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# OPTIMIZATION ANALYSIS OF CT SYSTEM IMAGING

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## ABSTRACT

Aiming at the problem of how to reconstruct an image based on the absorbed data from the unknown medium using the CT system with known calibration parameters, this paper proposed the Optimized filtered back-projection model of Image Denoising. This model first uses the Ramp-Lak filtered back-projection algorithm to reconstruct the image of the unknown medium to obtain the position and geometry of the medium. Then, considering the limitations of the single filtered back-projection algorithm, Shepp-Logan filtered back-projection algorithm and Lewitt filtered back-projection algorithm was used separately to reconstruct the CT image. Then the gray-scale variance function is used to calculate the sharpness of the above three groups of images. The image used the Ramp-Lak filtered back-projection algorithm got the highest score, indicating that the resolution is the best. Then, because the noise signal generated during the back-projection of the image will affect the sharpness of the image, the Wiener algorithm is used to denoise the image with the highest score above, so that the noise of the image is greatly reduced. A clearer image result is obtained, which more accurately determines the position and geometry of the unknown medium, and provides a reference value for imaging of the CT system.

**Keywords:** CT system, Filtered back-projection algorithm, Image reconstruction, Gray variance method, Image Denoising

## 1. INTRODUCTION

With the development of contemporary medicine and the improvement of people's living standards, many hospitals urgently need advanced CT systems to diagnose patients' conditions. How to use CT to reconstruct better images quickly is the key to better CT diagnosis. However, deviations often occur during the CT system's installation, which will affect the imaging quality. So it is necessary to perform parameter calibration on the installed CT system and image the samples of the unknown structure accordingly.

  

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Modern CT systems are very complex, and different reconstruction algorithms take different amounts of time to simulate this complexity. Kim, Daehong [1] and others used the total variation denoising algorithm in the CT imaging system to verify the feasibility of sinogram reconstruction using a repair method based on a sinusoid with decomposition. Wang, Linyuan [2] and others studied the condition numbers and singularities of system matrices and regular matrices using singular value decomposition methods and proposed an empirical lower bound estimation method, which helps to estimate the number of projection views needed for accurate reconstruction. Do, Synho [3] and others systematically tested and examined the role of the high-fidelity system model using raw data in an iterative image reconstruction method that minimizes the energy function. The iterative image reconstruction algorithm improves the image successively through several iterations. It has the advantages of improving spatial resolution under high contrast and reducing noise at low contrast, but the disadvantage is that the operation speed is slow and is Sensitive to the dose. Image quality deteriorates when the dose is low. Rowley, Lisa M [4] and others used the Bayesian penalty likelihood algorithm to optimize the reconstructed image. However, the key of the Bayesian algorithm is to find a suitable energy function to protect the edges of the image while denoising. But it is difficult to choose the right energy function.

The filtered back-projection reconstructed image is convoluted on the basis of back-projection, eliminating the edge sharpening effect [5] caused by pure back-projection, compensating the high-frequency components in the projection and reducing the density of the projection center. And ensure the edges are clear and the interior is evenly distributed. Image reconstruction with filtered back-projection is fast. Spatial and density resolution are relatively high. But in the filtered back-projection reconstruction algorithm, the design of the filter function is very crucial. Common filter functions are the Ramp-Lak filter, Shepp-Logan filter, and Lewitt filter. But the advantages and disadvantages of the three filters are different.

Based on these theories above, this paper uses the filtered back-projection algorithm (FBP algorithm) based on the Ramp-Lak, Shepp-Logan and Lewitt filter functions according to the data and questions in the National College Students Mathematical Modeling Contest A (2017) [6]. The image of the medium is reconstructed in three different ways to explore the difference. The gray-scale variance function is used to calculate the sharpness of the image. Then the clearest image is selected, and that image is denoised by the Wiener algorithm. This model provides a reference value for CT imaging.

## 2. MATERIALS AND METHODS

The basic idea of image reconstruction is to select the original density function, introduce the

  

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filter function, solve the modified density function, and back-projection. Based on this idea, it is necessary to obtain the specific situation of the projected image first. Therefore, based on the received information of the unknown medium from the CT system, an image in which the X-ray illuminates the template from 180 directions is drawn. Since there are 512 detectors in each direction, a raw projection data distribution image of 512x180 is obtained, as shown in Figure 1.

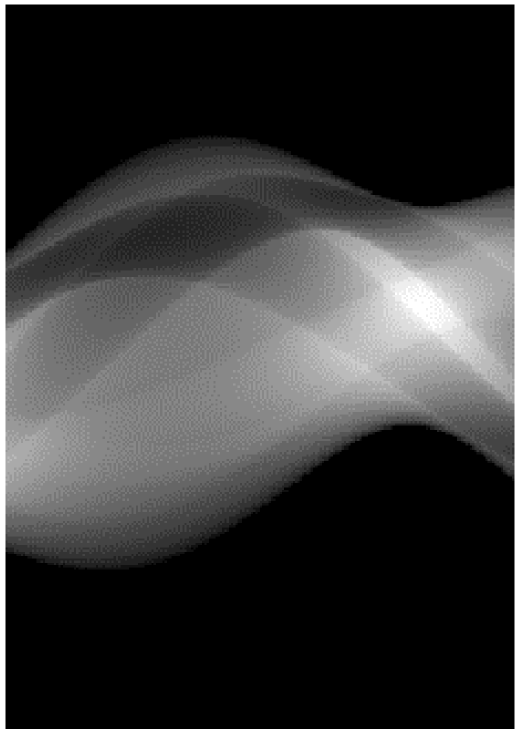

**Figure 1: Raw projection data distribution image**

However, this is not enough to obtain the clear projected image of the medium. In order to obtain the position and geometry accurately, the following three filter functions: Ramp-Lak, Shepp-Logan, and Lewitt filter functions will be introduced to correct the original projection data. Then a filtered back-projection model is established to reconstruct the image. The algorithm can be divided into the following five steps:

Step1: Determine the sampling points and angular direction sampling points and their sampling data.

Step2: Determine the Ramp-Lak, Shepp-Logan, and Lewitt filter back-projection function formulas.

Step3: Calculate the discrete convolution.

Step4: Beam calculation and linear interpolation.

  

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Step5: Reconstruct the image of any point $(x_i, y_j)$ using three filtered back-projection algorithms.

**2.1 Determine the sampling points and angular direction sampling points**

Set the number of translation sampling points to $N_t$. For the received data of 512 detectors, according to the parity rule, extract two sets of sampling points, namely uneven number sampling point group and even number sampling point group. And two sets of sampling points are respectively calculated. Where, $N_t$=256

$$\Delta x_r = d \qquad (1)$$

$x_r = nd$, and $x_r$ is the rotation coordinates.

Set the number of angular direction sampling points to $N_\phi$. In this paper, $N_\phi$=180, angle increment $\Delta\phi = \Delta = \frac{\pi}{180}$, and we have equation (2).

$$\phi = m\Delta \qquad (2)$$

It is easy to know that the picture pixels are 256 × 256, as shown in Figure 2.

