta=2,\ \gamma>0,\ \beta>0,\ \gamma<\beta,$ $\omega_{i,k}$ is wavelet coefficients and $\hat{\omega}_{i,k}$ is the processed wavelet coefficient after de-noising. $T$ is the threshold and the thresholds is $T=\sigma\sqrt{2\ln N}(i+1)^{-1}$, $i$ is the corresponding number of decomposition layers, $\sigma$ is the standard deviation of noise, $N$ is the total number of wavelet coefficients of the image.

In order to show the de-noising effect of the improved threshold function more intuitively, Gaussian noise with variance of 20 is added to Lena, House and Bottle respectively to carry out simulation experiments with Matlab.

(a)Lena

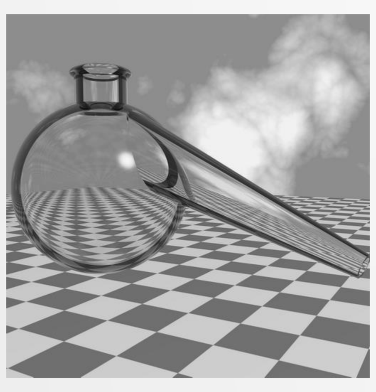
(b)Noisy image

(c) This paper method

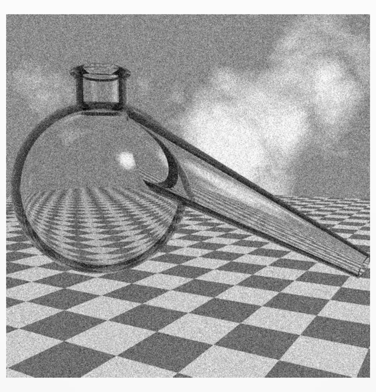
(a)House

(b)Noisy image

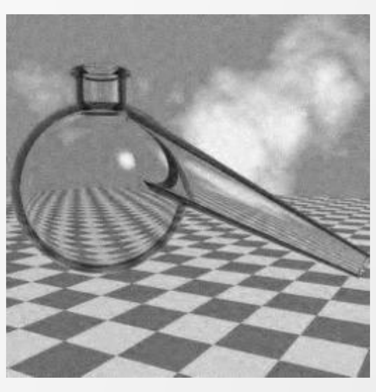
(c) This paper method



(a)Bottle



(b)Noisy image



(c) This paper method

## Fusion algorithm

The training process of edge detection algorithm of wavelet neural network is as follows

Step 1: The network is initialized and the sample inputs and target outputs of the training set are loaded, the number of input layer nodes is $M$, the number of hidden layer nodes is $n$, the number of output layer nodes is $N$ and the connection weight $\omega_{ij},\omega_{jk}$ between the neurons in the hidden layer and the output layer are determined according to the input and output data. Initialize the node, initialize the weight learning increment, given the learning rate and the number of iterations.

Step 2: Normalization of input date and output data.

Step 3: threshold $a$ and output layer threshold $b$, the output of hidden layer is calculated as

$$H_j=f\left(\left(\sum_{i=1}^{M}\omega_{ij}x_i-b_j\right)a_j^{-1}\right)\quad j=1,2,\cdots,n.$$

Where $n$ is the number of nodes in the hidden layer, $f$ is the excitation function of the hidden layer, and the excitation function is selected as the modulation Gaussian function wavelet $\psi(t)=\pi^{-\frac{1}{4}}(e^{-i\omega_0 t}-e^{-\frac{\omega_0^2}{2}})e^{-\frac{t^2}{2}},\quad \omega_0\ge 0$

Step 4: The calculation formula of the output layer of the wavelet neural network is $y(k)=\sum_{j=1}^{n}\omega_{jk}h_j\quad k=1,2,\cdots,N$, where $h_j$ is the output of the node of the hidden layer $j$.

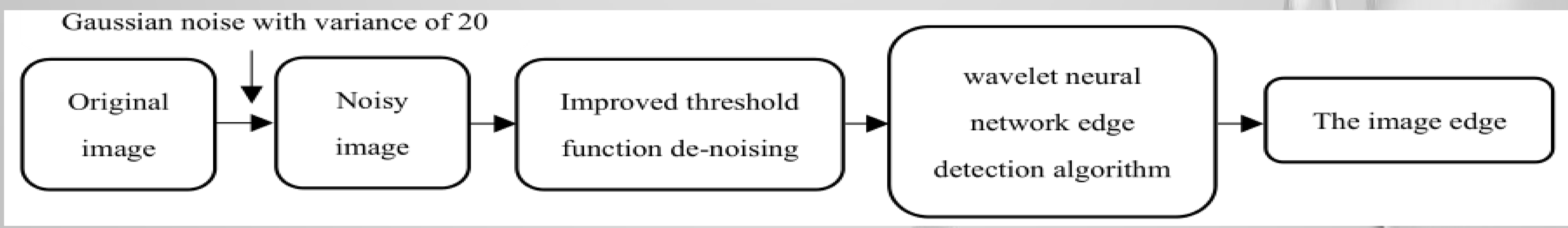
Step 5: Calculate network error is $E=\sum_{k=1}^{m}[y_n(k)-y(k)]$, where $y_n(k)$ is the expected output, $y(k)$ is the actual output of the wavelet neural network.

