Air Objects Recognition by the Phase Correlation Method

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***Abstract*—The article considers a method for determining the type of an air object on a digital image by comparing it with standard images using the phase correlation method.**

Keywords—airobject; image classification; phase correlation method.

I. Introduction

Systems for the detection and recognition of various classes of airborne objects (AO) are increasingly using optical video surveillance as an additional and even as basic tool. This is due both to the use of stealth technologies that mask the characteristics of an object in the radar detection area, and to advances in computer vision. Until recently, only airplanes were the object of detection in the tasks of recognizing the air situation. But in modern conditions, the list of AO classes has significantly expanded due to the use of unmanned aerial vehicles (UAVs), quadcopters, cruise missiles, and helicopters. This fundamentally changed the range of the AO's detectable parameters, from the shape and size to the dynamic characteristics of motion. In this connection, the task of improving the quality of recognition of the AO classes from digital video is especially urgent.

Video processing by ground-based air monitoring systems can be divided into a number of tasks. Among them, the following tasks can be distinguished: detection of a moving flying object; determination of object characteristics (range, size, speed, maneuverability, etc.); definition of AO class. These tasks can be solved both in stages and simultaneously. This can be the detection of all objects in one frame with the definition of their class and their subsequent accompaniment in the sequence of video frames, or the detection of moving objects in the video sequence with the subsequent identification of objects at each frame. In the proposed approach, we assume that a moving object or objects will first be detected and localized in the video image, and then the problem of assigning each object to a certain class will be solved.

In the field of pattern recognition in an image, the following stable terminology has been adopted for defining tasks [1]: detection – determining the class of each object in the image; classification – determination of the class of one object in the image; classification with localization – classification of one object and indication of its place in the image.

In this terminology, our task is the task of classifying an air object in a digital image.

II. The problem statements analysis and research objectives

In recognizing a AO class important to highlight the numerical characteristics of an object that are sufficient for its identification. The problem is that these features must be invariant with respect to geometric distortion (displacement, orientation, scale) of the object, which is especially important for AO. To partially overcome this difficulty, an approach is used with the calculation of numerical values that are invariant to the rotation of the image on the plane. These characteristics include *Xy* moments, Zernike moments and Wavelet moments [2, 3].

In this case, the classification problem is solved, as a rule, by machine learning methods [2] which leads to large expenditures of computing resources at the stage of training and operation.

In [4] various methods of using invariant moments are presented, and in [5] the application of these methods for recognizing AO classes is shown.

The paper [6] describes the solution of the recognition problem based on phase correlation. In [7], a method for comparing three-dimensional objects using phase correlation is described. In this paper, a method is proposed for calculating the degree of similarity between 3D objects, taking into account displacement and rotation along the *x*, *y*, and *z* axes using the phase correlation method.

This approach gives good results for aircraft recognition in aerospace images of aerodromes, where variations in object position are limited by turns on the plane. These methods are less suitable for recognizing a flying air object. For this kind of tasks, various methods of recognizing three-dimensional objects are used. Phase-Only Correlation (POC) allows you to recognize similar objects and determine their transformation [8].

The invariance of the moments with respect to image shift, zoom and rotation in the shooting plane gives good results in the problem of recognition when two-dimensional images are the reference ones. In practical problems associated with AO images, objects are usually present not only at different angles, but also with different illumination. However, the phase correlation method is robust to uneven, time-varying lighting changes. Therefore, the phase correlation method gives a better result than the approach based on invariant moments.

This work is devoted to the study of the phase correlation method. Section 3 discusses the theoretical background of the method, and Section 4 proposes a method for generating a set of images for the experiment. Section 5 describes an experiment with detecting an airborne object and determining the angle of rotation with respect to the standard. Section 6 discusses the results obtained.

III. Theoretical Background of the Phase Corelation Method

In describing one-dimensional signals, the phase of harmonic signals in spectral decomposition is quite important. But this is most clearly seen when obtaining a spectrum of a photographic image as a result of a two-dimensional Fourier transform.

