A SAR ATR Method using WVV Descriptor of a Subset of Scattering Centers

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Abstract: Automatic target recognition with SAR image (SAR ATR) is crucial for military and civilian applications. SAR image can be obtained in most weather types, day-and-night, and high resolution. In response, researchers have developed feature-based classification methods for ATR with scattering center (SC) extracted from SAR image, which provides a physically relevant description of the target. However, classification in realistic scenarios is still difficult as the number and distribution of SCs could sensitively change according to various operating conditions such as target, sensor, and environment. The key challenge lies in one-to-one correspondence of the point pattern matching between the test and the corresponding template. For practical SAR ATR applications, collecting datasets in various conditions is also another challenge as it is expensive and involves several complex processes. It is useful to replace the templates for train with simulated SAR images created by electromagnetic prediction software using a computer-aided design (e.g CAD) model of the target in that case. However, there are significantly distributional differences between measured data and synthetic data because of the difference in the used CAD model and real model or the type of simulator, which causes poor recognition rates under standard operating conditions (SOC). Therefore, it is necessary to develop a robust ATR method to classify targets under extended operating conditions (EOC) as the real world even when tested by measured data and trained by synthetic data. One promising way to overcome these challenges is to reconstruct the SCs by using the world view vector (WVV) descriptor, which contains a set of 360 vectors represented by the angular coordinate. The WVV-based feature reconstruction with point location and amplitude could consider the structure similarity as well as the point similarity for the two SC sets.

In this paper, we propose an improved WVV-based ATR method using a subset of the SCs, instead of using all SCs. The flowchart is divided into 3 steps, a subset of SCs selection, WVV-based reconstruction, and matching score computation. Once the SC sets of the test and template are extracted, a subset of SCs within the statistically calculated radius is only selected and then reconstructed by the WVV descriptor. The WVV is created by computation of the polar radius and the polar angle of the rest points after establishing a polar coordinate system with origin at each point. The polar angles are then resampled at intervals of 1° and the polar radii are interpolated linearly. Finally, the SC sets are reconstructed into the WVV set as the same number of the SC sets. The similarities between the test and template are evaluated based on the WVV sets

and the amplitudes. Regarding the similarity as the weight of the bipartite graph matching, we find the optimal matching between the two SC sets. Afterwards, the matching score is determined to recognize the target by measuring the WVV-based similarity and then combining several weights related to the matched/unmatched number of SCs and selected/unselected number of SCs.

To evaluate the classification performance of our method, experiments are conducted on MSTAR and SAMPLE datasets under the standard operation condition (SOC) and various extended operation conditions (EOC) including noise corruption and partial occlusion. As a dataset for experiments, Moving and Stationary Target Acquisition and Recognition (MSTAR) has been widely used in the past two decades which consists of a collection of one-foot resolution SAR images collected at all azimuth angles. Meanwhile, synthetic and Measured Paired and Labeled Experiment (SAMPLE) is a dataset recently released by AFRL, which consists of measured and simulated SAR images using CAD models of 10-class MSTAR targets. Unfortunately, only some parts of the SAMPLE dataset collected at 10° to 80° azimuth angles are publicly open. The proposed method was first evaluated under SOC on the 10 classes of targets for overall classification accuracy. When the testing data are defined as the MSTAR dataset from each class collected at 15 depression angle and the training data are collected at 17 depression angle, the recognition rate is about 95%. Secondly, experiments are conducted under EOCs, noise corruption, and partial occlusion. When the SCs are randomly removed according to the percentage of missed points, the performance maintains at a high level of over 80% until the percentage is smaller than 65%. When the test data is occluded from randomly four different directions, the performance still maintains at a high level over 80% until the occlusion level of 30%. In the end, an experiment is conducted with SAMPLE dataset for exploration how effectively our method could be used in a real scenario on training synthetic images. The recognition rate is in the range of 85% to 90% depending on the template's depression angle. Compared with several state-of-the-art SAR ATR methods, our results show the feasibility and robustness when using the simulated image as template and the real SAR image as test data

We have provided an improved WVV-based ATR method using a subset of the SCs. The previous method using all SCs has robust ATR capability, insensitive to translation, random perturbation, and random addition and deletion of SCs. However, if some parts of the test and template SC sets were different, the WVV-based similarity was very low, and the classification result was wrong as the set of 360 vectors is sensitively changed according to the distribution of SCs. In the real world, the occlusion of target by external environment like artificial or natural objects could always happen. Therefore, we developed the method that is less susceptible to partial differences between the two SC sets by selecting a subset of SCs and considering several weights related to the unmatched number of SCs and unselected number of SCs which couldn't be applied to the WVV-based similarity. For evaluation of our proposed method, we conducted several experiments under SOC and EOC. When using measured data as test and template, our performances in experiments are similar or a little higher than other SAR ATR methods. However, even when the template consists of only synthetic data, the ability to classify targets is very

excellent. Therefore, we expect that the proposed method would be useful in a practical SAR ATR system with simulated images as the template DB. Future works can be conducted beyond the experiments presented here with more synthetic SAR images.

Keywords: SAR ATR; World View Vector (WVV); Scattering center (SC); SAMPLE.