Step 6: The network error is calculated $\Delta\omega_{n,k}^{(i+1)}=-\eta\frac{\partial e}{\partial\omega_{n,k}^{(i)}},\quad \Delta a_k^{(i+1)}=-\eta\frac{\partial e}{\partial a_k^{(i)}},\quad \Delta b_k^{(i+1)}=-\eta\frac{\partial e}{\partial b_k^{(i)}}$, where $\eta$ is the learning rate.

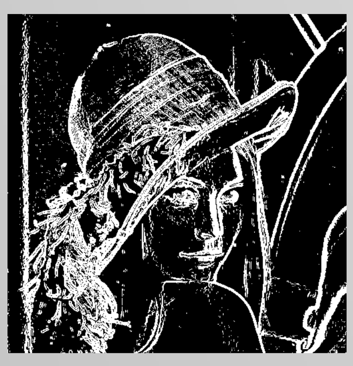
Step 7: The weight of the wavelet neural network and the coefficients of the wavelet basis function are corrected according to the calculated network error $E$

$$\omega_{n,k}^{(i+1)}=\omega_{n,k}^{i}+\Delta\omega_{n,k}^{(i+1)},\quad a_k^{(i+1)}=a_k^{i}+\Delta a_k^{(i+1)},\quad b_k^{(i+1)}=b_k^{i}+\Delta b_k^{(i+1)}$$

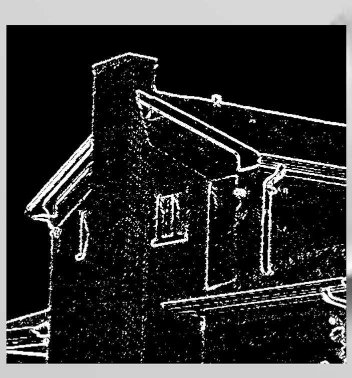
The specific flow chart of the image edge detection algorithm combining the improved threshold de-noising algorithm with wavelet neural network edge detection algorithm is as follows.



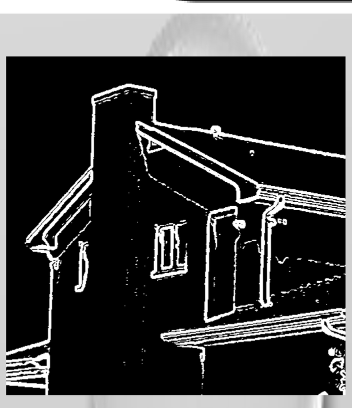

Wavelet neural network



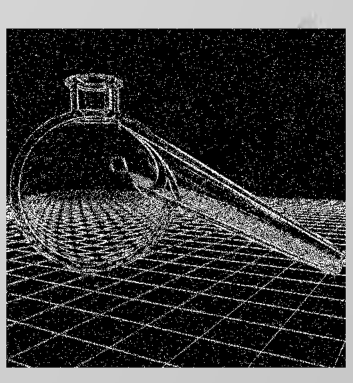
The fusion algorithm



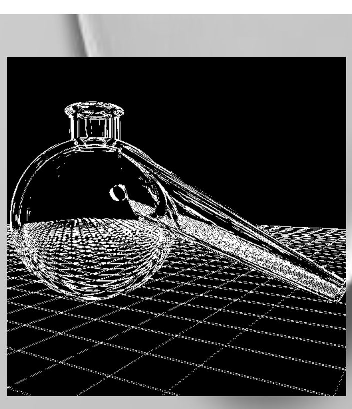
Wavelet neural network



The fusion algorithm



Wavelet neural network



The fusion algorithm

## Conclusion

This paper summarizes the advantages and disadvantages of the traditional threshold function, and proposes an improved threshold function denoising method. The improved threshold function is adjustable and differentiable everywhere and approximates the soft threshold function and the image at the threshold point is smoother. Then, the edge detection algorithm of wavelet neural network is used to extract the edge of the image denoised by threshold function, and the modulation Gaussian wavelet is taken as the excitation function of wavelet neural network. The new edge detection algorithm which combines the advantages of the two methods in image processing is obtained.