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Performance Evaluation of Image Fusion Using Fractional Transforms

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ABSTRACT: In this paper the fractional transform based image fusion methods are studied. The fractional fourier transform is well known fractional transform. Fractional wavelet transform has multi-resolution and fractional domain analysis characteristics. It simultaneously has the good localization characteristic in the time domain and the frequency domain. For fusion of two images , they are decomposed first by fractional transforms and then , then fusion rules are applied to gain the fusion coefficients, finally obtains the fusion image after taking inverse fractional transform. The simulation results show that the performance evaluation of the fused image based on fractional wavelet transform is better than that based on conventional wavelet transform and fractional Fourier transform under same condition.

KEYWORDS: Fractional Fourier Transform, Fractional Wavelet transform

I.INTRODUCTION

As an important research field of information image fusion has attracted many domestic and foreign scholars to conduct the problem more in-depth. They have proposed many effective image fusion methods [1][2][8][9][10][11].
As a powerful tool for information fusion, image fusion has been widely used in military, remote sensing, robot vision, medical image processing and other areas. Recently along with some signal analysis mathematical methods and fusion ideas unceasing appearance, the image fusion realization methods is continually renewing and developing.
The wavelet transform (WT) is a successful tool for dealing with transient signals, data compression, bandwidth reduction, and time-dependent frequency analysis of short transient signals [2 ,3]. The wavelet transform also holds the important status in the signal processing. It has good time frequency localization performance because of its different resolution in the time-frequency plane different position. The wavelet transform is suitable for processing the non-steady signals and analyzing signals in frequency domain and time domain. If the signal is energy non-best accumulation in the frequency domain, wavelet transform analysis is not optimal.
The fractional Fourier transform (FRFT) is a new transformation that has been proven to have various important properties in the optical data processing field. It is a revolving operation of the signal Wigner distribution, also names revolves the Fourier transformation or the angle Fourier transformation. Its essence is a kind of unified time frequency transformation [12]. It can simultaneously reflect the signal information in the time domain and the frequency domain. The fractional Fourier transform developed the signal analysis into time-frequency fractional domain. It retains Fourier transform all characteristics, and also has some natures which the traditional Fourier transform does not have. herefore fractional Fourier transform has enormous improvement potential.
The fractional wavelet transform (FRWT) is a new time frequency analysis method. It combines the fractional Fourier transform and the wavelets transform merits, so it has multi-resolution and fractional domain analysis characteristics [7]. It becomes a research hot spot in signal analysis and process. Lately FRWT mainly is used in digital watermark and image encryption and has acquired a series of research results.In this paper we discuss the performance evaluation of image fusion algorithms using two fractional transforms:Fractional Fourier Transform (FRFT) and Fractional Wavelet Transform.

II. FRACTIONAL TRANSFORMS

(a) Fractional Fourier Transform: The FRFT can be explained that the representation of the Fractional Fourier domain is formed after the signal does counter-clockwise rotation any angle around origin in the time-frequency plane axes and this is a generalized form of Fourier transform.

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FRFT of the signal x(t) is defined as:

$$X_\alpha(u) = \{F^\alpha[x(t)]\}(u) = \int_{-\infty}^{\infty} x(t) K_\alpha(t,u)\,dt \tag{1}$$

where, FRFT transform kernel K_α (t,u).

$$K_\alpha(t,u) = \begin{cases} \sqrt{\dfrac{1 - j\cot\alpha}{2\pi}} \exp\left(j\dfrac{t^2+u^2}{2}\cot\alpha - tu\csc\alpha \right), & \alpha \neq n\pi \\ \delta(t-u), & \alpha = 2n\pi \\ \delta(t+u), & \alpha = (2n\pm1)\pi \end{cases} \tag{2}$$

The equation α = pπ/2 is the FRFT angle of rotation. For two-dimensional signal x(s,t), the two-dimensional FRFT can be expressed as:

$$X_{p1,p2}(u,v) = F_{p2}^{t\to v}\{F_{p1}^{s\to u}[x(s,t)]\} \tag{3}$$

By the discrete, FRFT can also be calculated by using digital methods. The most commonly used algorithm is the decomposition fast algorithm which is proposed by Ozaktas [6]. The signals can be decomposed into FRFT convolution by the algorithm, the calculated results are compare similar with the continuous FRFT output. Decomposition type FRFT transformation matrix as follows:

$$F_p = DK_pJ \tag{4}$$

where, D and J are, respectively the twice inside difference between the matrix and the matrix of the extraction operation, K_α is a discrete FRFT nuclear transforming matrix, namely:

$$K_p = \frac{A_\alpha}{2\Delta x}\exp\left(\frac{j\pi(\cot\alpha)m^2}{(2\Delta x)^2} - \frac{j2\pi(\csc\alpha)mn}{(2\Delta x)^2} + \frac{j2\pi(\cot\alpha)n^2}{(2\Delta x)^2} \right) |m|,|n| \le N \tag{5}$$

