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Image Fusion Algorithm Based on Simplified PCNN in Nonsubsampled Contourlet Transform Domain

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Abstract

Pulse Coupled Neural Networks(PCNN) have characteristics in accord with human vision properties, Nonsubsampled Contourlet Transform (NSCT) can overcome the lacking of Shift-invariance in Contourlet Transform. So NSCT was used associated with PCNN in image fusion algorithms to make full use of their characteristics. Original images were decomposed to get the coefficients of low frequency subbands and high frequency subbands. The coefficients of low and high frequency subbands were processed by a modified PCNN. Matching degree of original images and spatial frequency were defined and used respectively in fusion rules. Fusion image was obtained by NSCT inverse transformation. Experimental result shows this method is better than Wavelet, Contourlet and traditional PCNN methods; it has bigger mutual information, so the fusion image include more information about original images.

Keywords: Nonsubsampled contourlet transform (NSCT); Pulse coupled neural networks (PCNN); Image fusion; Multiscale

1. Introduction

Image Fusion Technology, as an important part of the multi-sensor information fusion, is a very popular research area in recent years.The objective of image fusion is to combine information from multiple images of the same scene to acquire more exact and comprehensive description of the image. With the development of image sensor technology, image fusion of multi-sensor is applied widely on many fields, such as computer vision, remote sensing, intelligent robot, medical image analysis and so on.

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There are many kinds of image fusion methods , one kind of frequently-used method is based on Wavelet transform[1][2]. Wavelet transform decompose the original image into a series of sub-image with different spatial resolution and frequency domain characteristics.

Wavelet transform has good properties of time domain and frequency domain and multi-resolution. Image's low frequency information and three direction high frequency information (horizontal, vertical and diagonal) can be obtained easily. Its fusion effect is better. But wavelet transform suit isotropic objection, for those anisotropic objection, such as borderline and lineal objection in image, it is not a very good tool.

To overcome the shortcomings of the wavelet transform, M.N.Do and M. Vetteri put forward Contourlet Transform [3][4]. But Contourle Transform need downsample and upsampling, so Contourlet lack Shift-invariance property. Shift-invariance is very important in image enhance, smooth and fusion. There will be obvious Gibbs phenomenon in image fusion if no Shift-invariance. Based on Contourlet transform, Nonsubsampled Contourlet Transform (NSCT) with Shift-invariance property was given by A.L.Cunha [5][6].

Pulse Coupled Neural Networks is a new neural network given by Eckhorn R. Distinguished from traditional artificial neural nets[7][8]. It can be used in image fusion effectively for its global coupling and pulse synchronism[9].

2. Nonsubsampled contourlet transform

Contourlet transform which is proposed by Do M N has property of anisotropic and directionality. Contourlet transform is composed of Laplacian Pyramid decomposition and directional filter bank (DFB). The Pyramid decomposes the original image into low frequency subband and high frequency subband, high frequency subband is decomposed into several directions by DFB. Low frequency subband is processed like this repeatedly, so multi-resolution and multi-direction decomposition is completed.It allows different direction numbers in different scale, high frequency information can be divided into several directions. Then contourlet transform can approach arbitrary 2 dimension piecewise smooth function approximately.

Unfortunately, down-samplers and up-samplers are used in both LP and DFB in Contourlet transform. Thus,it is shift-invariant and cause Gibbs phenomena around singularities. In order to overcome the Gibbs phenomenon caused by lacking Shift-invarianc, downsample and upsampling are abandoned in Nonsubsampled Contourlet Transform. Nonsubsampled Pyramid filter bank is used first to complete multiscale decomposition, then Nonsubsampled directional filter bank is used to complete multi-direction decomposition.Input image make a convolution with a 2 dimension filter mask to obtain the low frequency approximate image, the differentials of original image and low frequency image is high frequency details. Then details are processed by Nonsubsampled directional filter bank to get the directional details.

3. 3. Simplified PCNN neuromime

Pulse-Coupled neural network is a feedback network composed by a certain number of neuron， every neuron consists of three parts: The branching trees, link field and pulses generator, I_j and J_i are inputs of the neuron, Y_j is output of the neuron, U_j is the interior modulation result. There are two parts in Branch trees, eg. Feed input F_j and link input L_j. M_{kj} and W_{kj} are the synapsis gain coefficient of Branch trees and link field between neuron j and neuron k， α_{kj}^F and α_{kj}^L are time attenuation constant， β_j is joint strength， V_j^T and α_j^T are amplification factor and time constant of threshold integrator respectively， θ_j is dynamical threshold.

