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An optimized reconstruction algorithm for point spread

Function Based on Slant Step Edge

Qu mengya , Zhang yongsheng, Li runsheng
Zhengzhou Institute, Zhengzhou 450052

Abstract: The existing slant step edge methods, greatly influenced by the edge? s sub-pixel positioning precision, the Edge spread Function (ESF) Samples5 quality and fitting models of the ES F curve, do not perform-stability and accuracy. An optimized reconstruction algorithm for Point spread Function (PSF) with better precision is proposed using the Slant St EP Edge. The gradient operator is introduced in Edge line fitting to refine the edge points ' sub-pixel positions for greater Accura Cy. The improved method adopts new techniques of moving window in the ESF de-ioising and resampling method to improve ESF Le ' s quality. Finally, robust PSF reconstruction results are obtained by Gaussian function fitting. Experiments demonstrate that the new algorithm shows the very very performance gain in the precision of step edge line fitting and Also the superiority in accuracy and stability of the PSF reconstruction.

Keywords: point spread function; edge spread function; Slant Step Edge Metho D; Gradient operator; Sub-pixel Fitting

Point diffusion function PSF (point spread Function) as measures important indicators for imaging quality of optical systems in remote sensing platforms , the is ahotspot of recent years . PSF describes point Light pulse light Fuzzy phenomena after the completion of the imaging System , Its Rebuild method for remote sensing The image quality assessment and image restoration are of great significance , main the optical systems for flow are based on the PSF for imaging performance evaluation . legeretc 00 tested the SPOT- 5 HRG and HRS on the rails " like situation , Pass PSF to obtain the absolute and relative MTF of the sensor (Modulation Transfer Function)quantization camera from Gio Cheng degree , and the HRS 1 and HRS 2 The imaging performance of IS compared . Liu Zhengjun etc 0 on Extraction PSF After using the deconvolution principle , through the Wiener Filter to CBERS-1 degenerate blur image to duplicate original , effect good .

commonly used PSF Estimation method has Edge method , Point Light method , Rectangle pulses H etc . where , due to step target on actual remote sense image easier ,Edge Method universally applied to PSF estimate count . Traditional Edge method H S 4 Edge dip limit , only applies to Edge angle and sampling direction approximate parallel or vertical ideal blade edge . When there is a certain dip in the edge of the blade, sampling direction and Edge ladder inconsistencies in the degree direction cause the sample horizontal axis to be stretched [6 , , strict Heavy impact PSF estimate precision . for this issue , main two workaround : First

is to traditional edge method PSFvaluation for correction and then get real PSF and ; ; Two is skew based on

geometric projections Edge Method PSF High precision estimate 810 . where , correction is inferred under discrete model , presence sub-pixel point error and not common ; Tilt Edge method to project the sample point to the edge gradient side to get an accurate edge-diffusion function up ESF (Edge spread Function) sample then , rebuild with PSF valuation . slanted Edge side method Less dip limit than traditional method , is currently widely used on PSF estimate method . But its estimated precision is still in the process of rebuilding with edge line fitting Precision , ESF resample quality and line diffusion function LSF line spread Function) effect of fitting precision . Choi and so on to indicate that the edge points are estimated to be in line with the true edge The deviation of the is the underlying factor that affects the PSF estimate Precision . fan flush etc 0 point to, when ESF sampling direction and edge gradient direction not consistent , Pull error away from center row sample coordinates there is a pass increasing trend , fitting precision of edge line severely disturbed . saunier etc Mdiscovery ,ESF non-uniform Distribution of the sample points and Nonlinear noise to low , interference with high brightness areas makes the ESF To The combination method and denoising smoothing are critical .

for Tilt Edge method PSF errors in estimates are error-prone reason , Detailed analysis PSF differences in different stages of A Rebuild method , improvements to existing algorithms , Optimized Edge Edge straight line fitting ,ESF resampling and LSF Fitting procedure . finally using simulation image and actual UAV remote sensing image pair improved algorithm Edge Line fitting precision and PSF rebuild Precision evaluated with analysis .

1. Edge Method PSF Estimation principle

During Remote sensing image imaging , sensor performance drops , Large factors such as to cause image quality degradation . set e(x y) to target image ,o (xy)degraded image for system response , degenerate model can be described as [4

o (xy),) = e (x,, y* H) * (x, y) + n ( ) X,y) . (1)

where : H (x,) is PSF ; N (x,) is additive noise ; * represents A convolution operations .

