# Research on Sonar Fan-shaped image display

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**Abstract.** In the field of underwater acoustic field, a good sonar data real-time display system plays an important role in the whole sonar system. This paper is based on a fact that the sonar scanning an image is formed by a fan-shaped which has a certain angle and the sonar image display is usually realized through a hardware circuit called a digital scan converter (DSC), ultimately realized the sonar Fan-shaped image display by using an algorithm which called R-Theta digital sweep surface transformation algorithm------a two-dimensional linear interpolation algorithm. This algorithm has less distortion and high image resolution compared with the rectangular display without DSC.

## 1. Introduction

Digital Scan Converter (DSC) began to be used in the B-mode ultrasound field in the late of 1970.Using DSC in B-mode ultrasound, can increase the scanning speed appropriately regardless of the limitations of the probe scanning speed and solve the problem of image flicker in conventional devices【1】. The image memory of DSC can store the echo signal in order to freeze the ultrasound images, multi display, a variety of before and after processing and measurement. This makes a lot of image processing and measurement techniques can be gradually introduced to the sonar image, makes sonar images display with great flexibility. The DSCA of B-mode ultrasound scanning is one of the key of modern fan-shaped scan, which has a great influence on the quality of the image. There are two classes of DSCA that have been proposed so far, One is to show the sampling data which obtained from the high-speed A / D sampling of the polar coordinate fan-shaped scan image signals to the rectangular coordinate system ;the other is the image data acquisition and display is in a similar space without making a coordinate transformation algorithm【2】.

In this paper, the R-Theta algorithm is used in the study of sonar image segment display, which belongs to the first kind of DSCA algorithm.

## 2. The principle of the sector display algorithm and software realization

### 2.1 The principle of the sector display algorithm

R-Theta Digital sweep surface transformation algorithm is a two-dimensional linear interpolation algorithm, which points are as follows【3】:

In an open angle of 150 degrees in the Fan-shaped image, it is composed of 167 ultrasonic scanning lines (each scanning line is like a bar on a fan), and the angle between the two ultrasonic scanning lines is about 0.9 degrees. If we extract 675 sample points form each of the scanning line by Equal Intervals and then make the middle of Fan-shaped angle reference line named $\theta = 0^\circ$ .Then the radial distance r and the angle $\theta$ that between each scanning line and the reference line can be calculated in advance.

The purpose of the algorithm is to map the fan-shaped image as shown in Figure 1 to the memory matrix.

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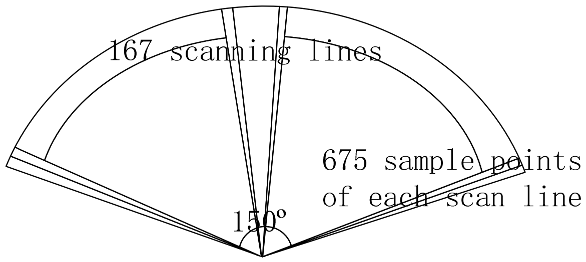


Fig. 1 Using 167 scanning line fan-shaped scanning graphics of 150°

For all the pixel values between the two adjacent scanning line, we can use the following three equations interpolation:

$$f(x,y) = z(i)\theta err + z(i+1)(1-\theta err) \tag{1}$$

$$z(i) = s(i,j)\mathrm{Re}rr + s(i,j+1)(1-\mathrm{Re}rr) \tag{2}$$

$$z(i+1) = s(i+1,j)\mathrm{Re}rr + s(i+1,j+1)(1-\mathrm{Re}rr) \tag{3}$$

Wherein, $f(x,y)$ is the pixel data needed to be interpolated of the storage unit, $s(*,*)$ is the sample value in the polar coordinates around $f(x,y)$, $z(k)$ is the middle value of the Kth scanning line. $\mathrm{Re}rr$ and $\theta err$ is the relative error of the distance and angle between the radial and azimuthal angles, it can be given by the following equation:

$$\mathrm{Re}rr = \frac{\left|r-r'\right|}{\Delta r} = \left|r-\sqrt{x^2+y^2}\right|/\Delta r \tag{4}$$

$$\theta err = \frac{\left|\theta-\theta'\right|}{\Delta\theta} = \left|\theta - \arctan(y/x)\right|/\Delta\theta \tag{5}$$

