NASoftware Limited
Incorporating InfoSAR

SARMTI Image Analysis

SAR provides all-weather high resolution images of ground scenes; typically these are presented to an operator for interpretation. Hoewever, the data collected to form these images contains substantial information about the scene which can be extracted automatically to provide operator assistance or even trigger a response to the scene. Modern surveillance radars, such as the UK ASTOR or Watchkeeper,
operate in dual mode. They have a SAR mode, which offers high-resolution (≈1m) imagery of stationary objects making up a scene, i.e. a mapping mode. The GMTI mode detects targets with radial motion and measures their velocity with lower cross-range resolution (≈100m).
They cannot operate in both modes simultaneously so the operator selects which mode it should operate in. Both systems are suboptimum in that they do not make use of all the information in the radar return. SAR operates on low-frequency components to form the map; high frequencies caused by target motion degrade the image. GMTI operates on high-frequency Doppler shifts and is limited by the low-frequency returns that lie in the clutter notch. NASoftware SARMTI uses all the information within the radar return to provide both sets of information at high resolution simultaneously from the same data set.

One novel technique developed by NASoftware is SARMTI: the ability to produce moving target information directly from SAR data. SARMTI operates by exploiting the response of the basic SAR filter to moving targets. In fact, conventional SAR is merely a special case of the SARMTI processor, when the target is not moving. This technique has major advantages compared with the currently used MTI methodology:

- No need for a separate MTI mode or additional antennae.
- Estimates across-track velocity and acceleration and along-track velocity, for both slow and fast movers. Motion estimates are about 10 times better than MTI
- Automatic registration within SAR image, to within one pixel. Azimuthal registration is about 100-1000 times better than MTI
- Distributed targets are imaged at full resolution so that target recognition techniques can be applied.
- Moving targets are detected and dominant motions measured, unlike either SAR or MTI.
- Target resolution is the same as SAR and much better than MTI.
- Target position accuracy is the same as SAR and much better than MTI.
- Target automatically registered in background clutter, unlike MTI.
- SARMTI yields identical high resolution imaging of moving targets in both range and cross-range (≈1m). GMTI cross-range resolution is determined by the real beam width (≈100m).

- Moving targets at the same range and lying within ≈2m in cross-range direction can be resolved and detected in SARMTI. This is not possible with GMTI.
- Target recognition algorithms could be applied to the images of moving targets in SARMTI. This is not possible with GMTI.
- Images of the moving targets can be inserted at the correct position in the background map image within the resolution of the SAR system in both range and cross-range (i.e. ≈1m) with SARMTI. This is not possible with GMTI.
- Range velocity can be derived more accurately in SARMTI than GMTI. In addition, the range acceleration and cross-range velocity of each moving target can be measured in SARMTI . This is not possible with GMTI.
- Moving target detection is more sensitive with SARMTI than GMTI because of the higher cross-range resolution.
- Very slow movers, which overlap the clutter notch, can be detected and their motions measured with SARMTI. This is not possible with GMTI.

An important aspect of SARMTI is that it operates on the output of a conventional single-phase-centre SAR with no modification to the SAR system hardware. It is a signal-processing function that operates on the Phase History Data from the conventional SAR. Thus SARMTI can be introduced as an upgrade to existing SAR systems.

Another key principle is the realisation that both SAR and MTI represent different suboptimum approaches to deriving information from a radar return:

- SAR concentrates on low-frequency signals alone. It yields high-resolution mapping of stationary scenes. Moving objects degrade the result.
- MTI exploits the high-frequency components in the radar return to derive range velocity and detect moving targets. Narrowband clutter degrades the result.
- SARMTI represents an optimum approach which utilises all frequency information within the radar return. Thus it combines the good features of both SAR and MTI.

Example Scenario

As an example we show an image that demonstrates some of the advantages of this SARMTI algorithm. A typical SAR image of an urban area at Tsukuba in Japan was imaged with PiSAR. This has 1.5m resolution with 1.25m pixel spacing. The image was first segmented to derive underlying RCS. This corresponds to the background in Figure 1. Roads, open areas and buildings are clearly visible.

