Chapter 2

Methods for Improving the Performance of an SAR Recognition System

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Summary. The focus of this chapter is on methods for improving the performance of a model-based system for recognizing vehicles in synthetic aperture radar (SAR) imagery under the extended operating conditions of object articulation, occlusion, and configuration variants. The fundamental approach uses recognition models based on quasi-invariant local features, radar scattering center locations, and magnitudes. Three basic extensions to this approach are discussed: (1) incorporation of additional features; (2) exploitation of a priori knowledge of object similarity represented and stored in the model-base; and (3) integration of multiple recognizers at different look angles. Extensive experimental recognition results are presented in terms of receiver operating characteristic (ROC) curves to show the effects of these extensions on SAR recognition performance for real vehicle targets with articulation, configuration variants, and occlusion.

2.1 Introduction

In this chapter we are concerned with methods for improving the recognition of vehicles in Synthetic Aperture Radar (SAR) imagery. The recognition systems start with real SAR chips (at one foot resolution) of actual military vehicles from the MSTAR public data \([1]\) and end with the identification of a specific vehicle type (e.g., a T72 tank). Several major challenges for identifying the vehicles are the presence of significant external configuration variants (fuel barrels, searchlights, etc.), articulated configurations (such as a tank with its turret rotated), and partial occlusion. The detection theory \([2, 3]\), pattern recognition \([4, 5, 6]\), and neural network \([7]\) approaches to SAR recognition all tend to use global features that are optimized for standard, non-articulated, non-occluded configurations. Approaches that rely on global features are not appropriate for recognizing occluded or articulated objects because occlusion and articulation change global features like the object outline and major axis \([8]\). Our previous work \([9, 10, 11, 12]\), relied on local features to successfully recognize articulated and highly occluded objects. SAR recognition results for
our basic approach are compared (in [9]) to other different approaches using real SAR images from the MSTAR public data.

In our research on SAR automatic target recognition (ATR), we initially started using invariant locations of SAR scattering centers as features [12] and later developed our basic recognition approach based on using quasi-invariant locations and magnitudes of the scattering centers [9, 10, 11]. This followed the traditional approach to improving recognition performance by finding additional features that can help to distinguish between the objects. This is the first method of improvement discussed in this chapter. The second method of exploiting model similarity was inspired by the research on predicting the performance of recognition systems by Boshra and Bhanu [13] that introduced the idea that recognition performance depends on the distortion in the test data and the inherent similarity of the object models. Related to the third method for improving recognition performance, we had previously shown that a significant number of SAR scattering center locations do not typically persist over a few degrees of rotation [10]. However, this had been viewed as a problem for modeling, rather than a potential opportunity for independent observations at different look angles. In this chapter, we integrate results from multiple look angles to improve recognition performance.

This chapter discusses three basic approaches to improve the performance of an SAR recognition system:

1. Incorporation of additional features.
2. Exploitation of a priori knowledge of object similarity.
3. Integration of multiple recognizers at different look angles.

The next section discusses SAR target characteristics; Section 2.3 gives a description of the basic SAR recognition system; Section 2.4 introduces the additional feature of peak shape factor and shows performance improvements for additional features; Section 2.5 describes techniques to measure and utilize model similarity to improve recognition performance; Section 2.6 demonstrates the independence of multiple look angle SAR recognition and the results for performance improvements; and the final Section 2.7 provides the conclusions of the chapter.

### 2.2 SAR Target Characteristics

The typical detailed edge and straight line features of man-made objects in the visual world do not have good counterparts in SAR images for subcomponents of vehicle-sized objects at one-foot resolution. However, there is a wealth of peaks corresponding to scattering centers. The relative locations of SAR scattering centers, determined from local peaks in the radar return, are related to the aspect and physical geometry of the object, independent of translation and serve as distinguishing features. Target regions-of-interest (ROI) are found in the MSTAR SAR chips by reducing speckle noise using