If p=1,FRFT is the conventional Fourier Transform. The p-order inverse fractional Fourier Transform(IFRFT) is the FRFT with –p order. FRFT is a kind of global transformation,so it is unable to give the signal local characteristics which are very important in the non-steady signal processing. The most important properties of FRFT are:

i) Unitarity: $(F^p)^{-1} = (F^{-p}) = (F^{-p})^\dagger$ where $(.)^\dagger$ denotes Hermition conjugation.

ii) Index additivity: $F^{p1}F^{p2} = F^{p2}F^{p1} = F^{p1+p2}$

iii) Reduction to the ordinary Fourier Transform when p=1.

(b) Fractional Wavelet Transform: There are several Fractional Wavelet Transform realisation methods. Mendlovic and Zalevsky to adapt the localisation existing in the FRFT to the localisation existing in the Wavelet components, Mendlovic and Zalevsky suggest the definition of the FRWT: performing a FRFT with the optimal fractional order p over the entire input signal and then performing the conventional wavelet decomposition

The fractional wavelet transform (FRWT) is a unified time-frequency transform essentially and can reflect the signal information in the time domain and frequency domain simultaneously. FRWT uses the single variable express time-frequency information and does not have the cross term, so it suits processing non-steady signal. Furthermore, the additional variable p improves FRWT flexibility. FRWT has some natures which the traditional time and frequency transform does not have [10-12].

III. FRACTIONAL TRANSFORM IMAGE FUSION

(a)FRACTIONAL FOURIER TRANSFORM IMAGE FUSION:First we perform fractional Fourier transformation on two source image A and B to obtain the fractional field transformation result; obtain the fusion coefficient according to the maximum value fusion rules; finally obtain the fusion image through fractional Fourier inverse transform (IFRFT).

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The flowchart of the FRFT is illustrated in Fig.1. **Fusion Rule:** Average value rule is adopted for fusing two images A and B using Fractional Fourier Transform**.**

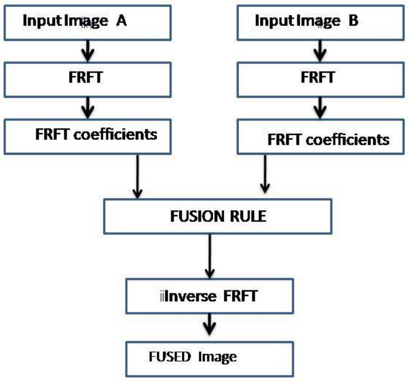

Fig 1:Flow Chart of Image Fusion using FRFT

(b) FRACTIONAL WAVELET TRANSFORM IMAGE FUSION: First perform fractional Fourier transformation on two source image A and B to obtain the fractional field transformation result; then take wavelet transform (WT) to decompose to different frequency band and the direction; obtain the fusion coefficient according to fusion rule value largest fusion rules; finally obtain the fusion image through wavelet inverse transform (IWT) and fractional Fourier inverse transform (IFRFT). The flowchart of the FRFT is illustrated in Fig.2.

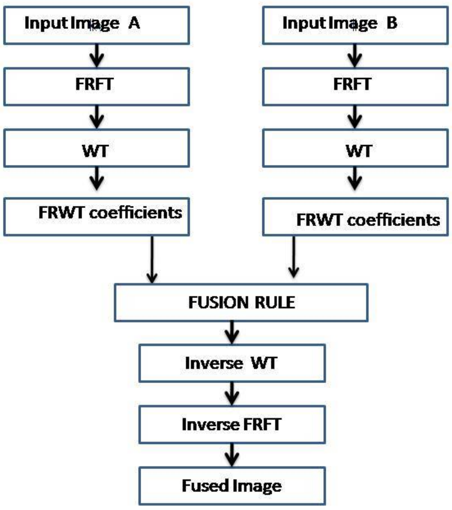

Fig 2:Flow Chart of Image Fusion using FRFT

Fusion Rule: The low frequency coefficients follow the average value and the high-frequency coefficients follow the largest absolute value rule for image fusion using Fractional Wavelet Transform(FRWT).