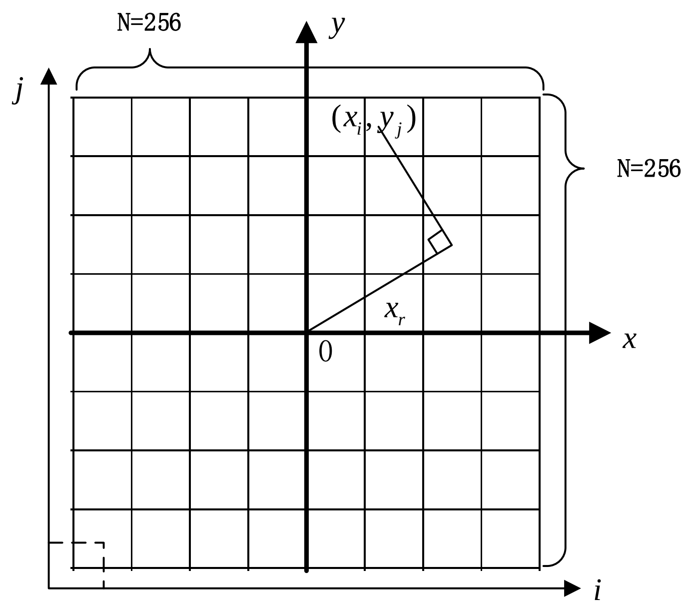


**Figure 2: Pixel coordinates used for image reconstruction**

  

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In the figure above, the pixel position is recorded as$(i, j)$, $i$ is the coordinate of the pixel in the x direction, $j$ is the coordinate of the pixel in the y direction. The minimum of $i$ and $j$ is 1, so the pixel coordinate of the lower left corner in Figure 2 is (1, 1).

**2.2 Determine the R-L, S-L and Lewitt filter back-projection function formulas.**

In the filtered back-projection algorithm, commonly used filter functions include Ramp-Lak filter function, Shepp-Logan filter function and Lewitt filter function. In this paper, these three kinds of filter functions above will be used for back-projection imaging calculation. The formulas [7] are as follows. Due to space limitations, this paper will not deduct them.

The sampling sequence of the Ramp-Lak filter function is

$$h_{R-L}(nd) = \begin{cases} \frac{1}{4d^2}, n = 0 \\ 0, n = even\ number \\ -\frac{1}{n^2\pi^2 d^2}, n = uneven\ number \end{cases} \quad (3)$$

The sampling sequence of the Shepp-Logan filter function is

$$h_{S-L}(nd) = \frac{-2}{\pi^2 d^2 (4n^2-1)}, n = 0, \pm 1, \pm 2, \ldots \quad (4)$$

The sampling sequence of the Lewitt filter function is

$$h_{Lewitt}(nd) = \begin{cases} \frac{1-\frac{2}{3}esp}{4d^2}, n = 0 \\ -\frac{1-esp}{n^2\pi^2 d^2}, n = uneven\ number \\ -\frac{esp}{t^2\pi^2 d^2}, n = even\ number \end{cases} \quad (5)$$

**2.3 Calculate the Discrete Convolution**

When the rotation angle is $\phi_m$, adopt projection $p(x_r, \phi_m)$, and determine the projection function $h(x_r)$. And the filtering projection is performed

$$\tilde{p}(x_r, \varphi_m) = p(x_r, \phi_m) * h(x_r) \quad (6)$$

I.e.:

$$\overline{p}(x_r, \phi_m) = \int_{-\infty}^{\infty} p(x_r - x_r') h(x_r') d\, x_r' \quad (7)$$

Since the data acquisition is spatially discrete, and the amplitude is also discrete after A/D conversion, it should be discretely convolved.

  

From the above we know that $x_r = nd$, $\phi = m\Delta$. So correspondently $x_r$ takes the variable n, and $\phi_m$ takes the variable m, the expression is

$$\tilde{p}(n,m) = p(n,m) * h(n) = \sum_{l=-N_l}^{N_l} p(n-l,m)h(l) \qquad (8)$$

### 2.4 Beam Calculation and linear Interpolation

In CT image reconstruction, interpolation is a critical step. And interpolation is also the purpose of beam calculation. We have obtained the discrete filter function $h(n)$ and the projection data $p(n,m)$ from above. Consider them to be discrete convolution, we can obtain the filtered projection data $\tilde{p}(n,m)$, and then we perform linearly interpolate. We have

$$\tilde{p}(x_r,m) = \tilde{p}(n,m) * \psi(x_r)$$

From the above we know that both $x_r = nd$ and $\phi = m\Delta$ are discrete. For a certain point $(x_i, y_j)$ in space, at a certain angle of view $\phi = \phi_m = m\Delta$, there is

$$x_{r,m} = x_i \cos\phi_m + y_j \sin\phi_m \qquad (9)$$

Since $(x_i, y_j)$ is the pixel coordinate of any point in space, $x_{r,m}$ obtained by the formula above is not exactly $\phi = m\Delta$ integer multiple of d, but may be located at between $n_0 d$ and $(n_0+1)d$, i.e.

$$x_{r,m} = (n_0 + \delta)d, 0 < \delta < 1 \qquad (10)$$

because

$$\tilde{p}(x_{r,m}, \phi_m) = \tilde{p}_{m\Delta}(n_0 d) + \frac{\tilde{p}_{m\Delta}[(n_0+1)d] - \tilde{p}_{m\Delta}(n_0 d)}{d}(x_{r,m} - n_0 d) \qquad (11)$$

Ignore the subscript associated with the fixed viewing angle $m\Delta$ and let d=1, there is

$$\tilde{p}(n_0+\delta) = (1-\delta)\tilde{p}(n_0) + \delta\tilde{p}(n_0+1) \qquad (12)$$

In order to get $n_0$ and δ in the interpolation formula, we use beam calculation to find a solution.

As mentioned before, the image area is usually divided into N×N pixels. When the ray rotates around the center of the image area after translation, the beam is translated from the first beam to the other end for each angle of view. The number of the bundle is also gradually increasing, as shown in Figure 3.