Edge Method Using step response calculation PSF . assumes edge border brightness mutation in edge gradient direction of the field use a step function e(x) the represents . its system output o(x) for imaging system to step Signal Response , : ESF. LSF to PSF on a specific party up points . The relationship of the three can be represented as

X x-w

ESF (x) = I LSF(x) DX = I I H (xyy) dydx .

(2)

based on the type (1) and Style (2), output to the step response system line differential available

D (o(x)) d(e(x)),

= * H (x)=

DX DX

8 (x) * H (x) = h (x.). (3)

where x) is a pulse function . because of the compatibility of PSF and symmetric M ,H (x,y) can be expressed as a product , : h (x , y) = h ( ) X) h (y). theoretically The one-dimensional of the rails and vertical rail direction PSF The same , passes the ESF To merge the Micro To get LSF rebuild PSF . diagram 1 Show Edge method principle flowchart for estimate PSF .

The error generated by each link will be produced on the next link Live effects , final on PSF rebuild Results :1 edge edges the Precision of the line fit determines the ESF Quality of initial samples , edge The position deviation of the line will cause ESF sample error ; 2) because LSF Yes ESF derivative , Minor deviations from ESF easily cause a variant of the LSF , so ESF The accuracy of fitting and resampling is directly determined by the the LSF Sample quality ;3 LSF fitting Two-dimensional reconstruction can

getPSF, so LSF Sampling and fitting precision directly affect PSF Rebuild Effects . for these key points , on Tilt blade the 3 key link for the side method is optimized, finally applies Gaussian functions based on stability Health estimates LSF To obtain the PSF .

Edge Line fitting

Edge line fitting containing edge subpixel positioning The and the least squares line fit two procedures . Existing methods often take the third -order polynomial fitting inflection point , and place its second order zero position as edge subpixel position S 5' However, this method is not robust in strong noise Environment , subpixel positioning of edge points is severely interference . thus introducing gradient operators in Edge detection , using gradient amplitude sub-pixel repair on edge gradient direction of edges in edge gradients positive , to obtain high-precision sub-pixel edge position . Its steps are as follows .

1) using the best edge detection operator one Canny Count child ^ adaptive method to determine each The pixel-level position of the edge point on the sample line .

2) to the gradient direction at each pixel-level edge point for

gradient Amplitude G (x,) .

3) gradient component in gradient direction Gx and Gy as the right value , subpixel correction to edge edges :

X G Xi d Xi

: two 1 -------

x N

Ix

i = 1

IX G y, d y,

Ad y = Soil

I=1

type : ^ and is the pixel and pixel-level edges in the gradient direction for a distance component ;gxi and Gh is a gradient component ; N is the gradient side up pixel count .

After obtaining the sub-pixel position of a high precision edge of the edges , Mining fitting the edge line with the least squares straight line and making a ESF Sample . diagram 3 gives the least squares fitting of edge edges of edge to results . after getting the edge of the edges to fit a straight line , sampling points Project The edge of a line to the edge gradient direction Get initial ESF sample , procedure like 4 is shown in .

2.1 is based on the of the mobile window ESF Sample denoising and resampling Edge margin positioning error , Drop sampling confusion now like , Effects of sampling phase and noise H , ESF Initial sample to To Existing gross error , in local area irregular , for get fixed mining sample interval high precision ESF samples to ESF Initial samples de- noising and resampling . ESF resampling methods are not parameterized parties method and Parameterized methods ? . where , Non-parameterized method with EC The way is used to consolidate point-bit information , Avoid introducing the fitting method itself
intrinsic fitting error , Better adaptability , But it ignores the sample point itself function Properties , cause extraction of ESF Asian exists in the curve pixel level error . commonly used parameterization methods have three spline interpolation law 114 , High-time polynomial fitting M and Fermi function to fit M. where , three cubic spline interpolation ESF fitting precision is more than low ; High-time polynomial fitting because there are no fixed shapes ESF sample quality depends larger , vulnerable to noise117 ; Fermi functions have a fixed function form , can be in _ To a degree Suppress noise effect , But because of its own model and ESF curve a certain difference , Fitting precision is also not ideal . improvements based on parameterized methods , takes a ESF Sample Denoising and resampling method based on mobile window , Its implementation is schematic diagram 5 shows .

