Investigation of MINACE composite filter capabilities for multicolor images correlation recognition purposes

N N Evtikhiev, E Yu Zlokazov, E K Petrova, R S Starikov, D V Shaulskiy
National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe shosse, 31, 115409 Moscow, Russia

E-mail: k1121@mail.ru

Abstract. Article represents the results of investigations in the area of distortion invariant images recognition using composite correlation filters. One of the most successive for application is a filter known as MINACE (minimum noise and average correlation energy). The capabilities of MINACE filter synthesis for multicolor image recognition problem are discussed.

1. Introduction
Application of CF (composite filters) allows to increase the degree of target object variance of correlation image recognition method in presence of object image distortions such as plane or spatial rotation, scaling, illumination changes, deformation etc. The main idea of CF synthesis is based on substitution target object single reference image by linear combination of several images with target object under different a priori determined appearance variations. One of the most perspective CF for application is MINACE (minimum noise and average correlation energy) filter [1]. This type of CF demonstrated good results of target object recognition represented by grayscale images with complex backgrounds and spatial noises. Moreover MINACE filter synthesis algorithms are simple by means of computational burden [2-6]. Also the possibility of realization of MINACE filter based correlation image recognition method in optical image correlator attracts a special interest [7-9].

The usage of several color channels in target object images allows to enhance the result of object recognition problem, as multicolor images can provide more information about objects than halftone images in some cases. The present article is dedicated to the problem of multicolor images correlation recognition using MINACE CF.

2. Problem description
The modeling problem conditions assume discrimination of target object images from three types of clutter objects images in conditions of plane rotation. Figure 1 illustrates the examples of images under researches. All the images had resolution of 512x512 pixels. The standard RGB colors model is used in the work. MINACE CFs were synthesized according to the method described in [7-9]. The discrimination capability of filters was estimated using Neyman–Pearson criterion.

Different types of MINACE CFs were synthesized for preliminary tests. All the synthesized CF were trained to invariantly recognize a target object under different plane rotations in the range of 45 degrees. All the preliminary CF had different synthesis conditions such as amount of training images etc.
Figure 1. Examples of test images. Target object (T-true) clutter objects (F-false)

Figure 2. Target object images in different colors.

Figure 3. a) Halftone grayscale image of target object; b) red channel image of target object.

3. Preliminary modeling

Different types of MINAE CFs were synthesized for preliminary tests. All the synthesized CF were trained to invariantly recognize a target object under different plane rotations in the range of 45 degrees. All the preliminary CF had different synthesis conditions such as amount of training images etc.

Figure 4 represents the example of MINACE CF discrimination characteristic for red channel images of test objects. In most cases the probability of correct discrimination was estimated to be more than 99.9% according to Neyman–Pearson criterion. Also target object recognition results were obtained for the case of complex scene image of test objects (figure 5a). Figure 5b illustrates the result of correlation function calculation of MINACE CF and the scene from figure 5a. Presented result demonstrates high discrimination stability of MINACE CF in conditions of high similarity of target and clutter objects forms.
Figure 4. Example of MINACE CF discrimination characteristics – the dependence of correlation peak height from input object rotation angle. Thick solid blue line – target object correlation characteristic, thin lines – clutter objects characteristics, dashed line – threshold value.

Figure 5. a) The image of a complex scene contained by target and clutter test images; b) example of calculated correlation function between MINACE CF and scene from figure 5. Target object has the highest correlation peak.
4. Problem description
The discrimination possibility of objects with the same form and different colors was investigated. For simplicity we used an object images with only one non zero color channel, for example the red one or green. An objects were placed on multicolor background with active both red and green channels. See for example figures 2a and 2b. Several variants of a recognition task were discovered:
- both training images and images to be recognized had all three color channels;
- training images had only red channel representation while images to be recognized had three-cannel RGB representation.

![Figure 6](image1.png)

**Figure 6.** a) The scene with two target object images in different colors; b) calculated correlation field of this scene and MINACE CF.

A green channel was used for object representation in training images. Images to be recognized had green color to represent object. All the color channels that represent the test object had the maximum sharpness of color. The obtained discrimination characteristics of target object and three clutter objects demonstrated the high obtainable quality of recognition. Also the modeling of recognition of a scene with two images of target object in different colors using CF synthesized on a basis of target object images in all three color channels. The results are illustrated on figures 6–8. These results demonstrate the efficiency of multicolor recognition.

![Figure 7](image2.png)

**Figure 7.** a) Halftone grayscale image of target object; b) red channel image of target object.
5. Different background and object colors

The possibilities of recognition quality enhancement due to utilization of object and background color differences information is discussed. We discovered the case when green and red channels are used for object representation and blue and green colors are used for background (see figure 2c). The next recognition conditions were studied:

- both training images and images to be recognized had all the RGB channels in representation;
- both training images and images to be recognized had only red channel representation with suppressed green and blue channels;
- training images had only red channel while images to be recognized were represented using all the thee RGB channels.

It was observed that in all cases the probability of correct recognition was more than 99%. The highest recognition quality was observed in the case of one channel selection in training images.

Figure 9 represents the example of discrimination characteristic obtained in the case of training set of only red channel images and test images in all three color representation.

Figure 9. Discrimination characteristic of MINACE CF obtained in modeling the case when training images had only red channel representation while images to be recognized had full RGB colors representation.
6. Conclusion
The represented results show the principal possibilities of multicolor images correlation recognition invariant to target object distortions using MINACE composite filters (CF). A mathematical modeling of these filters was provided. The obtained results demonstrate the increase of flexibility and quality of object recognition using multicolor information of object images.

Further researches assume investigation of more complicated objects recognition and quantitative estimation of possible quality enhancement by varying of color channels information during the filter synthesis

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