  

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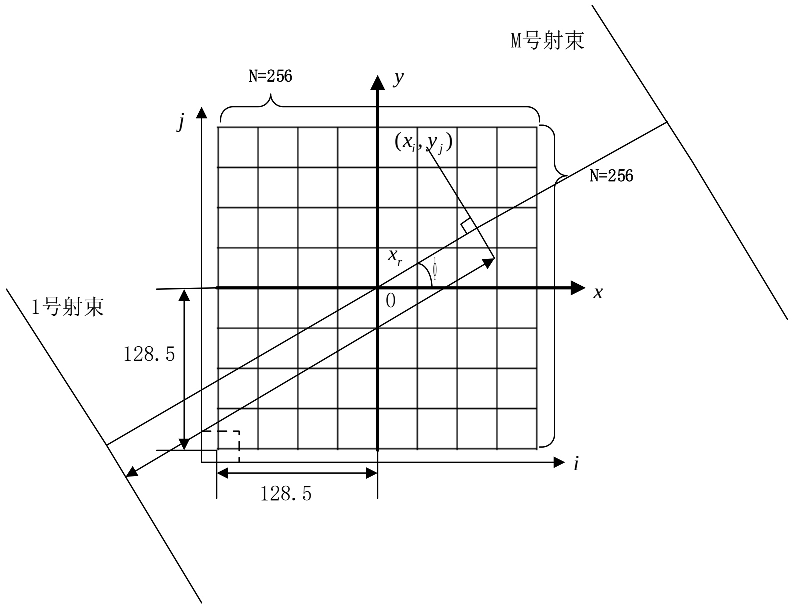


**Figure 3: Beam bundle calculation**

When one end of the beam is used as the origin, a negative value can be avoided in the actual calculation. So this coordinate is marked as $\tilde{x}_r$. Since the width of the pixel is 1, the minimum value of $i$ and $j$ is also 1, so for any pixel $(x_i, y_j)$ and any viewing angle $\phi$, there is

$$x_r = x_i \cos\phi + y_j \sin\phi = \left(i - \frac{N+1}{2}\right)\cos\phi + \left(j - \frac{N+1}{2}\right)\sin\phi \qquad (13)$$

When $x_r$ is converted to $\tilde{x}_r$, there is

$$\tilde{x}_r = x_r + \frac{M+1}{2} = \left(i - \frac{N+1}{2}\right)\cos\phi + \left(j - \frac{N+1}{2}\right)\sin\phi + \frac{M+1}{2} \qquad (14)$$

I.e.：

$$\tilde{x}_r = integer(n_0) + decimal(\delta) \qquad (15)$$

Where, M is the number of beams, $n_0$ is the beam number sought, and $\tilde{x}_r$ corresponding to $(x_i, y_j)$ is between the number $n_0$ beam and the number $(n_0 + 1)$ beam, and is δ apart from number $n_0$ beam.

### 2.5 Reconstructing Arbitrary Point Images Using Filtered Back-projection Algorithm

Combining the linear interpolation method above, the filtered projection value at $\tilde{x}_r$ corresponding to any pixel point (x, y) is obtained according to a finite number of filtered projection values. And then any point is reconstructed by back projection using the above

  

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formula:

$$\hat{a}(r,\theta) = \int_0^{\pi} g[r\cos(\theta-\phi),\phi]\,d\phi \tag{16}$$

$$a(x,y) = \hat{a}(r,\theta) = \int_0^{\pi} \tilde{p}(x_r,\phi)\,|x_r = x\cos\phi + y\sin\phi d\phi \tag{17}$$

When using programing to find a solution, replace $(x,y)$ with $(i,j)$, $x_r$is represented by $\tilde{x}_r$, and let$\phi = m\Delta$ . △ is the angular increment, $m = 1,2,\ldots N_\phi$ （$= 180$）, when $\phi = m\Delta$, there is

$$\tilde{x}_r|\phi = m\Delta == \left(i - \frac{N+1}{2}\right)cos(m\Delta) + \left(j - \frac{N+1}{2}\right)sin(m\Delta) + \frac{M+1}{2} \tag{18}$$

And the expression (17) is

$$a(i,j) = \sum_{m=1}^{N_\phi} \tilde{p}\left[\tilde{x}_{r,m}(i,j), m\Delta\right] \tag{19}$$

I.e.:

$$a_m(i,j) = \sum_{m=1}^{N_\phi} \tilde{p}\left[\tilde{x}_{r,m}(i,j), m'\Delta\right] \tag{20}$$

notice that $a_0(i,j) = 0$, so the recursive formula of back projection reconstruction can be turned into

$$a_m(i,j) = a_{m-1}(i,j) + \tilde{p}\left[\tilde{x}_{r,m}(i,j), m\Delta\right] \tag{21}$$

In this equation, $m = 1,2,\ldots180$.

From algorithm above we can know that when the CT image is reconstructed by the filtered back projection, the first back projection is performed on all the pixels after the first filtering action. And then the corresponding pixels are correspondingly performed back-projection after the subsequent filtering effects until the last back-projection is done. Due to the fastness of the reconstruction, all pixels can be considered to be almost reconstructed together.

Then repeat algorithm steps by introducing Ramp-Lak, Shepp-Logan and Lewitt filter functions respectively to implement the computer simulation of the filtered back-projection algorithm. The results are shown in Figure 4, Figure 5 and Figure 6.

  

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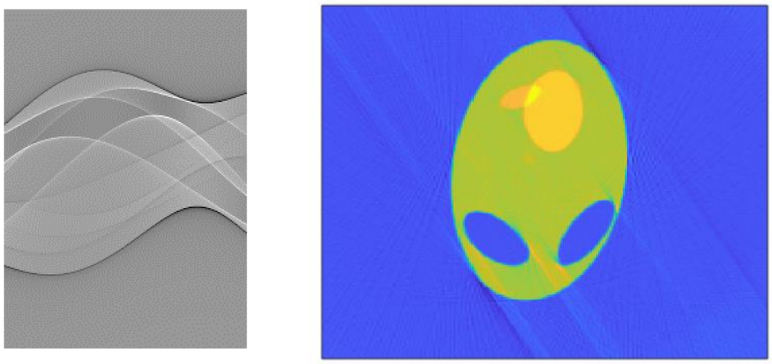

**Figure 4: Projection data processed by Ramp-Lak filter and reconstructed image after projection**

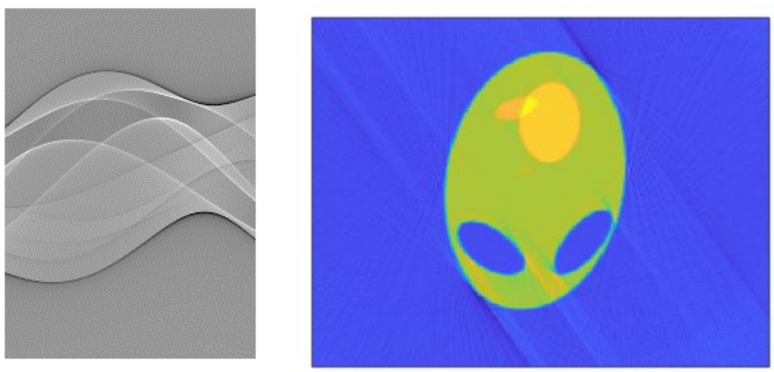

**Figure 5: Projection data processed by Shepp-Logan filter and reconstructed image after projection**

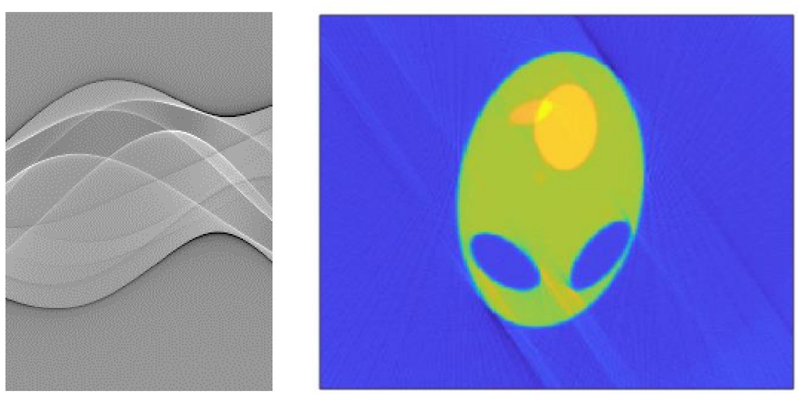

**Figure 6: Projection data processed by Lewitt filter and reconstructed image after projection**

  