The basic idea of this method is to ESF sample to segment to close , move get ESF resampling values , and sample before resampling the makes noise removal to remove gross errors . Move window size 1 like element , move step to 0.05 pixel . Its specific steps are as follows :

1) three-times polynomial ESF sample point in window (in Windows)? fitting .

2) Select 1.5 times fit residuals standard deviation as threshold pair of This gross error is excluded .

3) The eliminates gross errors and then reseat the remaining samples .

4) to fit a value at the center of the window as a resampling value .

5) to 0.05 pixels to step move window , Repeat steps

1) ~ step 4 until resampling complete .

2.2 LSF Sampling and fitting

Is provided by the type (2) Know , for discrete samples , LSF can be passed through the ESF Sample Direct difference get :

ESFi - ESFi 1

LSFI = -', a ^ (5) Ax

When you get the LSF after the sample , first to LSF to tail truncate fetch to weaken LSF tail jitter effect . LSF shape near Gaussian type , but not exactly Gaussian expression , To reduce less PSF estimated Error , on the resulting LSF curve for one-dimensional gauss function fitting , Use the fitted data to form a PSF discrete

Matrix . The fitting model for can be represented as

H (x)) = aexp [- (x - u) 2/2a 2]. (6)

can be based on the least squares principle , takes the Levenberg - Mar - Quardt optimization method for model (6) to solve the .

after analysis , Improved algorithm steps such as .

1) use gradient operator to edge subpixel positioning , and a line fitting of the obtained subpixel edge points to the .

2) ESF sampling , with mobile window based ESF de- noising and resampling methods get high precision ESF sample .

3) to ESF sample differential get LSF sample , and end The section intercepts .

4) to LSF samples based on robust estimate Gaussian letter number fit to get one-dimensional PSF, and use PSF symmetric heavy building two-dimensional PSF.

3. Precision Assessment and analysis

to verify the optimization effect of the improved algorithm and its different conditions applicability under , the edge line fitting precision of the algorithm respectively and PSF rebuild precision evaluated with analysis , and with existing methods The is compared to .

3.1 To Edge Line fitting Precision Analysis

to evaluate the edge line fitting accuracy of the improved algorithm , Mining simulate the degradation of different tilt and noise conditions with a computer simulationEdge Image , with improved algorithm and three times polynomial fitting Method The edge edges of the simulated degenerate edges are fitted with a , to get the proceedsresults compared to design truth values . where , simulate degenerate edge generation The procedure is as follows :

1) using computer simulations to generate a non-degraded edge image and add white noise to it ;

2) construct with Gaussian function PSF ;

3) Take advantage of PSF on edges with noise and no noise The looks like a degraded edge image that was simulated with convolution processing .

simulate degraded edge parameters are set to : High Reflection area The field's DN value is 240, Low Reflection region DN values ; Edge dip 0 set to 0. , 15°, 22.5°, 30°,45°; Gaussian function parameter number a to 0.5,1.0,1.5; White noise parameter 5 is 0.1 . The has a total page amplitude degraded edge image . uses the least squares straight line to fit the margin of the edge and the design truth of the edges of the , and take absolute value , The resulting results are table 1 shows .

from the table 1 to see , improved algorithm edge edges line to is better than three times polynomial . Three-time polynomial noise affect greater , When the image contains noise, its fit precision is large down ; improved algorithm still behaves better at higher noise intensity , The calculated value is smaller than the actual emulation value . So it uses this algorithm for Edge line fitting , can be weakened in the edge detection ring

section interference with system errors , gets more accurate fitting results

3.2 PSF Rebuild Precision Analysis

3.2.1 simulate edge test

simulate edge test , to evaluate the improved algorithm at different edges the applicability under edge dip and noise conditions and PSF estimate precision , has a total design of The amplitude contains different edge angles , noise parameters and high simulation Edge image of function parameters . where , edge angle, and the Gaussian function parameter setting is the same as the 3.1 section ,, noise parameter 0 and 0.5. with traditional edge method , tilt Edge method and improvement calculation methodamplitude simulation Edge PSF estimates . tilt Edge method under ESF The fitting method differs from three-spline inserts values and high-order polynomials . will each method PSF estimate respectively vs. simulated truth value , using peak Snr PSNR (Peak Signal To Noise RatioM) to evaluate PSF estimate Precision . results are shown in the Figure 6 .

u ~ 0 ~ [u 0 22.3
blade Tilt . U blade tilt /(. 1
(e) has noise (f) Noise
diagram 6 different methods PSF Peak signal-to-noise ratio for estimates

profiling diagram 6 You can see the following 3 Point .

