POSE ESTIMATION FOR ISAR IMAGE CLASSIFICATION

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1. INTRODUCTION

Automatic Target Recognition (ATR) systems are an important part of modern military strategy. Correct recognition of military targets such as aircraft, naval ships, missiles etc, is indispensable to attack the target accurately. However, several kinds of radar signatures can be applied to acquire information about the target characteristics. Usually, these radar signatures deal with the extraction of certain geometrical parameters or characteristics of a target that can be obtained from a radar image such as Inverse Synthetic Aperture Radar (ISAR). On the other hand, estimating the pose of target can improve the ATR performance (recognition rate and complexity) by inserting this information into the ATR system. Therefore, pose estimation of SAR imagery is very important to the ATR.

In this work, we present a radar information system for target recognition based on ISAR images that incorporate the pose information. The methodology used in this framework is issued from artificial intelligence in following the Knowledge Discovery from Data (KDD) Process which has been adapted to radar field. Generally, four steps are usually involved in automatic target recognition (ATR). They are data acquisition, data pre-processing, data representation and data classification for decision making. These four steps are illustrated in figure 1.

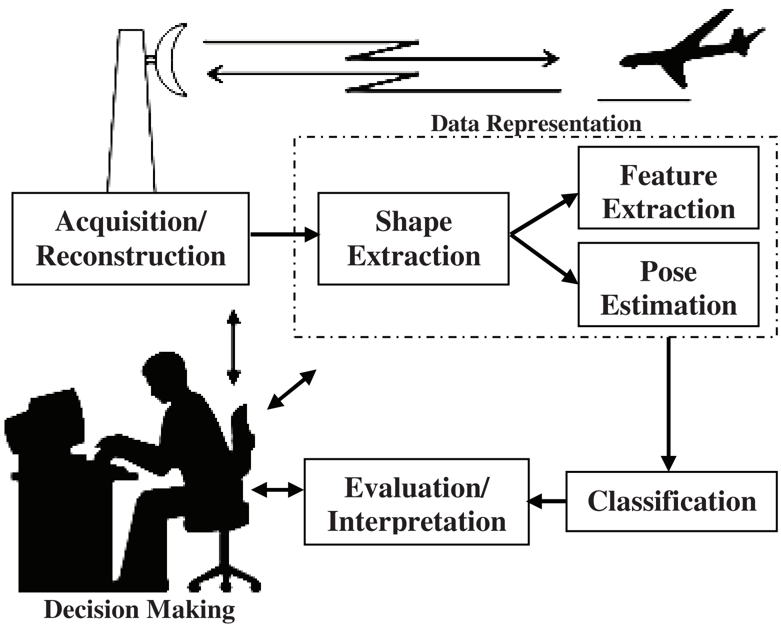


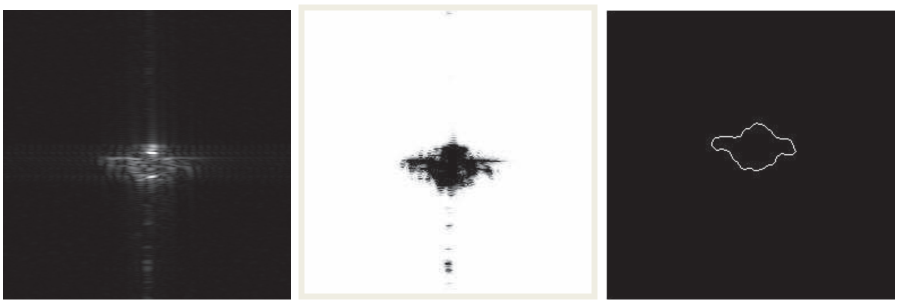
Fig. 1. Process for radar ATR system

After extracting the target shape from ISAR images, the shape descriptors are computed using two methods: the Fast Fourier Transform (FFT) and Moment Invariants (MI). The classification stage is finally performed using K-Nearest Neighbor (K-NN) and its version that incorporate the angle information, K-Nearest Angle (K-NA). These two classifiers are based on Euclidean distance.

