ISAR IMAGING FROM TARGET CAD MODELS

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ABSTRACT:

To acquire radar target signature, various kinds of target are necessary. Measurement is one of the data acquiring method, but much time and high cost is required to get the target data from the real targets. Even if we can afford that, the targets we can access are very limited. To obtain target signatures avoiding these problems, we build the target CAD (Computer Aided Design) model for the calculation of target signatures. To speed up RCS calculation, we applied adaptive super-sampling and tested quite complex tank CAD model which is 1.4 hundred of thousands facet. We use calculated RCS data for 1D range profile and 2D ISAR (Inverse Synthetic Aperture Radar) image formation. We adopted IFFT (Inverse Fast Fourier Transform) algorithm combined with polar formatting algorithm for the ISAR imaging. We could confirm the possibility of the construction of database from the images of CAD models for target classification applications.

KEY WORDS: ISAR, range profile, CAD model, SBR, RCS

1. INTRODUCTION

Target imaging technique using range profile and ISAR imaging is an important technology for modern advanced radar (Zyweck, 1995). These images allow identifying location and amplitude of scattering centers of a target. Differences result from target shape, so these features are used to classify a target for a radar system. In some cases these images are used for the RCS diagnosis to secure stealth capability.

Target signature for radar images can be collected using measurement radar or an instrument. Target could be a real one or a scaled model. Regardless of radar environment such as outdoor field or indoor measurement facility, it costs a lot to use real radar systems and targets for the collection of target RCS data. And real target is not always available for measurement. So the simulation with CAD model can be a method for getting RCS data.

This paper describes the results of ISAR imaging from the predicted RCS data using SBR algorithm adapted to the faceted target CAD model. Adaptive super-sampling method is used for the improvement of the ray tracing speed in calculating RCS values. The range profile and ISAR images validate procedure. IFFT algorithm is used to make ISAR images.

2. RCS PREDICTICTION USING SBR

High frequency method has been mainly used for the calculation of target reflectivity using CAD model because calculation time for a real target is quite acceptable. Recently low frequency method has been tried for the calculation but the former method is still used for the analysis of big size targets.

SBR (Shooting and Bouncing Rays) is one of the well-known algorithms in the high frequency methods. This is a mixed algorithm of GO (Geometrical Optics) and ray tracing. It is easy to implement because it performs simple iterations of ray tracing (Ling, 1989). But it takes much time in ray tracing so the minimization of the calculation time is one of the key point in implementation. Another thing to be taken into consideration is the target CAD model. As it contains very diverse geometrical elements, the plane faceted CAD model is used for the application of SBR algorithm.

Adaptive super-sampling is the method which reduces the total number of rays by increasing the ray density near the boundaries in implementing SBR algorithm (Glassner, 1989). It is well know method in ray tracing. This method uses four or five rays for a single ray tube instead of single ray positioned at center. The ray is divided into smaller ray when the planes which each ray meets are not identical as shown in figure 1.

For a single ray tube, this method requires four times as much time compared with the method which traces the center of ray. But as the total number of tracing rays decreases, the overall calculation time is reduced. If the target has a simple shape as in figure 1, the larger the primary ray size, the more effective in reducing the calculation time. We also implemented fast line cross test algorithm not to skip division for smaller facet, which is perfectly included inside ray tube. This enables us to use bigger initial ray and reduces computation time greatly.

Figure 2 is a trihedral corner reflector which was used for confirming the performance of the applied algorithm. The length of each side of the corner reflector is 0.15m. Table 3 shows a calculation summary of a trihedral corner reflector when the ray density is 64 rays/λ with and without adaptive super-sampling method. Initial ray density is 16 rays/λ. From the table we can see that the number of tracing rays decreases to 3% and the calculation time decreases to 8%.

Figure 4 is the CAD model of T72 tank and figure 5 is its faceted CAD model which is composed of 1.4 hundred of thousands of plane facets. If the algorithm mentioned above is used the calculation time decreases from 90 seconds to 21 seconds. Pentium IV 3.0GHz CPU mounted PC was used for the calculation.