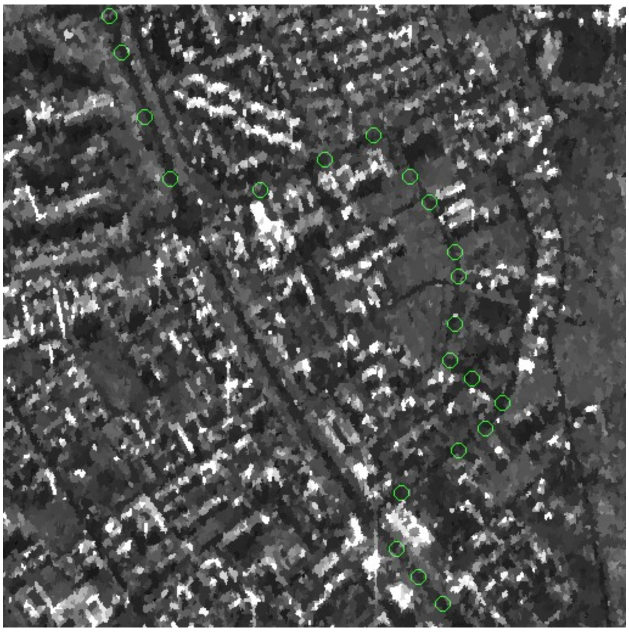

Figure 1: Moving targets inserted in an urban area.

This segmented image was adopted as the background RCS. Moving targets were then inserted, starting down the main road from top left to bottom right. The moving targets then detoured away from this main road and followed side streets before returning to the main road. The received signal from the background and moving targets, travelling in each direction along the streets, was then simulated and the SAR image for a stationary scene constructed, as shown in Figure 2. It is apparent that the responses from the different moving targets are displaced and blurred in both range and cross-range.

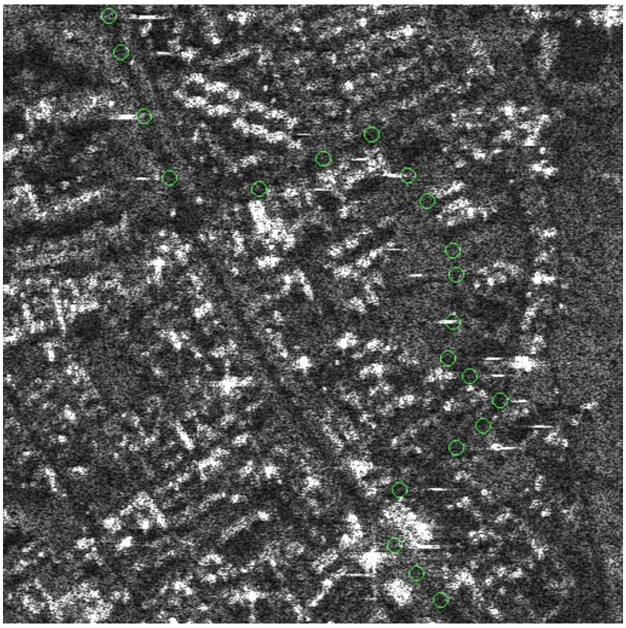

Figure 2: Simulated SAR image of urban area with moving targets. Original target positions denoted by green circles.

The SARMTI algorithm was then applied to this data and various moving targets were detected, as illustrated in Figure 3. These detections are inserted back onto the original segmentation. It is apparent that there are 5 false detections, mainly arising in regions of strong clutter. However, all 21 movers are detected and placed within one or two pixels of their correct position. It is perfectly possible to follow the route that these movers took through the side streets. This suggests that this SARMTI algoriothm could have great potential operational value.

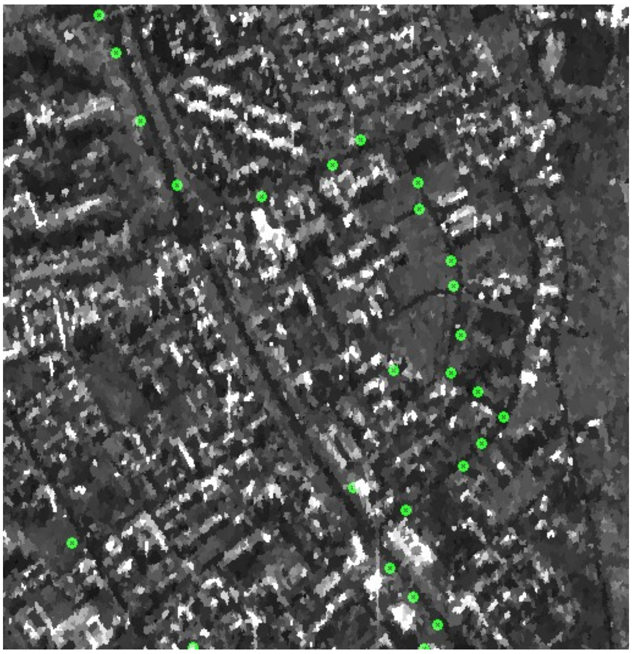

Figure 3: Detected movers imposed on the segmented image.

