Three Dimensions Reconstruction of Single-spectrum Multi-X-ray Views of Contraband Based on Space Carving Method

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Abstract. In consideration of imaging principle and sampling process of the X-ray imager, the collected images often appear blurry and noisy. We propose to add image processing in the reconstruction process to optimize the 3D reconstruction surface results of X-ray images in this paper. This paper proposes an automatic image data acquisition method to acquire images. According to the characteristics of X-ray images, an image processing method is drawn up. In this paper, the original image and the processed X-ray image are divided into two groups, and three-dimensional reconstruction is performed respectively, and the visualization effect and reconstruction time of the reconstruction result is compared. Experiments show that the running speed of the program is improved, and the visualization results show that the surface texture refinement and the reconstruction structure of the reconstruction effect after image processing have also been well optimized.

1. Introduction
In order to create a more secure and stable social environment, the national security inspection department needs to improve the accuracy of security inspections and comprehensive inspections to reduce the occurrence of unstable factors. At present, to provide a basic guarantee for creating a safe and stable living environment, dual-energy X-ray security inspection machines have been widely used in densely populated places such as customs, airports, railway stations, passenger stations, subway stations and so on. When a threat item is found at the security inspection site, a second inspection of the luggage is required. However, due to the relatively large size of the security inspection equipment,
the process of returning and re-inspecting seriously affects the throughput efficiency of the security inspection site. The process of returning, and re-inspecting seriously affects the throughput efficiency of security inspections. With the development of science and technology, X-ray backscatter have been put into use on the market. However, the backscattering type is flawed due to its principle. In the imaging process, the imaging effect of the diffuse reflection light information on the surface of the object is very poor, and the equipment price is very high or even exceeds the price of the dual-energy security inspection machine. At present, it cannot be widely used in various places due to its visualization effect and economy. In order to improve this situation, by selecting X-ray images obtained by a single-energy X-ray imager, three-dimensional reconstruction of contraband is achieved through three-dimensional reconstruction technology to improve the accuracy of object detection.

However, security inspection is a rigorous and complicated task. When threat items are placed in a cramped and cramped package, they can easily be blocked and squeezed by other objects. The 2-dimensional images obtained by the current single-energy X-ray inspection, used to identify the "blind spot" of contraband. Threat items such as gun parts, ceramic knives, and bottled alcohol are easily overlooked and pose safety hazards. The security inspection process uses artificial image judgment, which depends on the ability of security personnel to understand X-ray fluoroscopy images. It requires the security inspector to concentrate for a long time, which is easy to cause misjudgment and missed judgment, and the personnel cost in the use process far exceeds the equipment cost. Therefore, multi-view images can make up for the shortcomings of a single view. When items are heavily stacked, multi-view can solve the problem of stacking items. However, security inspection is a rigorous and complicated task. When threats are placed in small and crowded packages, they can easily be blocked and squeezed by other objects. Therefore, the multi-view analysis makes up for the shortcomings of single-view and solves the above-mentioned problems through multi-view when the object position is severely blocked. With the development of science and technology, large results have been achieved in the three-dimensional reconstruction of visible light images. Traditional methods of 3D reconstruction have many different forms. With the development of deep learning, three-dimensional reconstruction methods based on deep learning also emerge endlessly. However, there are many troubles with the 3D reconstruction of x-ray images. In our experiments, we use multi-view X-ray images for 3D reconstruction. This method changes the pathological problem in the single-view reconstruction process. We use a single-spectrum X-ray imager to acquire multiple views and use the Space Carving algorithm to reconstruct the three-dimensional structure of the contraband. This method is based on the way of 2D contour projection to carve the 3D structure of the object.

In this paper, we use single-spectrum X-ray images to reconstruct the contraband, which improves the visibility of contraband and improves the accuracy of the contraband detection stage. We believe that this method can improve the detection accuracy of both manual detection and automatic identification systems.

2. The State of Art

With the rapid development of computer vision, the three-dimensional reconstruction of digital images is widely used in industrial production and daily life. There are more and more traditional methods of 3D reconstruction. With the development of deep learning, there are more and more 3D reconstruction methods based on deep learning. However, there are still many difficulties in the three-dimensional reconstruction of X-ray images. In our experiment, we use multiple multi-view X-ray images for 3D reconstruction.