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It can be seen from Figure 4, Figure 5 and Figure 6 that the images reconstructed by the three filtered back-projection algorithms successfully express the features of the original object. The images are clearer and the reconstruction quality is better. However, the measurement of the quality of imaging and the advantages and disadvantages of the three methods are not known. In the following part we will introduce the gray-scale variance method to compare the clarity of the three images.

### 2.6 Calculate the Sharpness of Three Sets of Images Using the Gray-scale Variance Function

In the quality evaluation of non-reference images, the sharpness of the image is an important indicator to measure the quality of the image. It can better correspond to the subjective feelings of the human, and the sharpness of the image mainly represents the degree of blurring of the image. Therefore, the gray-scale variance function (SMD) will be introduced below to analyze and solve the sharpness of the three sets of images.

When fully focused, the image is the clearest. And the number of high-frequency components in the image will also reach the top. Therefore, the grayscale change can be used as the basis for the focus evaluation. The formula of the gray-scale variance method is as follows:

$$D(f) = \sum_y \sum_x (|f(x,y) - f(x,y-1)| + |f(x,y) - f(x+1,y)|) \quad (22)$$

The gray-scale variance evaluation function has better computational performance, but its disadvantages are also obvious. The sensitivity is not high near the focus and when the function is too flat near the extreme point, the focus accuracy is difficult to improve. Therefore, the gray-scale variance product method (SMD2) is used to solve the sharpness of the three sets of images, that is, multiplying two gray-scale differences in each pixel and then accumulating them pixel by pixel. The formula is

$$D(f') = \sum_y \sum_x |f(x,y) - f(x+1,y)| * |f(x,y) - f(x,y+1)| \quad (23)$$

The image scores of the three filtered back projection algorithms are calculated as follows:

**Table 1: image scores of the three filtered back projection algorithms**

| Ramp-Lak's score | Shepp-Logan's score | Lewitt's score |
|---|---|---|
| 394936 | 355261 | 334415 |

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It can be seen from Table 1 that the image obtained by the filtered back projection algorithm using the Ramp-Lak filter function has the highest score, that is, the reconstructed image obtained by the back-projection algorithm using the Shepp-Logan filter function has the highest resolution. Therefore, the Ramp-Lak filter function can be considered as the most suitable function for the filtered back projection algorithm.

### 2.7 Noise Reduction of Images Using Wiener Algorithm

It is known from the above, the Ramp-Lak filter function can be considered as the most suitable function for the filtered back projection algorithm. However, this image inevitably contains more noise. Therefore, the commonly used noise reduction method, Wiener algorithm, is used to denoise the image obtained by the back-projection algorithm using the Ramp-Lak filter function.

The Wiener algorithm is based on the minimization criterion of mean-square error, which minimizes the error of the mean squared error between the final processed image $f'(x,y)$ and the original image $f(x,y)$, which significantly reduces image noise and improves image sharpness. Therefore, the Wiener algorithm is also called the optimal linear filter[8]. The non-blind image restoration Wiener deconvolution time domain expression is:

$$f'(x,y) = TF^{-1}[AG] \quad (24)$$

Where, A is a linear Wiener filter whose expression in the frequency domain is

$$A = \frac{H^*(u,v)}{|H(u,v)|^2 + \frac{P_n(u,v)}{P_f(u,v)}} \quad (25)$$

Where, $H^*(u,v)$ is the conjugate function of the system degradation function $H(u,v)$ , and $P_f(u,v)$ and $P_n(u,v)$ are the power spectra of the original image and the noise image, respectively. [9]

After Wiener filtering, the image obtained is shown in Figure 7:

  

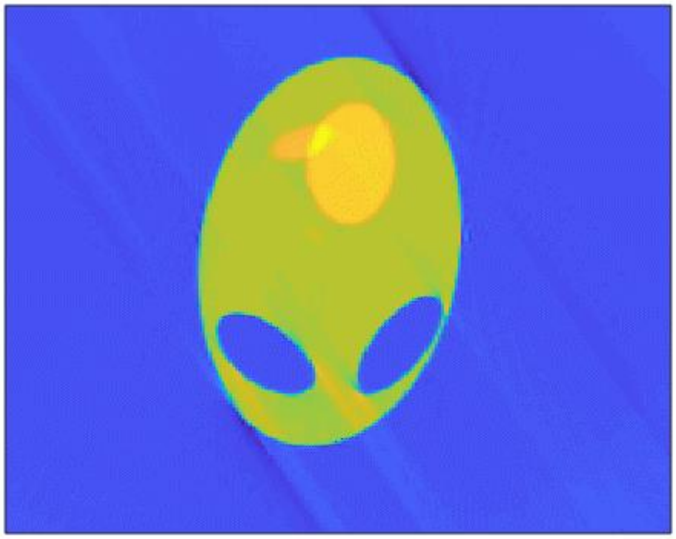

**Figure 7: Denoised image using Wiener algorithm**

After Wiener noise reduction processing, the optimized solution of the reconstructed image using the Ramp-Lak filter function is obtained. Figure 8 and Figure 9 are partial plots of the absorption rate gradation processing results obtained before and after noise reduction process.

