

A NEW METHOD FOR MOVING TARGET DETECTION IN SAR IMAGERY

Murat Hakan Yusufoglu, Mesut Kartal

Informatics Institute, Istanbul Technical University, Istanbul, Turkey

hakan.yusufoglu@gmail.com, kartalme@itu.edu.tr

Keywords: Synthetic Aperture Radar, Moving Target Detection, Shear Averaging, Sub-aperture Processing.

Abstract: This paper presents a new algorithm for detection and parameter estimation of moving targets in synthetic aperture radar (SAR) images. The proposed algorithm is capable of detecting targets moving in both range and azimuth directions, and also motion parameter estimation of the detected targets. This new algorithm uses “sub-aperture processing” and “shear averaging algorithm” for detection of range and azimuth direction movements respectively. Detection algorithm is processed in range and azimuth directions independently; therefore, algorithm is suitable for parallel processing. In addition to this property, detection performance and motion parameter estimation accuracy is high because of the non-sequential processing of range and azimuth motion detection. Computer simulations gives promising results of detecting moving targets in all directions and also extracting motion parameters of the detected target.

1 INTRODUCTION

Synthetic aperture radar technology brings new developments in modern world. Today, numerous SAR applications are seen in very different areas. These applications include environmental research, scientific, civilian and military purposes. The main application area of SAR is aimed for detailed imaging of specific earth terrains. By using SAR imagery technology, any terrain image can be collected easily. These detailed images are useful for researching terrain properties.

Detection and motion parameter estimation of moving targets within the observed region is also possible by using the SAR images. Information of detected moving objects can be used in very different applications, such as monitoring traffic flow (Palubinskas and Runge, 2008), observation of military field, tracking of a specific moving target and motion parameter estimation of the targets.

Different algorithms are proposed for detection of moving targets. They are detecting moving targets by using displaced phase centre antenna (Jung, 2009, and Qin, Zhang and Dong, 2006), along track interferometry (Kohleppel and Gierull, 2008), single-channel radar processing (Li, Xu, Peng and Xia, 2006, Liu, Yuan, Gao and Mao, 2007, Kirscht,

1998, and Kirscht, 2002), and focusing algorithms (Fienup, 2001).

As discussed by Kirscht (1998), moving targets are appeared defocused or at wrong positions depending on the direction of the target motion within the SAR image. If a target moves in azimuth direction, motion causes blurring effect in azimuth direction, and if it moves in range direction, motion also causes a displacement in azimuth direction or for a higher range velocity of the target, it even disappears (Kirscht, 1998 and Fienup, 2001). Many algorithms are evaluated based on these blurring and displacement effects on the images to detect moving targets.

Our proposed algorithm is capable of detecting targets moving not only in azimuth direction, but also in range direction. “Sub-aperture processing” and “shear averaging algorithm” is used to detect moving targets in range and azimuth directions respectively. Detection algorithm for range direction and for azimuth direction can be processed separately. This property gives the advantage of using parallel processing techniques. Therefore range and azimuth movement processes can be completed simultaneously. Also, independent motion detection processing of range and azimuth movements gives more accurate detection results.

2 THE PROPOSED ALGORITHM

In the proposed algorithm, single-channel SAR system is considered and spotlight mode raw data is used. A good clutter cancellation is applied before starting the algorithm steps.

Motion effects on the SAR images as discussed by Kirscht (1998) and Fienup (2001) are used in the algorithm. Target motion in azimuth direction, causes smear effect due to the motion induced phase errors. On the other hand, target motion in range direction causes displacement of the targets in azimuth direction.

After all moving targets has been detected number of detected targets, their velocities and movement directions are reported. Range and azimuth movement detection processes are detailed in the following subsections.

2.1 Range Direction Movement Detection

In the proposed algorithm, range direction movement is detected by using sub-aperture processing (Franceschetti and Lanari, 1999). Raw data is divided in two equal blocks across the azimuth direction, and two SAR images are formed. This process provides looking to the same observed region in two different time intervals. The first image contains data from beginning to the divided position of the antenna. Therefore, an image is generated for “t” time position of the antenna. The second image contains data from the divided position to the end position of the antenna. So, second image is generated for “t + 1” time position of the antenna.

After generation of the images, these two images are overlapped with the help of the SAR system parameters. By taking the difference between the two overlapped images, stationary targets will be disappeared and only moving targets within the observed region are detected.

After moving target has been detected, position difference of the target between the first and the second images gives the range direction movement information of the target. This information is used to extract range direction motion parameters.

2.2 Azimuth Direction Movement Detection

Shear averaging algorithm is used for detecting moving targets in azimuth direction. There are

numerous algorithms for detecting azimuth movement. But shear averaging algorithm is chosen for its sensitivity to the azimuth component of velocity, providing very fast calculation, higher order phase errors detection ability, and not requiring a prominent point scatterer on the target (Fienup, 2001).