(c)Objective Performance Evaluation. Human visual perceptioncan help judge the effects of fusion results. However,

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it is easily influenced by visual psychological factors. The effect of image fusion should be based on subjective vision and objective quantitative evaluation criteria. Some objective evaluation merits, such as entropy, average gradient, and standard deviation, and so forth, are employed to describe the information contained in the fused images [26, 27]. (1) Information entropy (IE): the IE of the image is an important index to measure the abound degree of the image information. Based on the principle of Shannon information theory, the IE of the image is defined as

$$E = -\sum_{i=1}^{m} P_i \log_2 P_i$$

where pi is the ratio of the number of pixels with gray value equal to i over the total number of the pixels. IE reflects the capacity of the information carried by images. The larger the IE is, the more information the image carries.

(2) Average gradient (AG): AG is the index to reflect the expression ability of the little detail contrast and texture variation, and the definition of the image.

IV.EXPERIMENTS & RESULT

Experimental Source Images. Multifocus images,Figures 3(a) and 3(b) are a pair of test images with different focuses, the right focusing image and the left focusing image of a lock. The images are 256 by 256 image in .tif format.
For Fractional Fourier Transform the order of fractional transformation p1=.95 and p2=.95.As for Fractional Wavelet Transform(FRWT)we have used 'haar'wavelet and the level of decomposition is 1. In case of FRWT the order of fractional transformation p1=.95 and p2=.95.

(a) Original Image A

(b) Original Image B

Fused Image

(c) Image fusion Using WT

Fig 3: Image fusion using Wavelet Transform

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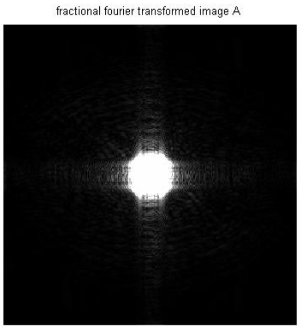
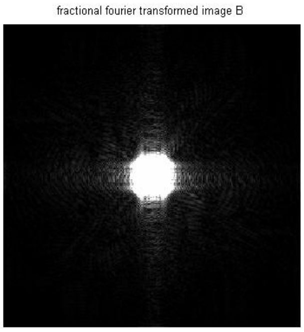
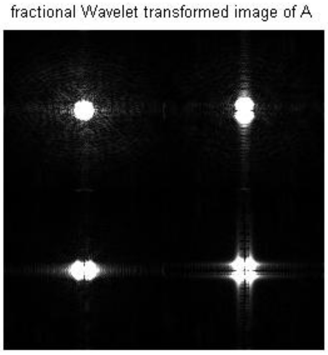


(a) FRFT of Image A

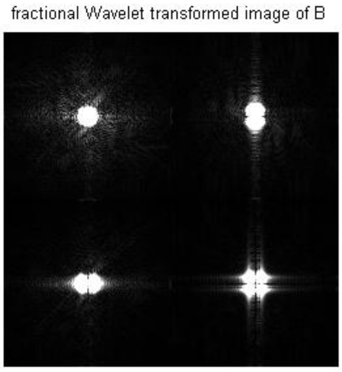


(b) FRFT of Image B

(c) FUSED Image Using FRFT



(d) FRWT of Image A



(e) FRWT of Image B

(f) Fused Image using FRWT

Fig 4: Image Fusion Using Fractional Fourier Transform (a)(b)(c) and Fractional Wavelet Transform(d)(e)(f)

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TABLE I: PERFORMANCE OF DIFFERENT FUSION METHODS

Fusion Method	Entropy	Average Gradient
Wavelet Transform(WT)	6.421	3.447
Fractional Fourier Transform(FRFT)	6.542	3.678
FractionalWavelet Transform(FRWT)	6.563	3.863

V. CONCLUSION

The fractional fourier transform (FRFT) is a unified time-frequency transform. It has many good properties.Fractional wavelet transform (FRWT) is also another time-frquency transform and has properties such as multi-resolution and fractional domain analysis characteristics. So FRFT and FRWT can present images better . FRWT is more suitable multi-scale analysis tool of the image in many cases such as image fusion. This paper analyses the performance evaluation of this two fractional transform with a comparison to standard wavelet transform for fusion of two multi-focus images. The experimental results demonstrate that the fusion algorithm using fractional transforms are of great validity and of feasibility.

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