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -3.8328 | -3.78204 | -2.29264 | -3.52684 | -1.07706 | 0.967309 | -2.93098 | -1.71128 | -0.08068 | 0.026522 | 0.741289 | -4.38749 | -0.34543 | 1.305295 | 0.919514 | -2.25694 | -1.6136 | -1.10432 | 0.053875 | 1.894577 | 0.108149 | -1.77923 | 0.137015 |
| -3.89876 | -7.53448 | -3.01067 | -0.89582 | -1.80501 | -2.04637 | -2.80286 | 1.012092 | -0.08942 | -2.89167 | -0.34644 | -1.568 | 1.270329 | -1.07526 | -1.61614 | -0.95618 | 0.266998 | -0.60721 | 0.417117 | -0.11062 | -1.09822 | -0.34279 | 1.737762 |
| -5.19757 | -6.21549 | -2.31907 | -2.4913 | -4.37654 | -0.18455 | -0.34474 | -1.15658 | -2.21121 | -1.63056 | 1.489818 | -1.54617 | -1.91729 | -1.96294 | 1.140789 | 0.874251 | -1.61284 | -1.44345 | -0.1189 | 0.812106 | 0.283853 | -0.43479 | -0.44611 |
| -1.2023 | -5.03014 | -6.38769 | -4.75603 | -0.3053 | -0.9433 | -3.02377 | -1.7034 | 0.159588 | -0.7733 | -2.46065 | -1.07451 | -0.64966 | 0.119211 | 0.469308 | -1.10588 | -2.13556 | 1.438999 | 0.132625 | -0.40429 | -1.72349 | -0.72765 | 1.66871 |
| 1.89299 | -6.65118 | -5.41002 | -3.65053 | -1.87706 | -4.44558 | -0.19202 | 0.166811 | -3.61285 | -1.83072 | -0.42569 | 1.04063 | -1.45131 | -2.38206 | 0.832376 | 0.474189 | -0.71835 | -1.45845 | -1.58873 | 0.763079 | -0.1974 | 1.572331 | -0.04733 |
| 1.159409 | -0.59375 | -5.03296 | -7.97261 | -2.12204 | -2.24776 | -2.27291 | -2.53797 | -2.02021 | 1.402002 | -2.59428 | -0.40494 | -1.1692 | 0.058081 | 0.277226 | -2.40883 | -0.83134 | -0.32151 | 0.619833 | 0.050928 | -2.29521 | 0.943169 | 0.136574 |
| 3.4975 | -0.24978 | -5.38199 | -4.51528 | -4.85892 | -4.85421 | -1.85232 | 0.498114 | -2.66856 | -1.73708 | -0.82259 | 0.820319 | -2.12813 | -1.98056 | -0.31453 | 0.176681 | 0.033463 | -2.2487 | -0.4283 | -0.09128 | 0.257152 | 0.86429 | -1.62676 |
| 0.372147 | 3.277476 | -0.06549 | -7.41635 | -6.7495 | -1.64261 | -3.11887 | -1.95968 | -1.58503 | -0.56706 | -1.81055 | -1.83227 | 0.291848 | -1.18091 | -1.2849 | -1.06997 | -0.09215 | -0.70257 | 0.605349 | -2.68428 | -1.85001 | 0.680981 | 0.592016 |
| 3.520107 | 0.579984 | 1.004087 | -3.35689 | -6.68091 | -4.99671 | -2.49529 | -2.21869 | -2.38756 | -1.52477 | -0.33298 | -1.48939 | -1.71837 | -1.30243 | -0.222 | -0.95071 | -1.2085 | -1.92346 | -0.26311 | -0.55571 | 0.890917 | 0.080242 | -0.72644 |
| 1.62347 | 2.602119 | 3.239448 | -1.08134 | -5.34352 | -7.43062 | -4.03593 | -3.11451 | -0.87441 | -2.8289 | -1.07736 | -1.30769 | -2.15741 | -1.90483 | -1.57631 | -0.25714 | 1.418749 | -2.65613 | -0.63971 | -1.62831 | 1.238625 | 0.225393 | -0.05006 |
| 2.486997 | 1.794831 | 3.395157 | 0.429711 | -3.50828 | -7.48932 | -4.93906 | -3.40131 | -2.3554 | -2.88961 | -1.8675 | -1.43823 | -1.81209 | -0.03142 | -1.89309 | 0.212815 | -0.16932 | -2.68744 | -0.33731 | -2.52953 | 0.933938 | -0.63138 | -0.59782 |
| 1.696706 | 1.842457 | 3.416597 | 2.087376 | -0.98923 | -6.46192 | -7.73771 | -4.80573 | -2.93284 | -1.93477 | -1.46374 | -1.4355 | -2.51475 | -0.42767 | -2.41734 | -0.91011 | -1.25486 | -1.36626 | -0.54348 | -0.74491 | 1.193484 | -1.37573 | -0.27024 |
| 1.583735 | 1.873392 | 3.080333 | 0.945283 | 1.234641 | -2.64712 | -8.30904 | -5.09504 | -3.72467 | -2.5456 | -3.21059 | -1.63046 | -1.99464 | -1.0149 | -1.5873 | -0.97881 | -1.19874 | 0.023581 | -1.70279 | -0.54579 | 0.508994 | -0.57207 | -0.64455 |
| 2.047828 | 1.716132 | 2.922669 | 1.038391 | 2.989519 | -1.02486 | -6.83023 | -7.76498 | -4.58494 | -3.05766 | -2.85403 | -0.89486 | -1.53515 | -2.05916 | -0.89888 | -1.96368 | -0.38511 | 0.328457 | -2.99757 | 0.703895 | -0.6859 | -0.29777 | -0.13944 |
| 2.035928 | 1.956207 | 2.524682 | 1.05434 | 3.393952 | 1.042644 | -2.94646 | -8.06065 | -5.45559 | -4.89238 | -3.02216 | -1.90807 | -1.89354 | -2.68177 | 0.046588 | -1.77985 | -0.67518 | -0.15992 | -2.47042 | 0.772111 | -1.29785 | 0.254128 | -0.80048 |
| 3.548459 | 1.782319 | 3.256027 | 2.164735 | 2.896498 | 1.578728 | 1.83014 | -7.07136 | -8.79148 | -4.36433 | -2.81111 | -2.46907 | -1.49391 | -2.98793 | 0.47643 | -2.67541 | -1.35221 | 0.345533 | -2.69748 | -0.022 | -1.4192 | -0.25058 | -0.70866 |
| 0.748264 | 1.316427 | 2.649762 | 1.542606 | 1.15584 | 1.410931 | 3.27962 | -4.87795 | -9.4928 | -6.71056 | -5.7898 | -3.47493 | -2.21255 | -3.32149 | -0.46014 | -4.06509 | -1.59136 | -0.2426 | -3.24284 | -1.36903 | -1.44366 | -0.26684 | -0.85217 |
| 20.00147 | 6.243768 | 2.796138 | 2.261915 | 3.72817 | 2.13282 | 3.199474 | -0.76687 | -5.82501 | -9.02608 | -6.06765 | -2.59032 | -2.88233 | -2.40173 | -0.90102 | -2.35905 | -0.25372 | -0.93968 | -1.09394 | -0.6054 | -0.12654 | 0.546277 | -0.74709 |
| 53.93622 | 47.85323 | 29.97591 | 9.943554 | 3.329124 | 1.361798 | 3.610805 | 0.947539 | -2.40349 | -9.79757 | -7.66401 | -4.30645 | -3.62507 | -2.40151 | -2.61707 | -1.72941 | -1.6929 | -1.90589 | -0.28893 | -2.63472 | -0.84869 | -0.2926 | -0.79743 |
| 55.84631 | 56.38571 | 56.29215 | 50.8284 | 31.42037 | 7.575021 | 3.252005 | 1.070299 | 1.873952 | -6.83533 | -10.354 | -6.22416 | -4.54936 | -2.08573 | -3.02509 | -1.74579 | -1.9247 | -1.3893 | -0.4058 | -2.47536 | -0.04116 | -0.63002 | -0.20009 |
| 55.801 | 56.9124 | 55.47877 | 56.16102 | 57.32751 | 46.89419 | 22.22973 | 2.151605 | 3.516972 | -2.46277 | -10.8808 | -8.4141 | -5.01218 | -4.12199 | -2.72441 | -0.613 | -3.71356 | -2.05033 | 0.135374 | -2.53003 | -0.49413 | -0.68938 | -0.01624 |
| 54.74611 | 57.79779 | 55.22635 | 57.42546 | 55.97743 | 55.81441 | 55.91198 | 35.25182 | 6.699026 | -1.12649 | -4.91839 | -11.3378 | -7.06257 | -4.07662 | -3.23176 | -1.99161 | -2.99288 | -0.88248 | -0.32734 | -3.81104 | -0.33363 | -0.41702 | -0.51375 |
| 55.73111 | 56.8343 | 55.28765 | 57.58593 | 55.95619 | 56.46726 | 56.23221 | 55.61536 | 43.92191 | 15.10553 | -5.26446 | -11.6257 | -8.5852 | -5.24979 | -3.4346 | -2.6475 | -3.28 | -2.05864 | 0.143684 | -2.51933 | -0.61484 | -0.61215 | -1.33956 |
| 55.29557 | 56.91993 | 56.16533 | 56.4589 | 55.97986 | 56.79505 | 56.11802 | 56.20909 | 56.02009 | 47.27451 | 18.5085 | -10.3915 | -13.8257 | -7.22831 | -4.60136 | -0.97244 | -3.64277 | -1.78559 | -0.78458 | -3.33951 | -0.81454 | -0.49195 | -1.1572 |
| 55.26757 | 57.46233 | 55.29471 | 57.48782 | 54.91232 | 57.58162 | 55.40301 | 57.02827 | 55.76608 | 56.87091 | 47.00765 | 16.03562 | -10.3572 | -13.6335 | -6.84821 | -2.88382 | -2.77665 | -2.89331 | -0.81361 | -0.59496 | -1.94548 | -0.86034 | -1.36391 |
| 55.82863 | 57.1457 | 55.66527 | 56.57763 | 55.62209 | 57.41504 | 55.06821 | 57.37676 | 55.56872 | 56.84759 | 56.54508 | 46.38455 | 8.326694 | -12.5416 | -9.55378 | -5.29907 | -4.18149 | -2.13403 | -2.34445 | -1.07852 | -1.11271 | -0.38566 | -0.46313 |
| 56.46313 | 56.39853 | 55.70258 | 56.86028 | 55.65989 | 57.39796 | 55.18744 | 57.17884 | 55.91504 | 56.83455 | 55.76446 | 57.29695 | 42.0416 | -3.08933 | -11.0595 | -4.06406 | -6.38065 | -2.71908 | -2.49248 | -1.88591 | -2.16558 | -0.93122 | 0.203883 |
| 56.23755 | 56.4017 | 55.27849 | 56.9617 | 55.26601 | 57.57449 | 55.57852 | 57.02448 | 55.9736 | 56.26081 | 56.75048 | 55.76377 | 56.43516 | 32.77001 | -10.6221 | -8.00166 | -2.71091 | -3.52262 | -3.73308 | -1.75567 | -3.44727 | -1.21417 | -0.83684 |
| 55.70405 | 56.2582 | 55.70643 | 56.80784 | 55.50523 | 57.28296 | 55.6211 | 56.63691 | 56.13774 | 56.26741 | 56.76835 | 55.90263 | 56.79352 | 52.55552 | 17.31162 | -11.5774 | -6.84146 | -0.9647 | -3.7758 | -1.40129 | -3.78202 | -1.45392 | -1.35968 |
| 54.96467 | 56.57625 | 55.91411 | 56.44564 | 55.61459 | 56.87257 | 55.97322 | 55.98515 | 56.6303 | 56.23366 | 56.75301 | 55.78205 | 56.91015 | 55.72363 | 43.70419 | 4.090676 | -9.19597 | -6.8475 | -1.62833 | -0.58796 | -2.42046 | -3.04932 | -1.09284 |