In the algorithm, whole image is divided into small patches. By processing each patch, moving targets can be detected by using “shear averaging algorithm” detailed by Fienup (1989). If good clutter cancellation is applied at the beginning of the algorithm, only targets will be stayed in the image. So, moving targets can accurately be detected with very low false alarm rate.

In the proposed algorithm, following steps are used to detect azimuth motion.

- a. Divide the image into patches.
- b. Take a patch data, $g(u,v)$.
- c. Calculate $G(u,v)$ by taking azimuth FFT of $g(u,v)$.
- d. Calculate shear averaged quantity.
- e. Calculate phase error estimate in azimuth coordinate.
- f. Make phase correction.
- g. Take inverse Fourier of corrected data.
- h. Calculate standard deviation of the phase error.
- i. Compare standard deviation value with the threshold value to detect moving target.
- j. If a moving target is detected, find the azimuth velocity of the target by using the system model.

Threshold value could be calculated by processing either whole image or only patch data. The whole image processing gives a fixed threshold value. But, for good detection results in simulations, dynamic threshold value is calculated for each patch.

In “jth” step of the algorithm, azimuth velocity is calculated by finding the displacement of position of maximum amplitude within the unfocused and focused images. From simulation results, a relationship between real target velocity and detected target velocity is extracted and shown in Figure 1. This relation is used as a reference system model for the velocity estimation of the detected targets.

By combining the range and azimuth direction detection results, the real movement direction and velocity of the target is calculated.

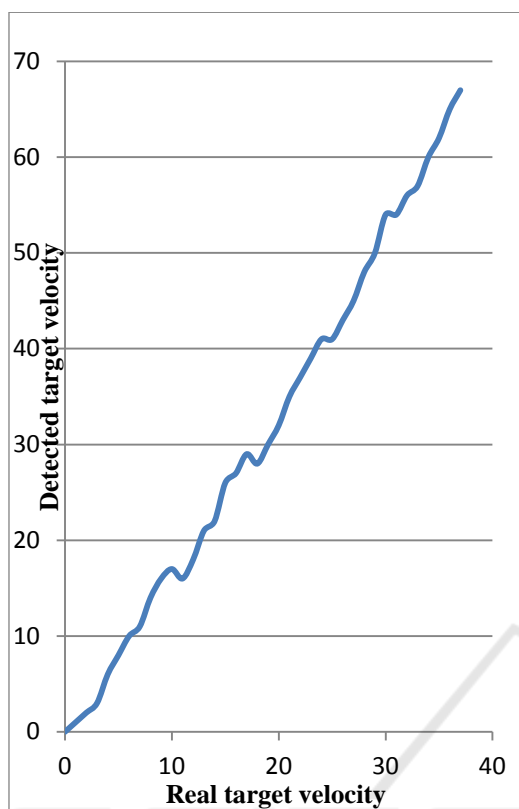


Figure 1: System model, extracted from simulation results, is used to find the azimuth velocity estimation of moving targets in azimuth direction.

process, moving targets with velocities smaller than 1.56m/s couldn't be detected by using two sub-apertures. But all other targets and also their movement direction are detected successfully.

Table 1: Simulation system parameters.

Center Frequency	10 GHz
Pulse duration	1 μ s
Radar PRF	200 Hz
Sampling Frequency	180 MHz
Chirp rate	1.5×10^{14}
Platform velocity	200 m/s
Slant range scene center	10 km
Resolution range	0.3 m
Resolution azimuth	0.3 m
Squint angle	0°
Scene size	200 m x 200 m
SAR image size	512x512 pixels
Number of sub-apertures	2
Aperture size (Az x Range)	256x512 pixels
Patch size (Az x Range)	128x16 pixels
Moving target velocity	3.9 m/s

Excluding targets with very low range velocities, the moving targets are detected and separated from stationary targets by sub-aperture processing. Also, their motion parameters are extracted. In addition to range direction detection results, azimuth movement, its direction and velocity of the target are detected successfully.

3 SIMULATION RESULTS

The performance of the proposed algorithm is tested with Matlab simulation. In the simulation scenario, moving and stationary targets are put within the simulation data. The simulated scene used in the simulations is shown in Figure 2. Simulated SAR system parameters are given in the Table 1.

Simulated scene contains 3 targets. Only the rightmost target is non-stationary, and the other two are stationary. The moving target is marked in the images shown in Figure 3 and Figure 4. In these figures, moving targets have a constant velocity of 3.9m/s (14km/h) only in range and azimuth direction, respectively.