As can be seen above, using the four sample points $s(i,j)$ 、 $s(i,j+1)$ 、 $s(i+1,j)$ 、 $s(i+1,j+1)$ of the two adjacent scanning line and using the above equation for the linear interpolation operation three times, you can get the desired value of the pixel .For any pixel value stored in the matrix in the sector in the fan-shaped region, it can be obtained in this way.

## 2.2 Software implementation of the algorithm

Similar to the implementation hardware, the Software implementation of the algorithm also use the linear interpolation operation 3 times, here we quote the display of the sonar image.

First we can set up a rectangular coordinate system which using the central of the fan-shaped as the origin, As we can see in the Figure 2.

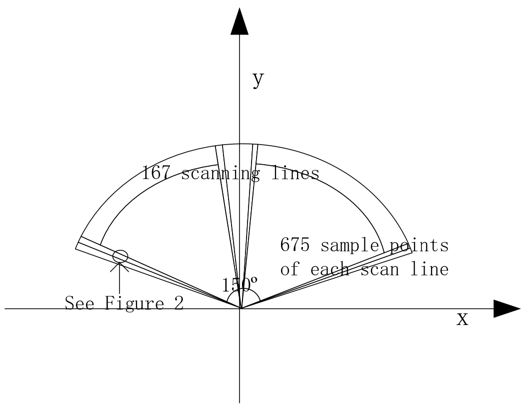


Fig. 2 The fan-shaped picture in a rectangular coordinate system

In the rectangular coordinate system, any point in the Figure 2 can be marked. Sonar image has an opening angle of 150。,167 scanning lines and each of them has 675 sample points. The display of the image requires that the central angle of the sector is $150^\circ$ and each of the scanning lines allocated 675 pixels evenly. Then we can obtain the following equation :

$$\Delta\theta = 150\pi/(180*166) \approx 0.01577 \qquad (6)$$

$$\Delta R = \frac{675}{675} = 1 \qquad (7)$$

The arbitrary point $(x, y)$ in the rectangular coordinate system can be transformed into polar coordinates in the form of $(r', \theta')$.

$$r' = \sqrt{x^2 + y^2}, \theta' = \arctan(y/x) + k\pi, \theta' \in [15\pi/180, 165\pi/180] \qquad (8)$$

According to the Fig.2, we have that :

$$r = [r'/\Delta R], \theta = [(\theta' - 15\pi/180)/\Delta\theta] \qquad (9)$$

Then we can obtain that :

$$\mathrm{Re}rr = \left|[r'/\Delta R] - r'\right|, \theta err = 1 - \left|[(\theta' - 15\pi/180)/\Delta\theta] - \theta'\right| / \Delta\theta \qquad (10)$$

And then we come to calculate the value of $z(i)$ and $z(i+1)$:

According to the equation, To get the value of $z(i)$, you must first get the value of $s(i, j)$ and $s(i, j+1)$.

According to Fig. 2 we can see that these two points are the original sampling point, the key problem is that how to determine the value of $s(i, j)$ and $s(i, j+1)$ from the known conditions while the original sampling points is 167*675.First we can register a 167*675 bytes of memory named sam[657][167] to store the original sample points in the initial stage of the program, Let $s(i, j)$ denote the address of sam[j][i] ,and $s(i, j+1)$ denote the address of sam[j+1][i] Then the question is converted to acquire the value of i and j. We can see from Fig. 2 that $j = r$ , $i = 166 - \theta, j \in [0,674], i \in [0,166]$ .then we have this :

$$\begin{cases} s(i, j) = sam[r][166-\theta] \\ s(i, j+1) = sam[r+1][166-\theta] \\ s(i+1, j) = sam[r][166-(\theta+1)] \\ s(i+1, j+1) = sam[r+1][166-(\theta+1)] \end{cases} \qquad (11)$$

