Chapter 101
Automatic Target Recognition From Inverse Synthetic Aperture Radar Images

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ABSTRACT

In this chapter, Inverse Synthetic Aperture Radar, a special type of active microwave synthetic aperture radar is introduced and its applications in military surveillance are presented. Then, the basic principles involved in data acquisition and image generation are explained. The issues and challenges involved in processing the ISAR images for autonomous target detection and identification are discussed later. The proposed classification method is explained and its accuracy is evaluated experimentally against the conventional classification method in the rest of the chapter.

INTRODUCTION

Target recognition is the process of detection and identification of enemy targets such as ships, submarines, aircrafts, missiles, tanks, artillery shells, mortar shells, rockets, howitzers and armed personnel carriers etc. in military surveillance by the data gathered from different sensors. The sensor data is usually images generated by different sensing devices such as optical camera, forward looking infrared camera, Laser Radar, Synthetic Aperture Radar or from Inverse Synthetic Aperture Radar.

Optical and infrared cameras are ubiquitous these days and are widely used for short range surveillance purposes. They are unsuitable for military surveillance because they largely fail in extreme weather conditions. Imaging radars such as SAR and ISAR typically serve the military needs in target recognition. But, however, as SAR technology is not suitable for imaging the targets in motion. ISAR is the most accepted and adopted technology by the Navy and the Coast guard for surveillance and target recognition purposes because of its long range imaging capability and its ability to work in almost all

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the weather conditions day and night to image the targets moving unpredictably. The images generated by the ISAR (ISAR images) are used for the purpose of target recognition extensively.

Progressive research in the microwave and image processing technologies is providing opportunities to develop high capable radar systems employing multiple frequencies and polarizations with advanced target recognition capabilities. The auxiliary features of microwave radar technology such as day-and-night, extreme weather operations, and the ability to penetrate through foliage, surfaces, cloud and ground are adding more advantages in military surveillance over optical and infrared radar systems. Advanced image processing techniques are playing key role in the removal of noise and in extracting the targets carefully from the superfluous background details which affect the accuracy of the target recognition. As rapid response is crucial in advanced remote sensing applications such as artillery shell detection and tracking; missile early warning and defense; automatic missile guidance; air, ground and maritime surveillance the need of advanced image processing and artificial intelligence techniques is increasing in development of autonomous decision making systems.

Basically, radar is a remote sensor or remote object detection system. It uses electromagnetic radiation to detect the range, speed, direction, altitude and other characteristics of remote objects. The abbreviation radar comes from RAdio Detection And Ranging. The basic principle of radar is to illuminate an object with the help of electromagnetic radiation and analyze the received response.

Even though radar systems were introduced in the beginning of the twentieth century, they were not used widely until the 1930s. The developments in the radar technology were accelerated when the military realized the usefulness of radars in defense surveillance. They became popular during World War II due to their great military utility. Now radars are widely used for applications such as air traffic control, weather forecasting, navigation of ships, and speed limit enforcement. Radars have been adapted not only to be able to give range and bearing to a target, but to characterize the size and number of objects in the target, and, with more advanced techniques, actually create pictures of objects. These techniques can work through clouds and at night, where photographic imaging would be useless.

Imaging radars are used in the defense patrol for the surveillance purposes to detect the maneuvering aircrafts, ships, guided missiles, motor vehicles moving strategically. Imaging radars are the special type of radars used to capture the images of the targets. These radars create two dimensional mappings (radar images) of the ground, environment, environmental conditions and targets of interest. The advantage of radars over the optical imaging sensors is that the radars are least sensitive to bad weather conditions such as cloud and rain. In order to use a camera, not only good weather is needed, but also sunlight to illuminate the ground.

Inverse Synthetic Aperture Radar (ISAR) is an imaging radar. It uses advanced microwave technologies to generate two-dimensional radar images of the targets moving in non-cooperative way such as ships, aircrafts, tanks, armed personnel carriers and space objects even in smoke, fog, haze and rain. ISAR radars are used in military patrol in hostile environments to capture the images of intriguing targets where the optical imaging systems fail utterly. ISAR is akin to conventional Synthetic Aperture Radar (SAR). Even though both radars follow the same underlying theory, the geometrical configurations of the SAR and ISAR differs them. In SAR imaging, the target is stationary and the radar is mounted on an aircraft. But, in ISAR imaging the radar is stationary and the target is moving irrationally. SAR is the most accepted active microwave imaging radar used to capture the images of terrain, ocean and atmosphere since decades. SAR uses the radar platform motion to generate its synthetic aperture. On contrary, ISAR uses the motion of the radar platform as well as the motion of the target to generate