Fig. 1 illustrates this statement using a real image of the A380 as input. The Fourier transform is applied to it. If we reconstruct the image in the first case by ignoring (zeroing) the phase, and in the second case, ignore the difference in amplitudes (all equal to 1), we find that information about the phase component is more important for understanding the image.

The phase part of the Fourier transform of the image contains much more recognizable information.

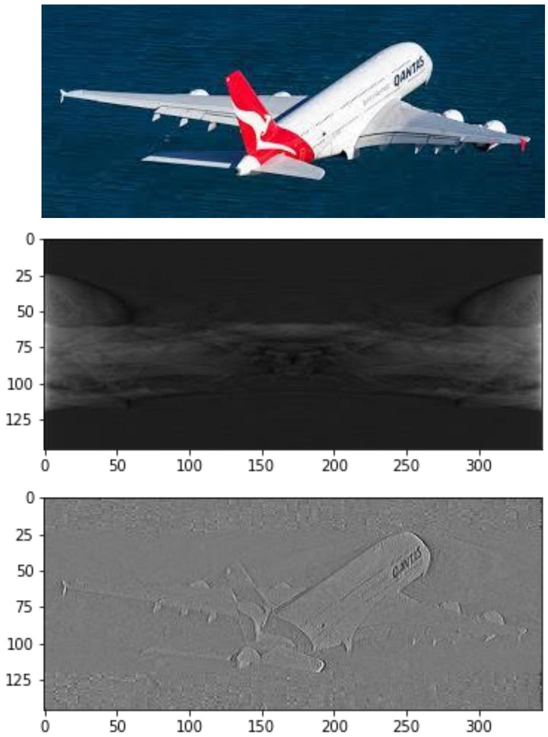


Fig. 1. Importance of phase information to Fourier transform Original image reconstructed ignoring phase and ignoring amplitude

The phase correlation is based on the Fourier shift property theorem: a coordinate system shift between two functions results in a linear phase difference in the frequency domain of the Fourier transform. If two two-dimensional functions $g_1(x, y)$ and $g_2(x, y)$, representing two images, are shifted relative to each other by a_1 horizontally and a_2 vertically:

$$g_2(x, y) = g_1(x+a_1, y+a_2), \qquad (1)$$

then their corresponding Fourier transforms $G_1(u, v)$ and $G_2(u, v)$ are related to each other as follows:

$$G_2(u, v) = G_1(u, v)\exp\{-i(a_1 \cdot u+a_2 \cdot v)\}. \qquad (2)$$

The phase correlation is calculated as the normalized cross-spectrum between G_1 and G_2 and is represented by a matrix:

$$K(u,v) = \frac{G_1(u,v)\overline{G_2(u,v)}}{\left|G_1(u,v)\overline{G_2(u,v)}\right|}, \qquad (3)$$

where $\overline{G_2(u,v)}$ is conjugate to $G_2(u,v)$.

The inverse Fourier transform for $K(u, v)$ is the delta function:

$$k(x,y) = \delta(x+a_1, y+a_2). \qquad (3)$$

In a discrete case, this means that the point at which $k(x, y)$ reaches its maximum determines the amount of shift between images. And the maximum itself determines the degree of similarity of the images.

If the spectrum is logarithmized, the phase shift in the exponent becomes a normal shift and can be detected by the maximum brightness values in the correlation image of the logarithmic spectra. This allows you to evaluate the rotation of the image.

IV. Database Generation

To recognize an airborne object, a set of reference images is needed, which is collected into a single database, with which a real sample will be compared.

To generate the initial AO images, we used three-dimensional mesh models as in Fig. 2.