However, the three-dimensional reconstruction methods of X-ray images have failed due to the different principles of image acquisition. At present, X-ray image three-dimensional reconstruction methods are widely used in medical clinics. Literature [1] proposed three-dimensional reconstruction of the femur, tibia, and fibula of the leg. Due to the similarity of human bones and the fixity of the human skeletal structure, the author achieved good results in the three-dimensional reconstruction of the leg bones through feature points and feature ellipses. Literature [2] creates a three-dimensional model of the shape and size of the spine according to the back and lateral contours of the human body and detects the
position of the spinal space and the shape of the spine to make an overall model of the spine. It provides a meaningful reference value for clinical medicine, but for the detection of contraband, this method loses significance due to the shape, size, type, and unknownness of contraband. Fortunately, in clinical medicine, a 3D reconstruction based on single-energy X-ray images based on deep learning was first implemented in the knee joint. Kasten et al. [3] used CNNs to perform 3D reconstruction of X-ray images with two-plane X-ray images of the kneecap. The digitally reconstructed ray image generated by CT scan is used to train the model and the bone shape and distribution are directly learned from the training image through the deep network to obtain higher reconstruction accuracy and efficiency. This method is very worthy of learning and reference. X-ray inspection technology also plays an important role in non-destructive testing. It is mainly used for quality testing of castings and weldments. Yin Tao et al. [4] performed non-destructive testing of fittings in power equipment and used MATLAB for three-dimensional reconstruction of the surface of fittings. By obtaining the condition of the accessory surface, the quality of the power equipment is evaluated without removing the shell. For the three-dimensional reconstruction of X-ray images of contraband, Riffó et al. [5] used a single-energy X-ray imager to perform three-dimensional reconstruction of the contraband and used 90 X-ray image sequences to perform three-dimensional reconstruction of the items in the package. The method reconstructs a three-dimensional object with fine details.

Due to the special imaging principle of X-ray imagers, many visible light 3D reconstruction methods often fail. Through the summary of the previous 3D reconstruction work of X-ray images. It is not difficult to find that the 3D reconstruction methods of X-ray images are divided into two forms: one is to use Space Carving to use multiple images to carve the surface of the object, the more images there are, the more accurate the reconstruction result will be; the second is the three-dimensional reconstruction based on deep learning, training the neural network to learn the three-dimensional structural space features to obtain the three-dimensional reconstruction of the image. In our experiment, using the Space Carving method of reconstruction, a set of processed multi-view image data is obtained through a series of processing on the image. This paper divides the original image and the processed X-ray image into two groups, performs three-dimensional reconstruction respectively, comparing the visualization effect and reconstruction time of the reconstruction result.

3. Image data acquisition and processing

3.1. Image data collection
During the experiment, in order to prevent the shaking of the object during the image acquisition process. We use a small rotating experimental platform to ensure the stability of the object during the image acquisition process. X-ray imager experimental equipment model is GDX-50/75 portable X-ray machine, used to collect X-ray images. This paper divides the original image and the processed X-ray image into two groups, performs three-dimensional reconstruction respectively, comparing the visualization effect and reconstruction time of the reconstruction result.

![Image acquisition system diagram.](image-url)
In the experiment, X-ray imager equipment and a small rotating platform are used to work together, and multiple multi-view X-ray images are obtained through the rotation of the rotating platform. The schematic diagram of the image acquisition device used in our experiment is shown in Figure 1. The contraband pistol is placed in the box, and the small rotating platform rotates counterclockwise. One X-ray image is collected every 10º, and the rotating platform rotates 360º to collect a total of 36 X-ray images, as shown in Figure 2.