**Figure 8: Partial data after Ramp-Lak filtered back-projection algorithm denoise**

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -4.52146 | -3.66306 | -2.92278 | -2.00562 | -1.57194 | -1.43971 | -0.89738 | -1.11735 | -0.90269 | -0.4159 | -1.05332 | -0.64174 | -1.06815 | -0.05895 | -0.44445 | -0.53875 | -0.89613 | -0.69339 | -0.2916 | 0.03015 | 0.038505 | 0.041749 | -0.16015 |
| -4.21397 | -4.2315 | -3.56315 | -2.42166 | -1.71513 | -1.62231 | -1.022 | -1.14618 | -0.97031 | -0.55471 | -1.12363 | -0.73438 | -1.13633 | -0.25346 | -0.40307 | -0.53935 | -0.93925 | -0.64026 | -0.02298 | 0.249104 | -0.07411 | -0.20382 | -0.45051 |
| -3.51704 | -4.53291 | -4.29341 | -2.92749 | -1.97825 | -1.75916 | -1.24372 | -1.12892 | -1.03161 | -0.97265 | -1.20017 | -0.75584 | -0.93381 | -0.46907 | -0.45698 | -0.51947 | -0.58676 | -0.40691 | 0.01293 | -0.20109 | -0.41621 | -0.1203 | -0.18438 |
| -2.25312 | -4.05783 | -4.76794 | -3.50817 | -2.55891 | -1.74365 | -1.31413 | -1.32424 | -1.39914 | -1.25506 | -0.80124 | -0.7772 | -1.09157 | -0.64462 | -0.1712 | -0.19797 | -0.6319 | -0.83385 | -0.20745 | -0.22679 | -0.00625 | -0.00576 | -0.48175 |
| -0.70959 | -3.02841 | -5.05388 | -4.16825 | -3.14669 | -1.93664 | -1.9111 | -1.67075 | -1.19445 | -1.35068 | -0.79127 | -1.02107 | -0.65708 | -0.43289 | -0.40737 | -0.57187 | -0.78519 | -0.54028 | -0.08528 | -0.51585 | -0.22428 | -0.07448 | -0.1304 |
| 0.581392 | -1.86331 | -4.38423 | -4.53571 | -4.06044 | -2.74698 | -1.97087 | -1.61021 | -1.37116 | -1.59 | -0.50582 | -0.7928 | -0.84413 | -0.91757 | -0.58527 | -0.27546 | -0.81143 | -0.77134 | -0.52257 | -0.32333 | 0.207451 | -0.04369 | -0.5245 |
| 1.473803 | -0.33527 | -3.10564 | -4.90168 | -4.70881 | -3.30213 | -2.22091 | -1.94638 | -1.24172 | -1.37815 | -0.8385 | -1.0722 | -0.8362 | -0.82568 | -0.85863 | -0.6127 | -0.82944 | -0.37399 | -0.57784 | -0.6462 | -0.45825 | -0.25531 | -0.19147 |
| 1.851738 | 0.728227 | -1.79158 | -4.22458 | -5.00793 | -4.13882 | -2.51558 | -1.97643 | -1.57226 | -1.49291 | -1.03293 | -1.00246 | -1.16888 | -1.09333 | -0.90326 | -0.54807 | -0.88732 | -0.692 | -0.92134 | -0.4577 | -0.26752 | -0.09307 | -0.45266 |
| 1.934493 | 1.794816 | -0.13522 | -2.93894 | -4.96649 | -4.72155 | -3.44588 | -2.42111 | -1.89562 | -1.44318 | -1.419 | -1.27046 | -1.40016 | -1.22837 | -1.08324 | -0.58255 | -0.82687 | -0.60684 | -1.16088 | -0.54292 | -0.40024 | 0.120185 | -0.31552 |
| 1.965525 | 2.249578 | 0.956344 | -1.32251 | -4.38421 | -5.21329 | -4.45794 | -2.86913 | -2.39946 | -1.79317 | -1.6396 | -1.46678 | -1.46243 | -1.40199 | -0.88057 | -0.51617 | -0.91346 | -0.94069 | -1.46897 | -0.32113 | -0.21953 | 0.151491 | -0.69584 |
| 2.02187 | 2.455309 | 1.969595 | 0.182879 | -3.30968 | -5.32618 | -5.49068 | -3.79966 | -2.79305 | -2.02495 | -1.80481 | -1.67492 | -1.44773 | -1.63721 | -1.02279 | -0.76073 | -0.85219 | -0.91509 | -1.45923 | -0.33969 | -0.36871 | 0.074024 | -0.80234 |
| 2.077819 | 2.352245 | 2.096126 | 1.121287 | -1.8221 | -4.53856 | -5.65403 | -4.8112 | -3.29833 | -2.54719 | -2.04622 | -1.92972 | -1.36663 | -1.52147 | -1.00531 | -1.13297 | -0.92546 | -1.02629 | -1.15933 | -0.4186 | -0.41811 | -0.16171 | -0.86148 |
| 1.988383 | 2.242205 | 2.102515 | 1.858398 | -0.31421 | -3.25407 | -5.63074 | -5.75391 | -4.04958 | -2.9232 | -2.11413 | -1.94819 | -1.50079 | -1.60553 | -1.36198 | -1.28831 | -0.85617 | -1.01075 | -0.76054 | -0.5349 | -0.20175 | -0.25369 | -0.77353 |
| 1.863077 | 2.193434 | 1.90127 | 2.131534 | 0.891865 | -1.42524 | -4.62619 | -5.86351 | -5.02017 | -3.70529 | -2.66842 | -2.10483 | -1.73473 | -1.51319 | -1.43531 | -1.04677 | -0.75436 | -1.02641 | -0.67205 | -0.85726 | -0.12892 | -0.40833 | -0.53266 |
| 2.24117 | 2.421139 | 2.046167 | 2.471201 | 1.681549 | 0.325547 | -3.21459 | -5.51951 | -6.00482 | -4.42596 | -2.9193 | -2.09799 | -1.9915 | -1.44748 | -1.61374 | -1.02303 | -0.92415 | -1.11821 | -0.6886 | -1.12382 | -0.24924 | -0.59397 | -0.39701 |