Because there are many parameters needed to be configure in PCNN model,it is difficult in-service use.many modified PCNN mode are put forward.One simplified PCNN model is shown in figure 1. its mathematical model is given in formula (1) and (2).

$$\begin{cases} F_{ij}[n] = I_{ij} \\ L_{ij}[n] = \sum_{kl} w_{ijkl} Y[n-1] \\ U_{ij}[n] = F_{ij}[n](1+\beta L_{ij}[n]) \end{cases} \quad (1)$$

$$\begin{cases} Y_{ij}[n] = \begin{matrix} 1, & U_{ij}[n] > E[n-1] \\ 0, & U_{ij}[n] \le E[n-1] \end{matrix} \\ E_{ij}[n] = \exp(-\alpha_E) E_{ij}[n-1] + V_E Y_{ij}[n] \end{cases} \quad (2)$$

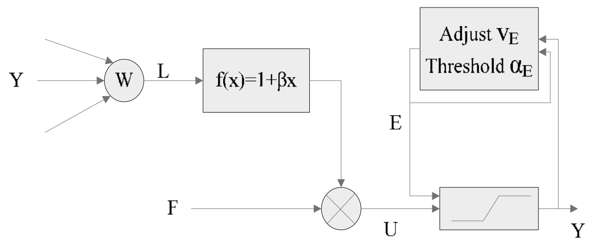


Fig. 1. Simplified Neuron model of PCNN

4. Image fusion algorithms combined NSCT and simplified PCNN

Procedures of Image fusion algorithms combined NSCT and PCNN are following:

Step1. Calculate the NSCT jth layer coefficients $C_{A,j}(x,y)$, $C_{B,j}(x,y)$ of the original image A and B respectively.

Step2. Normalizing $C_{A,j}(x,y)$,$C_{B,j}(x,y)$, and input them to channel F to stimulate PCNN net.

Step3. Initializing $L_j(x,y,0)=U_j(x,y,0)=0$, $E_j(x,y,0)=1$, in initial time, pixels are not fired ,so $Y_j(x,y,0)=0$, generated pulse number $T_j(x,y,0)=0$.

Step4. Calculating $L_j(x,y,n)$,$U_j(x,y,n)$,$E_j(x,y,n)$, $Y_j(x,y,n)$ according formula (2) and (3).

Step5. Counting the pulse number $T_j(x,y,n)= T_j(x,y,n-1)+ Y_j(x,y,n)$.

Step6. Calculating fused coefficients according to some fusion rules.

Step7. Using $C_{F,j}(x,y)$ as NSCT coefficients make reconstitution to get the fused image.

In order to get better fusion effect, different fusion rules are used in low frequency and high frequency domain.

4.1 Low frequency coefficients fusion rules

A parameter called match degree was proposed for image fusion. The matching degree of image A and image B is defined as following:

$$M_j(x,y) = \frac{2T_{A,j}(x,y,N_{\max})T_{B,j}(x,y,N_{\max})}{T_{A,j}(x,y,N_{\max})^2 + T_{B,j}(x,y,N_{\max})^2} \quad (3)$$

Here, $T_{A,j}(x,y,n)$ and $T_{B,j}(x,y,n)$ are fire times of image A and B in jth layer decomposition after N_{max} times iteration.

Chosen a threshold T_{th} in the fusion rules, T_{th} can be calculated as: $T_{th} = \sqrt{2}\sigma_n^2 / \sigma_x$

Here,

$$\sigma_n = \frac{median(|M_j(x,y)|}{0.6745} \quad , \ \sigma_x^2 = \text{var}(M_j) - \sigma_n^2$$

Coefficients of low frequency subband after NSCT may be fused according following rules:

a.if $M_j(x,y) \leq T_{th}$ and $T_{A,j}(x,y,N_{max}) \geq T_{B,j}(x,y,N_{max})$, let $C_{F,j}(x,y)=C_{A,j}(x,y)$.

b.if $M_j(x,y) \leq T_{th}$ and $T_{A,j}(x,y,N_{max}) < T_{B,j}(x,y,N_{max})$, let $C_{F,j}(x,y)=C_{B,j}(x,y)$.