### 3.2. Image data processing

Due to the basic principles and sampling process of X-ray imaging, the X-ray image will be blurred. Generally speaking, X-ray image blur includes motion blur, geometric blur, and detector blur [6]. The former is due to the image acquisition process. The relative movement of the object and the X-ray imager causes this effect. The latter two situations are caused by the inherent inevitable error of the X-ray imager itself. During the security inspection process, due to the occlusion, noise, collection, and clutter of the items in the package, the appearance of the contraband may become very difficult to identify. Therefore, manual inspection, automatic identification, and three-dimensional reconstruction add a lot of difficulties, so image processing becomes very important. In the process of multi-view 3D reconstruction of contraband, the small amount of image information will not affect the 3D reconstruction of contraband.
This article uses OpenCV3.4.0 to process the X-ray image of the pistol. The image processing flowchart of our experiment is shown in Figure 3 below. Because X-ray images have a small amount of noise and complex background in the acquisition process, this paper uses image filtering to smooth the image, and then process the image through adaptive thresholding and morphological closing operations. Image filtering can dilute the pixels of the image; then through the thresholding process to remove the noise in the original image and part of the image redundant background, the edge information of the X-ray image becomes clearer in this process, and the contrast of the image is changed; however, morphological processing The operation takes a small amount of residual discontinuous information in the threshold processing stage through morphological closing operation to remove some discontinuous pixels, so that the contour information of the X-ray image is more clear and concise.

After afterimage processing of the image data, a good processing result is obtained. It can be seen from the image processing effect that the contrast of the X-ray image is improved and the edge information of the image is enhanced, for example, the contour edge of the pistol in the image is visible.

4. Experimental result

Our method was implemented in the Python3.7 experiment system and OpenCV3.4.0 compiler environment. The 3D reconstruction of contraband in this experiment uses the Space Carving reconstruction method. In our experiment, a single-spectrum X-ray imager device was used to collect 36 X-ray images from different angles. 36 multi-view X-ray images are used as input data. Reconstruct the three-dimensional structure of the prohibited pistol by using the spatial sculpture reconstruction method. Reconstruct the structure file (shape.vtr) from the experimental results. Use the 3D visualization tool ParaView to view the reconstruction results.

In our first experiment, 36 original image data were used as the first set of reconstruction data. Use the first set of reconstruction data to perform the three-dimensional reconstruction. The running time of the 3D reconstruction process is 29.984s, and the visualization results are shown in Figure 5 below.

In the second set of experiments, we processed the X-ray image data to obtain the processed 36 X-ray images and then passed the processed 36 X-ray images into the Space Carving reconstruction algorithm. The computational time for 3D reconstruction for the image reconstruction after image processing was 29.243s, and the visualization results were reconstructed and shown in Figure 6. The reconstruction results of image visualization show that the reconstructed surface of the gun is relatively smooth and the structure of the gun is clear.
Comparing the information of the two sets of experimental results, it can be seen that the reconstruction running time of the second set of experiments is reduced by 0.7s; secondly, according to the visualization of the reconstruction results, it can be seen that the reconstruction effect of the second set of numbers is more delicate than the first set of data, and the surface texture More delicate. This paper proposes that the image processing process reduces the time of the image reconstruction process. This process reduces the amount of calculation data in the reconstruction process to increase the speed of the reconstruction process; the three-dimensional structure is also optimized to remove a small amount of redundant information. By adding the image processing part to the "spatial carving" algorithm, the texture refinement of the object surface and the structure of the object reconstructed by 3D reconstruction can also be optimized. It can be seen that this experiment has a good effect in optimizing the 3D reconstruction surface texture.

5. summary
This paper uses the three-dimensional reconstruction of single-spectrum X-ray images to help identify threat targets in baggage inspection. In our experiment, by adding an image processing part to the Space Carving algorithm, the X-ray image reconstruction speed is increased, and a good 3D reconstruction result is obtained; the texture of the gun body is also optimized, as can be seen from the visualization results. The contour information of the image is carved more clearly, which shows that this experiment has a good effect in optimizing the 3D reconstruction surface texture.

However, to evaluate our reconstruction effect from the experimental results, the reconstruction results still need to be further improved, and the reconstruction algorithm used in the experiment still needs further improvement. It can be seen from the visualization that the outline of the gun body is not clearly depicted. The main reasons are: the one is completely manually operated during the image acquisition process, and there may be errors in the placement of the pistol; the last is the selected reconstruction algorithm, which needs to be improved according to the X-ray image.
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