ATR Performance Using Enhanced Resolution SAR

L.M. Novak, G.R. Benitz, G.J. Owirka, and L.A. Bessette
MIT Lincoln Laboratory

Abstract

MIT Lincoln Laboratory has developed a complete, end-to-end, automatic target detection/recognition (ATD/R) system for synthetic aperture radar (SAR) data. A data-adaptive approach has been developed to enhance SAR image resolution based on super-resolution techniques – the approach is called high-definition imaging (HDI). This paper quantifies the improvement in ATR performance from enhanced resolution SAR imagery in the Lincoln Laboratory ATD/R system.

Introduction

Under DARPA sponsorship, MIT Lincoln Laboratory has developed a complete, end-to-end, automatic target detection/recognition (ATD/R) system for synthetic aperture radar (SAR) data. An evaluation of the performance of the Lincoln Laboratory ATD/R system has been documented in detail elsewhere [1,2]. Currently there is considerable interest in the use of resolution enhancement (super-resolution) techniques to improve performance of the automatic target recognition (ATR) stage.

MIT Lincoln Laboratory has developed a data-adaptive approach to enhance SAR image resolution based on super-resolution techniques – the approach is called high-definition imaging (HDI) [3]. The HDI algorithm employed is a version of the Constrained-Weight 2-Dimensional Maximum Likelihood Method (2-D MLM). It is a 2-D extension of the MLM adaptive-beamforming/super-resolution algorithm, also known as the Capon algorithm. The benefits of 2-D MLM include improved resolution (i.e., narrower lobe-widths than conventional imaging), reduced side-lobes, and reduced speckle. The algorithm employs complex imagery (magnitude and phase) as an input and performs approximately $10^7$ real operations per output pixel. This computational load is only one order of magnitude greater than current operational imaging techniques; hence, real-time operation of 2-D MLM is feasible. This paper quantifies the improvement in ATR performance from enhanced resolution SAR imagery in the Lincoln Laboratory ATD/R system.

System Description

Figure 1 shows a notional block diagram of the multi-stage ATD/R system. The performance of the ATD/R system was evaluated using single polarization (HH), 1.0 m $\times$ 1.0 m resolution, Ka-band data in the prescreening and discrimination stages. To evaluate the benefits of 2-D MLM processing in the system, the performance of the classifier was evaluated for the following three cases: (1) 1.0 m $\times$ 1.0 m resolution data, (2) 1.0 m $\times$ 1.0 m resolution data 2-D MLM processed to approximately 0.5 m $\times$ 0.5 m resolution data, and (3) true 0.5 m $\times$ 0.5 m resolution data. Note that we were able to perform these evaluations because the data we used was gathered at 0.3 m $\times$ 0.3 m resolution; thus we have the ability to reprocess the data to 0.5 m $\times$ 0.5 m and 1.0 m $\times$ 1.0 m resolution. The 2-D MLM processed imagery was used only in the classification stage for two reasons: First, from our evaluations in [2] it was observed that the use of the medium resolution (1.0 m $\times$ 1.0 m) data in the early stages of the ATD/R system followed by the use of higher resolution processing in the later stages did not significantly degrade overall system performance. Second, most of the “uninteresting” clutter false alarms have been rejected at the discrimination stage, thereby reducing the processing load on 2-D MLM.

Results

In these studies, a total of 74 km$^2$ of clutter imagery were used (56 km$^2$ of mixed natural and cultural clutter from Stockbridge, NY and 18 km$^2$ of highly cultural clutter from Ayer, MA). The target imagery used in these studies was gathered over several aircraft passes in SAR spotlight mode and provided a full 360 degrees of classification templates of a TEL type target (for the three above mentioned cases) and 192 independent target images for the ATD/R system testing. Figures 2 and 3 present ROC curves for the 56 km$^2$ of Stockbridge, NY clutter and the full 74 km$^2$ of clutter respectively; these ROC curves show that the overall performance of the ATR system is not significantly degraded by the introduction of highly cultural clutter. These two figures also show the main result of this study: using 2D MLM processed imagery in the classification stage of the ATR system provided significantly improved performance over the 1.0 m $\times$ 1.0 m resolution system; in fact, the 2D MLM classification stage provided system performance which was as good as the system performance obtained when true 0.5 m $\times$ 0.5 m resolution data were used in the classification stage.

References

Figure 1: (a) A notional block diagram of the multi-stage ATD/R system. HDI processed $1.0 \times 1.0$ m data provided system performance as good as true $0.5 \times 0.5$ m data.

Figure 1: (b) A notional block diagram of the multi-stage ATD/R system. In this case a total of $74 \text{ km}^2$ of clutter were used to evaluate performance. Note that system performance is not significantly degraded by the addition of highly cultural clutter.
Figure 2: ROC curves for the 56 km² Stockbridge clutter data and 192 TEL target images.

Figure 3: ROC curves for the 74 km² combined Stockbridge, NY and Ayer, MA clutter data and 192 TEL target images.