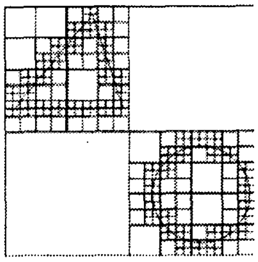

Figure 1. Adaptive super-sampling method

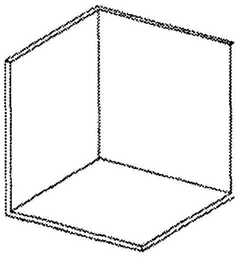

Figure 2. Trihedral corner reflector

Table 3. Calculation result of a corner reflector with and without adaptive super-sampling method

Method	Number of Rays	Time[s]
Normal Ray tracing	732,260	0.63
Adaptive Super-sampling	21,947	8.23

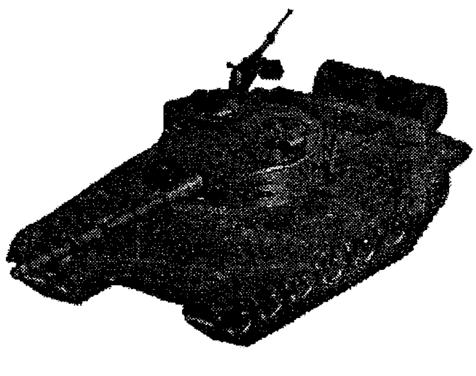

Figure 4. CAD model of T72

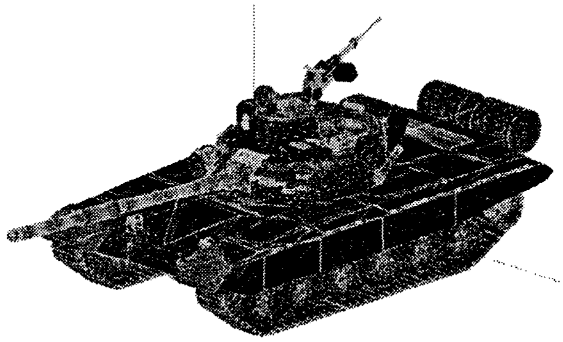

Figure 5. Faceted CAD model of T72

3. ISAR IMAGING

ISAR images contain information on the geometry of target. The ability to produce ISAR images of a target from its predicted RCS signature is valuable in that it can help locating scattering centers. These can be used for RCS diagnostic studies and target recognition. ISAR image can be obtained with the RCS data calculated by the method described in the former section. But to obtain required angular diversities, the RCS must be computed for many angles and it causes the considerable computational burden. The algorithms explained in the previous section were adopted to solve this problem. Once we get the RCS data over required frequency bandwidth and azimuth angular aperture, we can make images with the ISAR imaging algorithms such as Fourier transform, MUSIC, MP, and so on. Among those algorithms, Fourier transform is most popularly used due to its easy implementation and fast speed. Its resolutions in range and cross-range directions are directly related to the bandwidth and angular aperture. The wider the bandwidth and angular aperture, the higher the resolutions and the better image we can get. As the angular aperture becomes larger or as the size of a target becomes larger, the images come to suffer from MTRC (Moving Through Resolution Cell) phenomena. This problem can be covered by polar format algorithm (Mensa, 1991). The quality of images can be enhanced to some extent by simple zero-padding method or extrapolation algorithms without a change of parameters.

Range profile is the same as ISAR except that it has no information over angular domain and we can see the distribution of scattering centers only in range direction. Because it has no angular diversity, it is not affected by MTRC and does not need additional processing steps. And usually the data size is small. These properties make it possible for range profiles to be used for the target classification (Heiden, 1998).

Figure 6 is the range profile of T72 from the azimuth angle 0° which means the front side of T72. X-band frequency was used and the resolution is 0.3m in range direction. The position of scatterers can be seen clearly from the graph. ISAR imaging result is in figure 7. X-band frequency and 3° of angle aperture was used and the resolution is 0.3m in both directions. The elevation angle is 75° from the top side of the target. We can see the strong scattering centers from the hull and the wheels of T72.

Figure 8 shows another example of target CAD model, which is A10 fighter. The number of faceted plane is about 1.8 hundred of thousands. A range profile at azimuth angle 45°, elevation angle 75° is presented in figure 9 and ISAR image is in figure 10. Parameters used in this case are the same as T72.