Applications

There are many military and civil applications; civil applications include:

1. Traffic Monitoring

   Any location can be covered without the use of any roadside equipment and individual vehicles can be tracked. This is particularly useful for remote area surveillance.

2. Disaster Monitoring

   Disasters could be monitored in terms of traffic flow. MTI would establish general regions where SARMTI could show detail.

3. Coastal Monitoring

   High resolution monitoring of coastal traffic is possible with the potential for vessel recognition and tracking.

4. Policing

Cross border smuggling activities could be monitored in more inaccessible regions and suspect vehicles could be tracked in uninstrumented areas.

5. Terrorism

The above applies to terrorism with a key advantage being that this type of tracking would be unknown to the suspects.

Real Time SARMTI

The SARMTI technique is necessarily compute intensive. A conventional approach to providing fast implementations of a DSP application would be to utilise COTS DSP boards populated with currently popular DSP-oriented processors.

We worked with Raytheon NCS, and Intel Corporation to see how difficult a real time implementation would be. We looked at an Intel solution using a single Intel Caneland 4-socket system populated by 1.86GHz 45nm, Quad-Core Intel "Tigertown" processors. We see this setup as having several potential advantages:

1. A single Caneland system populated with quad-core processors provides 16 cores in an SMP environment, making it relatively straightforward to utilise all cores on a single executable by multithreading the code.
2. Current Intel processors will run at clock rates very significantly higher than more specialised DSP processors.
3. Intel enhancements to their instruction set, and their unrivalled experience in producing low power consumption processors, make them increasingly attractive for today's advanced airborne DSP applications.
4. Provision is made on the Caneland board for including standard DSP accelerators; the FPGA modules are socket compatible with the Four socket Caneland system and with Intel Xeon® processor-based dual-socket server boards. Thus, the potential advantages of a tailored FPGA solution to handle standard parts of the code, such as FFTs, is not lost by the primary use of COTS general-purpose Intel processors.
5. Intel provides a well-developed C compiler (icc) and a rich set of porting and optimisation tools with which to tune a multithreaded port of the application.

Results

The original application represented demonstrator code for the technique being studied; it generated simulated SAR data prior to processing this data and provided four runtime parameter sets generating four typical scenes.

Excluding the data generation, the code contained 20,000 lines of C and was unthreaded. As we were already familiar with the application, we profiled the code and produced an initial threaded version; minor alterations to the code were made for better efficiency. The unthreaded and initial threaded versions utilized FFTW library functions. The threaded code was then optimized by calling the FFTW functions with

Intel Math Kernel Library (MKL) FFTW wrappers and using vector operations from the MKL.

The following table shows the performance improvement that has been achieved on the Caneland system. The table below shows that the code is between 13.3 and 17 times quicker after the above optimisations have been carried out.

Phase 1 timings

	Demo 1.	**Demo 2.**	**Demo 3.**	**Demo 4.**
Original Time.	85 secs	120 secs	104 secs	166 secs
Optimised Time.	6.4 secs	8.5 secs	6.1 secs	11.8 secs
Speed Up. (Times quicker).	13.3 times	14.1 times	17.0 times	14.1 times
System Configuration Information: Intel® SFC4UR: "Foxcove" Rack Mount Server with 4 Quad Core Intel Xeon™ Processors L7345 ("Tigerton"), (1.86 GHz, 8MB L2 Cache, 1066 MHz FSB). The system includes 4 memory boards with 16MB of 667MHz FBDIMMs and a 73 GB SAS hard disk drive. CentOS* 5.1, 64-bit release ("x86_64) . gcc version 4.1.2 ; FFTW library; Intel icc 10.1, Intel Math Kernel Library (MKL) 10.0. Compile flags: gcc –O3 –xT, icc –O3 –xT; icc –O3 –xT –ip –fno-alias –fargument-noalias.				

Conclusions

This report on the principles underlying the SARMTI algorithm has demonstrated various important capabilities:

- Standard SAR radar data can be reprocessed using this algorithm to extract detections of moving targets and derive their motions.
- Slow moving targets, within the clutter band, can be detected.
- The correct position of moving targets is derived to within SAR resolution.
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- The targets are imaged at full SAR resolution.
- This means that the same target recognition methods that work for stationary targets can be applied to movers.
- The method is always significantly more sensitive than GMTI

If you would like to discuss the SARMTI technique with us then either email us at marketing@nasoftware.co.uk or call us on +44 151 609 1911.