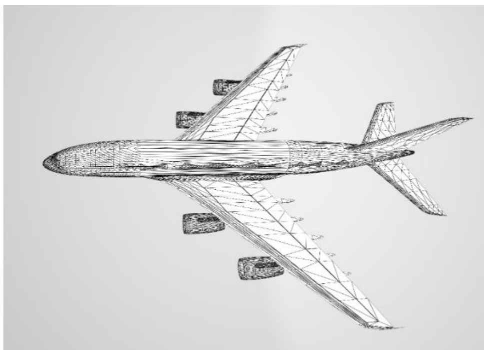


Fig. 2. Grid three-dimensional model of the A380 aircraft

For this task, models were used to determine one of the classes: aircraft, UAV, helicopter, quadcopter (Fig. 3). Different kinds of objects were used for each class.

At the same time, for each object, images corresponding to three different projections were used as a reference flat image (Fig. 4).

Fig. 3. Three-dimensional models of the main classes of AO for testing the phase correlation method

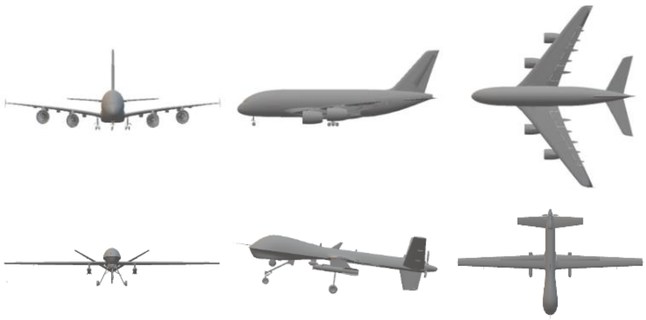
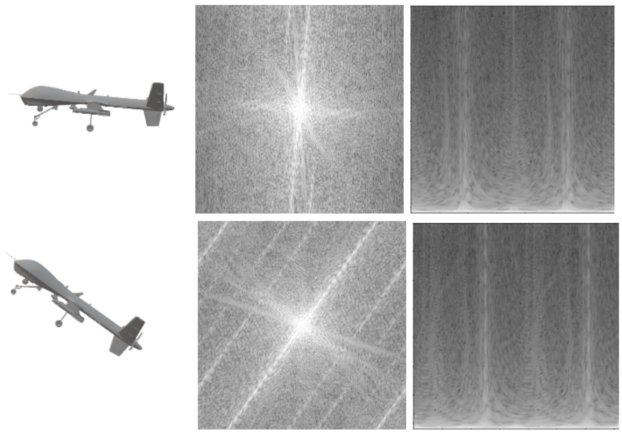


Fig. 4. Images corresponding to three different projections for aircraft and UAV

V. Experiment results

The experiments were carried out with test images of the same classes as those used in the database. Fig. 5 shows the reference and test image of the UAV. Their Fourier transforms already show the similarity of the images, the logarithmic spectrum translates the difference in angular position into the usual linear displacement.



a *b* *c*

Fig. 5. Image processing phases: *a* – reference and test image of the UAV, *b* – its Fourier transform; *c* – logarithmic spectrum

The correlation function (Fig. 6) allows not only to determine the similarity, but also to set the angle of rotation in relation to the reference image.

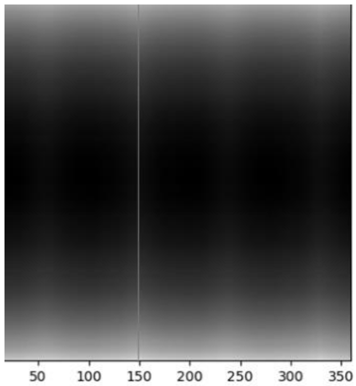


Fig. 6. Image of the correlation function for logarithmic spectra

The software for the project was developed in terms of 3D modeling in C #. The results processing programs are written in Python using the OpenCV library.

VI. Conclusions

The proposed approach makes it possible to obtain a solution to the problem of assigning an AO to a certain class and to calculate the characteristics of its position. This will also make it possible to determine the AO maneuver when analyzing the video sequence of images.

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