c.if $M_j(x,y)>T_{th}$, let $C_{F,j}(x,y)=\alpha C_{A,j}(x,y)+ \beta C_{B,j}(x,y)$. Here,

$$\alpha=\frac{T_{A,j}(x,y,N_{max})}{T_{A,j}(x,y,N_{max})+T_{B,j}(x,y,N_{max})} \ , \ \beta=\frac{T_{B,j}(x,y,N_{max})}{T_{A,j}(x,y,N_{max})+T_{B,j}(x,y,N_{max})}$$

4.2 High frequency coefficients fusion rules

Instead of using PCNN in NSCT domain directly,spatial frequency(SF) in NSCT domain is used to overcome Gibbs phenomena,SF is defined in formula(4),here, $C_{k,j}(x,y)$ denote the coefficients located at (x,y) in the j-th subbands at the k-th decomposition level.

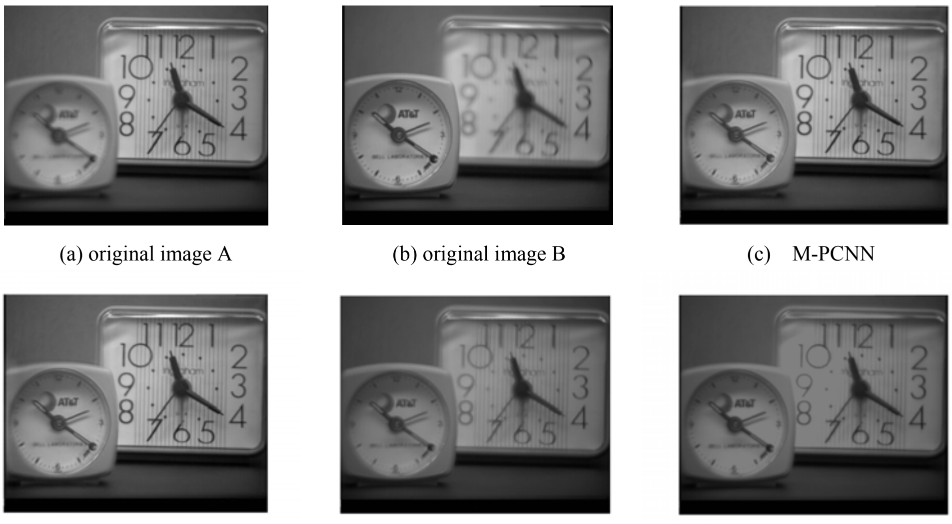
$$SF=\sum[(C_{k,j}(x,y)-C_{k,j}(x-1,y))^2+(C_{k,j}(x,y)-C_{k,j}(x,y-1))^2] \qquad (4)$$

SF indicate the image definition and activeness,clear image has big SF value. so it can be used as link strength β of PCNN neuron. after counting the pulse number $T_j(x,y,N_{max})$,high frequency coefficients can be fused as follow rules:

$$C_{F,j}(x,y)=\begin{cases} C_{F,j}{}^A(x,y), & if\, T_{A,j}(x,y,N_{max}) \geq T_{B,j}(x,y,N_{max}) \\ C_{F,j}{}^B(x,y), & if\, T_{A,j}(x,y,N_{max}) < T_{B,j}(x,y,N_{max}) \end{cases}$$

4.3 Experimental simulation

Two images are selected to make fusion, result shows in figure 2. In order to evaluate image fusion algorithms capability correctly, evaluation targets such as standard deviation, entropy and mutual information are used besides vision effect evalution. Comparing result shows in table 1.



(a) original image A (b) original image B (c) M-PCNN

(d) PCNN (e) maximum (f)average

Fig.2. Original image (a, b) and fused image (c,d,e,f)

From table 1 we can know, average method has big standard deviation, detail information is misssing seriously. Maximum region value method is better than average method, but losing a little texture and detail information. Traditional PCNN has good performance.but modified PCNN has bigger mutual information, so it include more original image information.

Table 1. Comparing between several fusion algorithms

algorithm	standard deviation	entropy	mutual information
average	90.80	5.04	20.12
maximum in region	89.58	5.35	19.81
PCNN	85.39	5.69	20.05
Modified PCNN	85.61	5.72	20.13

5. Conclusions

Using spatial frequency in NSCT domain to motivate PCNN rather than only using coefficients value in traditional PCNN can reserve image edge and texture well in image fusion algorithm. As well as include more original image information. It is a kind of high-efficiency fusion algorithm fitting with human vision properties.

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