| 1.867851 | 2.202008 | 2.027456 | 2.29316 | 1.804475 | 1.515766 | -1.09703 | -5.20379 | -6.63523 | -5.70336 | -3.93805 | -2.78613 | -2.4937 | -1.61426 | -1.93874 | -1.3418 | -1.35512 | -1.34294 | -1.00963 | -1.4656 | -0.56033 | -0.75392 | -0.51588 |
| 1.57489 | 2.834416 | 2.668189 | 2.494632 | 2.096916 | 2.356914 | 0.079504 | -3.84321 | -6.32516 | -6.54209 | -4.81154 | -3.31019 | -2.64825 | -1.7983 | -2.07727 | -1.46462 | -1.45929 | -1.22981 | -1.09638 | -1.33557 | -0.55078 | -0.58538 | -0.47421 |
| 20.13154 | 6.683116 | 3.320753 | 3.029632 | 2.985195 | 2.578731 | 1.144242 | -1.21124 | -5.32809 | -6.97522 | -6.1586 | -4.29035 | -3.02404 | -2.31366 | -2.25072 | -1.74109 | -1.64219 | -1.25021 | -1.36923 | -1.29486 | -0.78236 | -0.53653 | -0.44073 |
| 53.43854 | 47.49231 | 29.95388 | 10.32481 | 3.823876 | 2.295828 | 2.486988 | 0.550968 | -3.18455 | -6.23324 | -6.98506 | -5.36259 | -3.45185 | -2.72099 | -2.14071 | -1.80542 | -1.54894 | -1.09943 | -1.30434 | -0.94673 | -0.7898 | -0.34859 | -0.3428 |
| 55.11564 | 55.4829 | 55.71079 | 50.40996 | 31.36519 | 8.003779 | 3.69591 | 2.008566 | -0.64512 | -5.82152 | -7.43768 | -6.78112 | -4.52673 | -3.35138 | -2.34044 | -2.19844 | -1.86276 | -1.47067 | -1.505 | -1.06483 | -1.18179 | -0.44553 | -0.51223 |
| 56.4527 | 56.05407 | 55.83423 | 55.40857 | 56.72722 | 46.57927 | 22.32693 | 2.679999 | 3.618041 | -2.57272 | -6.95042 | -7.63925 | -5.87606 | -3.98775 | -2.624 | -2.44031 | -1.92263 | -1.50567 | -1.52626 | -1.14257 | -1.26908 | -0.3706 | -0.55875 |
| 56.63093 | 55.9795 | 56.5233 | 56.26959 | 55.51216 | 55.27688 | 55.36756 | 35.13468 | 7.06759 | -0.77098 | -4.83337 | -8.12234 | -7.27621 | -4.83324 | -3.12125 | -2.73659 | -2.24778 | -1.66957 | -1.54446 | -1.15014 | -1.33573 | -0.55897 | -0.61038 |
| 56.60554 | 56.00046 | 56.63351 | 56.22923 | 56.49561 | 56.13916 | 55.44639 | 55.12504 | 43.64209 | 15.23117 | -4.88219 | -10.684 | -8.82034 | -6.36621 | -3.71489 | -2.97721 | -2.25043 | -1.73451 | -1.7072 | -1.3779 | -1.43933 | -0.6994 | -0.52361 |
| 56.58386 | 56.02872 | 56.61077 | 56.12541 | 56.58055 | 56.16061 | 56.38332 | 54.76416 | 55.45015 | 46.95381 | 18.52653 | -9.9145 | -12.5729 | -8.19598 | -5.27773 | -3.45415 | -2.54897 | -1.98794 | -1.62732 | -1.25369 | -1.31034 | -1.02222 | -0.62002 |
| 56.55915 | 56.11612 | 56.57529 | 56.01822 | 56.5367 | 56.09947 | 56.55501 | 56.06203 | 55.44023 | 56.1753 | 46.73136 | 16.06916 | -9.94432 | -11.6558 | -7.03813 | -4.52884 | -2.95213 | -2.37294 | -1.75206 | -1.42537 | -1.18041 | -0.95499 | -0.49621 |
| 56.45746 | 56.13649 | 56.51054 | 55.97584 | 56.61274 | 56.02751 | 56.62635 | 56.05471 | 56.59853 | 55.23556 | 55.96638 | 46.0979 | 8.455131 | -12.0048 | -7.80916 | -5.89414 | -3.70357 | -2.97064 | -1.88404 | -1.60374 | -1.21782 | -1.00268 | -0.48261 |
| 56.26471 | 56.12462 | 56.33243 | 55.95488 | 56.59279 | 56.08552 | 56.64464 | 56.09684 | 56.55337 | 56.27337 | 55.38314 | 56.74095 | 41.81389 | -2.78764 | -10.4463 | -6.8748 | -4.33484 | -3.35764 | -2.40732 | -2.22396 | -1.55297 | -1.1503 | -0.4872 |
| 56.05742 | 56.01674 | 56.26397 | 55.97205 | 56.59071 | 56.11929 | 56.60919 | 56.13929 | 56.46993 | 56.29694 | 56.40105 | 55.13144 | 55.98572 | 32.63632 | -10.127 | -7.37297 | -5.19806 | -3.68231 | -2.47229 | -2.71546 | -2.00412 | -1.6652 | -0.75623 |
| 55.8966 | 55.89349 | 56.26115 | 55.94445 | 56.48123 | 56.14319 | 56.50549 | 56.17345 | 56.35001 | 56.41949 | 56.2758 | 56.42879 | 55.84208 | 52.19724 | 17.35868 | -10.9361 | -5.60815 | -4.35782 | -2.69077 | -2.50354 | -2.12356 | -2.07295 | -1.14223 |
| 55.688 | 55.77041 | 56.25239 | 55.97593 | 56.34484 | 56.1747 | 56.3159 | 56.20771 | 56.24498 | 56.51887 | 56.21696 | 56.54374 | 55.80888 | 55.18225 | 43.44514 | 4.334688 | -8.3662 | -4.90574 | -3.24904 | -2.34499 | -1.84931 | -1.83948 | -1.31092 |