2. METHODS AND EXPERIMENTAL RESULTS

2.1. Shape Extraction

Several approaches for shape extraction have been proposed and tested such as filtering method, watershed segmentation and GVF methods. All these methods did not yield satisfactory results. The best results, from both visual and classification perspectives, were obtained by the method that we have proposed in [1], a modified version of SUSAN algorithm followed by active curves evolution via Level Set. An example of this method is shown on Figure 2.



a) b) c)

Fig. 2. Results of shape extraction, a) ISAR image of Mig. 29, c) a modified version of SUSAN algorithm, d) The final shape extracted by Level Set

2.2. Pose estimation

Generally, the pose of a target is described by three degrees of freedom: roll, pitch, and yaw. However, in our experiment, the target depends of two angles: the elevation angle θ and the azimuth angle β. The interaction between radar and target is illustrated in fig.3.

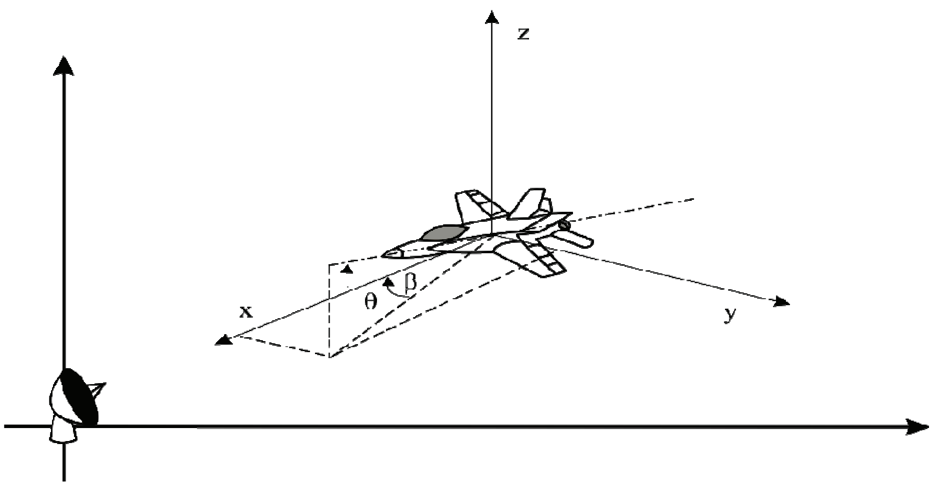


Fig. 3. The interaction between radar and target

Different image analysis techniques are used for pose estimation especially in SAR imagery, such as principle component analysis (PCA) [2], 2-D continuous wavelet transform (CWT) [3] and the Hough transform [4]. Another techniques consist of an adaptive classifier that requires training from truth data have been applied [5]. All these methods did not yield satisfactory results. The best results were obtained by the method that we propose in this paper. It consists to find the best axe of symmetry of the target shape. First, we use the Hough transform to find rapidly (save much computational resources) the initial axe of symmetry, then the result obtained is adjusted by scanning the angles neighbors. An example of this method is shown on Figure 4. In the full paper, we will compare our method with the methods of pose estimation discussed above.

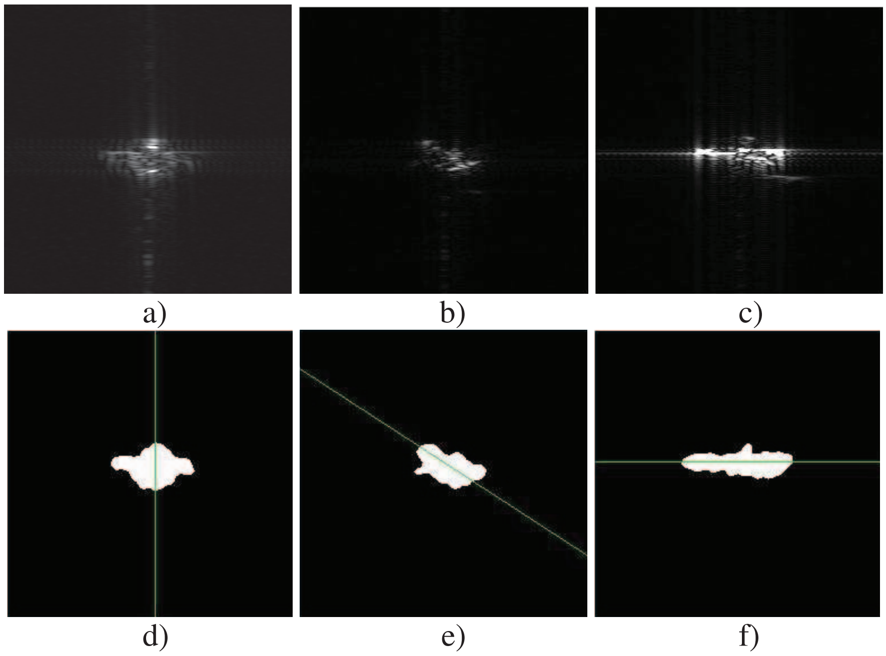


Fig. 4. ISAR images for Mig.29 for an elevation angle of 0° at several azimuth angle : a) ~0°, b) ~45°, c) ~90° and respectively their pose estimation obtained by our method : d) 0°, e) 90°, f) 48°