In the simulation scenarios, moving targets with different velocities between 0.39m/s to 15.6m/s are considered. All moving targets in the azimuth direction are detected successfully, and target velocities are estimated by using the system model given in Figure 1. On the range velocity detection

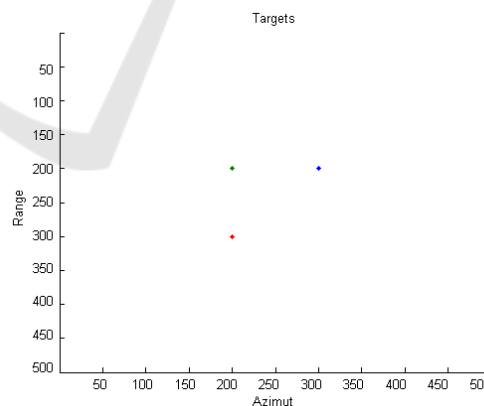


Figure 2: Simulated scene.

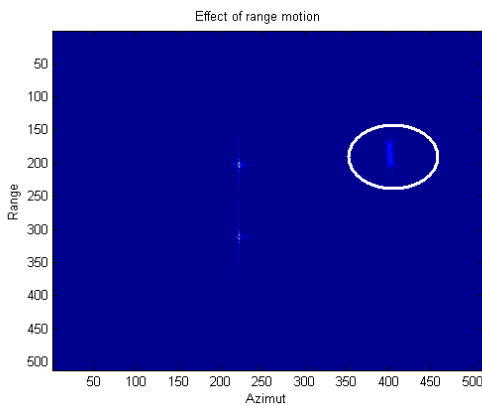


Figure 3: Range-only motion.

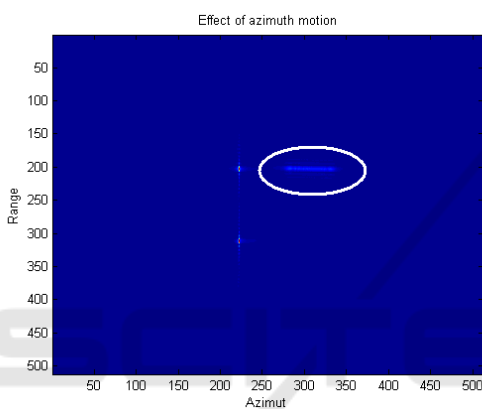


Figure 4: Azimuth-only motion.

4 CONCLUSION

A new algorithm for detecting both range and azimuth motion of moving targets in SAR images is proposed. The combination of sub-aperture processing and shear averaging algorithms provides the detection of the movement in all directions. Detection algorithm is processed in range and azimuth directions independently; therefore parallel processing techniques could be used. By parallel processing, moving targets can be detected very fast. Algorithm is capable of not only moving target detection, but also motion parameter estimation of the moving targets. Moreover, detection performance and motion parameter estimation accuracy is high because of the non-sequential processing of range and azimuth direction movement.

REFERENCES

- Fienup, J.R., 1989. Phase Error Correction by Shear Averaging. In *Optical Society of America, Signal Recovery and Synthesis III, digest of papers*.
- Fienup, J.R., 2001. Detecting Moving Targets in SAR imagery by focusing. In *IEEE Transactions on Aerospace and Electronic Systems*.
- Franceschetti, G. and Lanari, R., 1999. *Synthetic Aperture Radar Processing*, CRC Press. London.
- Jung, J.H., 2009. Ground Moving Target Displacement Compensation in the DPCA based SAR-GMTI System. In *2009 IEEE Radar Conference*.
- Kirscht, M., 1998. Detection, Velocity Estimation and Imaging of Moving Targets with Single-Channel SAR. In *Proc. of European Conference on Synthetic Aperture Radar, EUSAR '98*.
- Kirscht, M., 2002. Detection and imaging of arbitrarily moving targets with single-channel SAR. In *RADAR 2002*.
- Kohlleppel, R. and Gierull, G., 2008. Enhancement of along-track interferometry for ground moving target indication. In *International Geoscience and Remote Sensing Symposium*.
- Li, G., Xu, J., Peng, Y. and Xia, X., 2006. Detection, Velocity Estimation and Imaging of Fast Moving Targets Using Single Antenna SAR. In *International Conference on Radar, 2006*.
- Liu, S., Yuan, Y., Gao, F. and Mao, S., 2007. Method of moving target detection based on sub-image cancellation for single-antenna airborne synthetic aperture radar. In *Journal of Systems Engineering and Electronics*.
- Palubinskas, G. and Runge, H., 2008. Detection of Traffic Congestion in SAR Imagery. In *Proc. of 7th European Conference on SAR, Friedrichshafen, Germany*.
- Qin, F., Zhang, X., and Dong, M., 2006. A method of hybrid ATI and DPCA technique to detect moving target. In *CIE '06, International Conference on Radar*.