**Figure 9: Partial data after Wiener filtered back-projection algorithm denoise**

It can be concluded from Fig. 8 and Fig. 9 that after noise reduction processing, the number of noises of the image is greatly reduced, the contour of the image is clearer, and the noise reduction effect is better.

## 3. CONCLUSION

In this paper, based on the back-projection image in the CT system, three image reconstruction models based on Ramp-Lak, Shepp-Logan and Lewitt filter functions are established. The reconstructed image quality obtained by filtered back-projection algorithm is explored and determined. The location and geometry of an unknown medium in a square tray. Firstly, based on the established filtered back-projection algorithm, the image is back-projected and reconstructed by Ramp-Lak filter function to obtain the position and geometry of the medium. However, considering the limitation of the back-projection of a single filter function, the Shepp-Logan and Lewitt filter functions are used to repeat the above algorithm steps, and three sets of reconstructed images are obtained. In order to further compare the advantages and disadvantages

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of the back-projection image reconstruction using each filter function, the gray scale variance function is used to calculate the sharpness of the three sets of back-projection images, and the image quality obtained by using the Ramp-Lak filter function is the highest. Then the Wiener algorithm is used to denoise the selected image, and the reconstructed image with significantly reduced noise is obtained, which more accurately reflects the position and geometry of the unknown medium in the square tray, providing image reconstruction in the CT system. Reference.

The algorithm has the following disadvantages: Firstly, the reconstruction of the image relies too much on the experimental data. When the experimental data is unreliable, the image obtained by the reconstruction algorithm does not have high accuracy, thus lacks strict scientific. Secondly, there are many kinds of filter functions. In this paper, only three common filter functions are used for the reconstruction of back-projection images, and only the Wiener algorithm is used for noise reduction. It is not always possible to get the best back-projection reconstructed image. Accurately reflect the position and geometry of the unknown media in the tray.

However, the advantages of this model are also obvious: First, the development of modern science and technology provides a strong guarantee for the precision of CT, so that the data collected by the CT system has high accuracy, which can better ensure the back-projection reconstruction image. The accuracy. Secondly, the process of filtering the back-projection algorithm is simple and effective, and the position and geometry of the unknown medium in the tray can be obtained conveniently and quickly.

Therefore, the filtered back-projection image reconstruction model established in this paper can easily obtain the reconstructed image of the unknown medium when it guarantees certain reliability, which provides a simple and effective reference for future back-projection imaging using CT system parameters and related data.

## REFERENCES

[1] Kim, D. H., Sang, W. P., Kim, D. H., Yoo, M. S., & Lee, Y. (2018). Feasibility of sinogram reconstruction based on inpainting method with decomposed sinusoid-like curve (s-curve) using total variation (tv) noise reduction algorithm in computed tomography (ct) imaging system: a simulation study. Optik.

[2] Wang, L., Zhang, H., Cai, A., Li, Y., Yan, B., & Li, L., et al. (2015). System matrix analysis for sparse-view iterative image reconstruction in x-ray ct. J Xray Sci Technol, 23(1), 1-10.

[3] Do, S., Karl, W. C., Singh, S., Kalra, M., Brady, T., & Shin, E., et al. (2014). High fidelity system modeling for high quality image reconstruction in clinical ct. Plos One, 9(9),

  

e111625.

[4] Rowley, L. M., Bradley, K. M., Boardman, P., Hallam, A., & Mcgowan, D. R. (2017). Optimization of image reconstruction for 90y selective internal radiotherapy on a lutetium yttrium orthosilicate pet/ct system using a bayesian penalized likelihood reconstruction algorithm. Journal of Nuclear Medicine Official Publication Society of Nuclear Medicine, 58(4), 658.

[5] Mo Hua, Long Lingli. Convolution back projection graphic method for X-CT image reconstruction [J]. Chinese Journal of Medical Physics, 1999, 16(3):143-145.

[6] China Society for Industrial and Applied Mathematics. (2017). Higher Education Club Cup National Contest on Mathematical Modeling for College Students. http://www. mcm.edu.cn

[7] Fan Huiyun. Research on CT Image Filtering Back Projection Reconstruction Algorithm [D]. Northwestern Polytechnical University,2007.

[8] Yi Xiaofei, Chen Fujie, Yang Xuejun. Image template matching based on Wiener filtering [J]. Computer research and development,2000(12):1499-1503.

[9] Liang Xiaoping, Luo Xiaoshu. Wiener filtering image deblurring algorithm based on genetic adaptation [J]. Journal of Guangxi Normal University (Natural Science Edition), 2017,35(4):17-23. DOI:10.16088/j.issn.1001-6600.2017.04.003.

  