2.3. Shape Descriptors

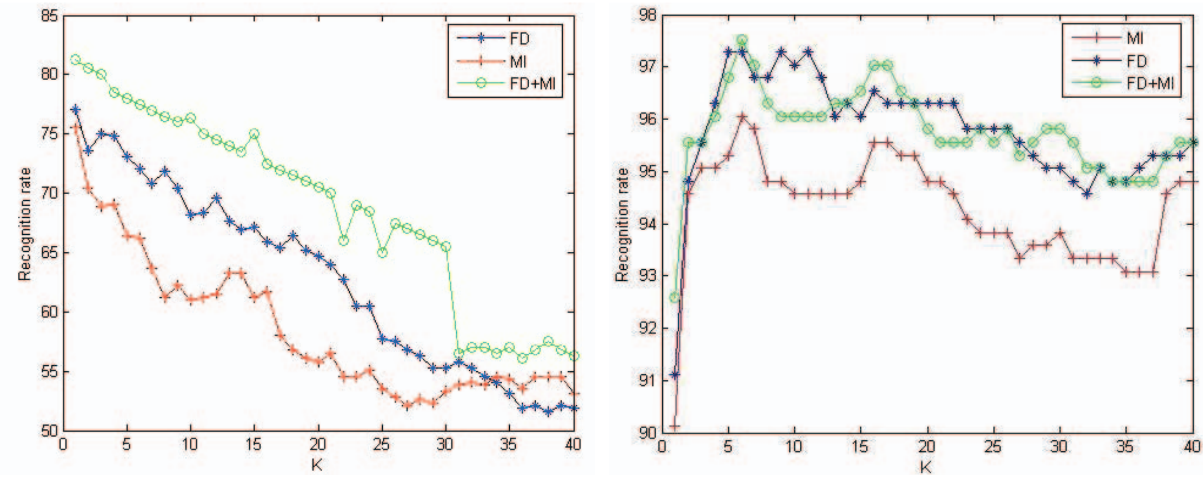
After extracting the target shape, we use two types of shape descriptors: Fourier Descriptors (FD) [6] and Moments Invariants (MI) [7]. FD and MI belong respectively to two different families, algebraic invariants and integral invariants. FD and MI are widely used as shape features due to their good performance in recognition systems and their implementation simplicity and efficiency. They are invariant to almost all geometrical transformations such as translation, scaling and rotation. We use each of these feature vectors for classification (FD, MI), as well as their fusion (FD+MI).

2.4. Experimental results

Experiments are carried out on synthetic data simulated in an anechoic chamber of ENSIETA (Brest, France). We used seven targets in our experimentation (A10, F16, Mig29, Rafale, Tornado, F117 and Harrier), placed on tunable support, and controlled remotely by a computer (Pentium IV). These targets represent aircraft scale reduced models (1/48). For each target we have 162 ISAR images of 256 × 256 grayscale pixels, and each image has a different angle of rotation (azimuth angle). After extracting the target shape, the Fourier descriptors (FD=31 descriptors) and the moment invariants

(MI=7 coefficients) are computed. The whole database is divided randomly into two data sets, 100 images of each target (61%) are used to construct the training data and the remaining images are used for testing.

Figure 5 shows the classification scores obtained using K-NN and K-NA (we assume that we know the true values of the angles), respectively for k varying from 1 to 40. Three conclusions can be drawn from these results. First, for both classifiers, the FD concatenated with MI descriptors seem to be more accurate than the use of each alone. Second, the K-NA classifier yields good results and significantly outperforms the K-NN one. We will present the results of K-NA classifier by using the angles estimated. We will also present results using a fusion of the two classifiers using probability theory and belief theory.



a) b)

Fig. 5. Classification rates according to techniques of shape descriptors using: a) K-NN, b) K-NA

3. REFERENCES

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