According to the equation above , we obtain that :

$$z(i) = sam[r][166-\theta] * \left|[r'+1] - r'\right| + sam[r+1][166-\theta] * (1 - \left|[r'+1] - r'\right|) \qquad (12)$$

$$z(i+1) = sam[r][166-(\theta+1)] * \left|[r'+1] - r'\right| + sam[r+1][166-(\theta+1)] * (1 - \left|[r'+1] - r'\right|) \qquad (13)$$

After 3 times interpolation calculation, the interpolation point $f(x, y)$ can be determined eventually.

## 3. Experimental results

We can see the benefits of the interpolation algorithm of the fan-shaped display by compare the experiments results, in which Fig. 3 is the display results which not used the interpolation algorithm, Fig. 4 is the display results used the R-Theta algorithm. We can clearly see through the R-Theta algorithm the sonar image shows higher resolution and less distortion.

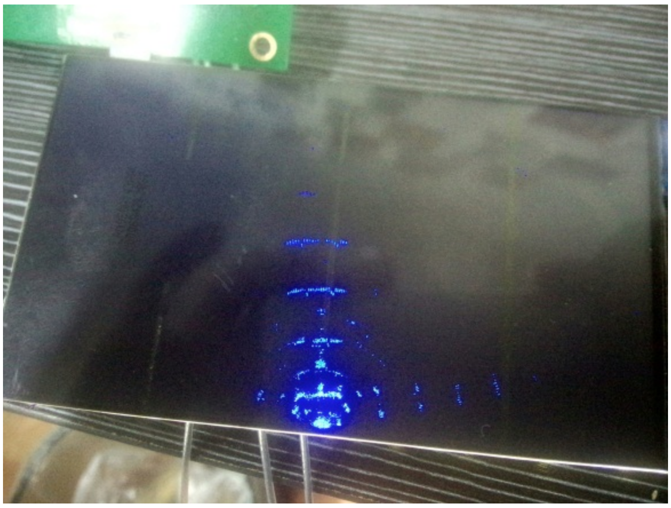

Fig. 3 sonar imagine without using interpolation algorithm

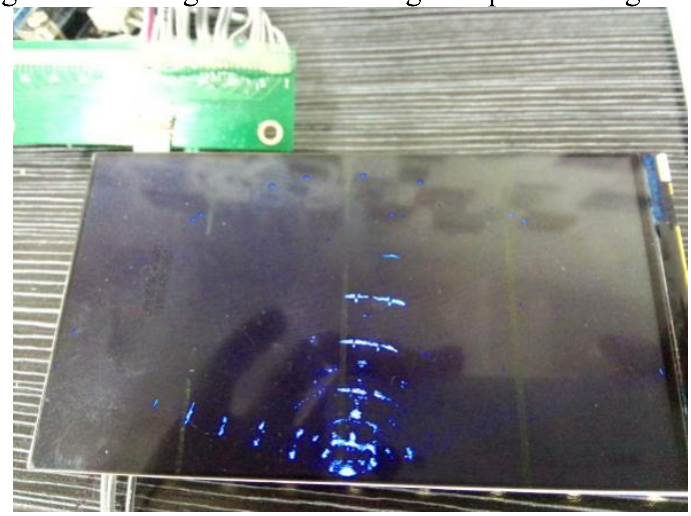

Fig. 4 sonar imagine with using interpolation algorithm

## 4. Summary

In summary, the realization of sonar image sector display is feasible and effective, but we should also recognize the limitations of fan-shaped display. The limitations include the following aspects: first, it requires a higher host's processing speed; secondly, it will takes longer generation time along with the increasing area of fan-shaped; newly, it need adequate display format; finally, there will have a certain gap between the refresh rate of image and the effects of hardware implementation. Therefore, before selecting a software realization method of the fan-shaped image display, we should do a reasonable performance evaluation and testing combined with the project, and avoid using trigonometric function, open square operation and other complex operations in writing some code.

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