1) Traditional method PSF estimate precision at different skew angles is worse , and the precision decreases significantly when noise is increased .

2) High-order polynomial PSF estimate precision slightly better than three times spline interpolation . Two methods are almost unaffected by edge inclination , butseverely affected by noise . When the image contains noise , its PSF estimated precision significantly lower ; When Gaussian parameters are reduced by hours , Edge Brightness mutation increase , easy to cause an estimate error , especially when ^ = 0.5 , For two methods PSF estimates are less accurate .

3) Improved methods PSF estimate precision compared to other parties the method has certain elevation , almost unaffected by edge inclination , and a more accurate estimate when noise is large , algorithm Steady Strong qualitative . But to a certain extent Gaussian parameter i.e. image degradation scale effect , and when the edge angle is 45. when ,ESF resample After the interval changes the maximum , its PSF estimates a slight drop . 3.2.2 UAV Remote sensing Image test

The parameter setting in the simulation experiment is ideal , Considering remote sensing The complexity of the actual imaging environment in the image capture , The result is not fully Validate improved methods PSF estimated performance . for this , mining Further evaluation of UAV remote sensing images with Songshan remote sensing target Field the algorithm in real image processing of the PSF rebuild Precision . target image as shown 7 shows .

theoretically , traditional method requires edge and sampling direction same or vertical , but experiment found the

ideal edge and sample direction to save at a minimum tilt 024_26. hereby , Select A ,B,c,d this 4 a red box as the ideal edge area , where A and B Select from edge fixed target , C and D Select a fan-shaped emitter target . using traditional edge-edge method to 4 Block area PSF estimate , Averages the resulting results as PSF Reference values . white box

E for the selected edge area with a large tilt angle , its enlarge results as shown in the diagram 7 (b) illustration shows . with traditional edge method , three-spline interpolation , High-time polynomial method and improved method to f zone for PSF estimate , and calculates the of the estimate and the reference value

Error in MSE (Mean Square Error) and PSNR. revenue results as shown 8 shows .

from Diagram 8 to see , contrast 4 Method , Improved algorithm PSF Rebuilding results PSNR Max , MSE Minimum , significantly lower to other 3 ways , indicates that the algorithm PSF estimates and references values closest ,PSF estimates the highest precision . other 3 ways 's PSNR all closer , but combine MSE view , Traditional blade Edge Law PSF lowest estimate precision , higher-order polynomial slightly better than three Sub-spline interpolation . takes into account that the actual image cannot be predictedlike noise and various errors , The computed in the UAV image test PSNR lower than simulation edge test , But test conclusion and simulation test basic keep _ to .

diagram 9 The provides an improved algorithm for PSF True Value and PSF estimate A three-dimensional effect of a discrete two-dimensional matrix of values . contrast two figure to see , Improved algorithm psf estimate with psf True Value lower than peak , But the graphic matches well . to prove the method's PSF The accuracy of the estimation is also achieved in the application of the actual image to the for a good effect

4. Conclusion

Improved algorithm first applies the gradient weighting method to the Asian image element position correction with a more precise edge line fitting the fruit ; and then take the based on the mobile window ESF denoising and resampling Method optimizes ESF Sample Quality , to obtain the available LSF Sample ; finally using analog edge image and real UAV remote sensing image Edge line fitting precision for improved algorithm, and PSF The reconstruction accuracy was evaluated and analyzed . can get the following 3 Point

Conclusion .

1) improved algorithm edge line fitting precision optimization effect obvious , and PSF High rebuild Precision , Strong stability .

2) Improved methods perform better on noise , and precision above traditional and existing tilt edge Edge method , apply to image quality Volume assessment and image recovery .

3) considers the combined effects of various factors , but not shadow sound factor to do a specific quantitative analysis , This is a question worth exploring and next _step work on .

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