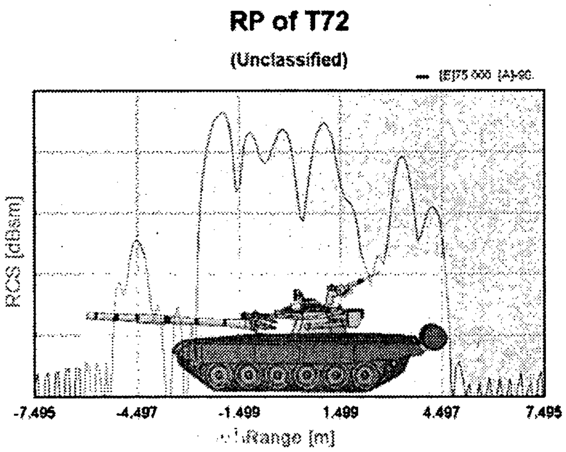

Figure 6. Range profile of T72

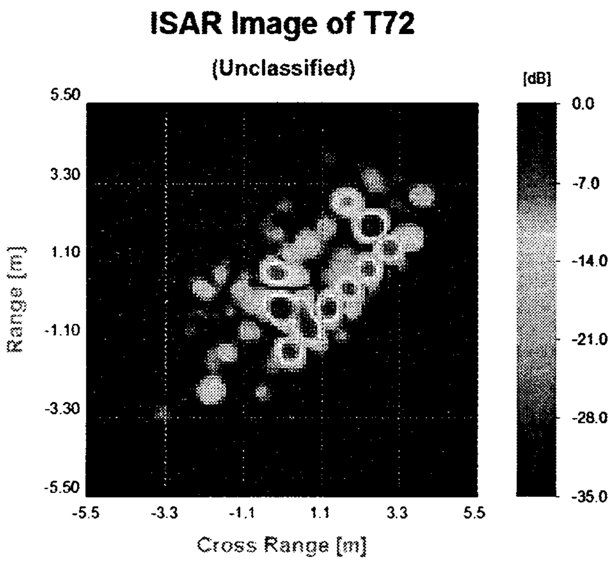

Figure 7. ISAR image of T72

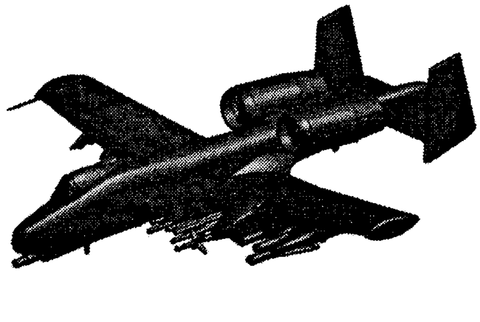

Figure 8. CAD model of A10

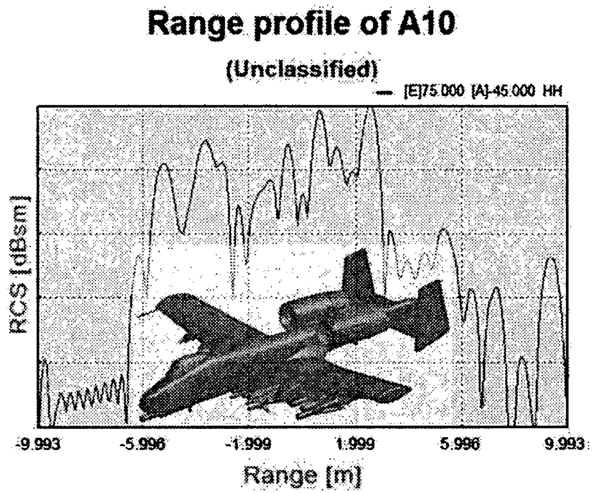

Figure 9. Range profile of A10

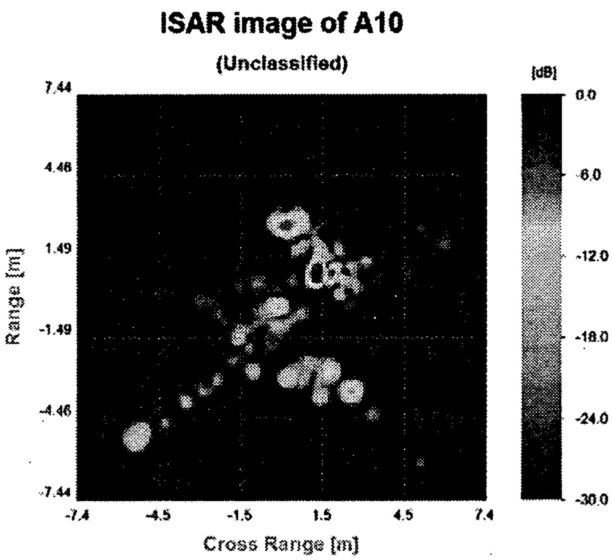

Figure 10. ISAR image of A10

4. CONCLUSIONS

This paper shows the results of fast RCS prediction of radar targets in order to make range profiles and ISAR images using the faceted target CAD model applied to SBR algorithm. To reduce the RCS calculation time we adopted adaptive super-sampling method and fast line cross test algorithm which are proved to be very effective. Even though there are more research topics left to us, we verified that two dimensional radar images of complex targets could be obtained from the simulation using complex CAD model.

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