Bucket detection for object recognition

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Abstract. A method of Bucket detection is taken to determine the similarity between the detected object and the reference object by measuring the intensity correlation between the two detectors. This model is based on an optical theory and provides a theoretical way of realizing object recognition.

1. Introduction
Target recognition is very important in complex environment and emergency environment, for example, the identification of the life body in the ruins of the great earthquake, the recognition of the enemy aircraft and identification of the types of the enemy aircraft. In practical problems, people usually use multiple ways to identify targets, and then analyze those results to make the accuracy of the results increase and react quickly[1, 2]. Recently in the theoretical and experimental research on the process of thermal ghost imaging, We found a method for target recognition provided by coincidence measurement based on the optical principle of ghost imaging[3-8]

2. Model establishment
Ghost imaging [4,5] has become a focus of great attention as well as contention, which is obtained by the second-order correlation of the intensity of the two detectors. One is the bucket detector to measure the total light intensity passing through an object, while the other detector never interacts with the object. Recently we find that this scheme modified a little can be used to realized object recognition.

FIG. 1. A model for the object recognition
The model setup of object recognition is shown in Fig. 1. A pseudothermal light source propagates through a beam splitter and then is divided into two beams. One beam passes through a reference object T1 and detected by one bucket detector D1, and the other passes through a test object T2 and detected by the other bucket detector D2. Then by measuring the intensity correlation between the two detectors, a method of bucket detection is taken to determine the similarity between the detected object and the reference object. Thus this model based on an optical theory provides a theoretical way of realizing object recognition.

3. Principle and Discussion

We assume that $E_0(x_0)$, $E_1(x_1)$ and $E_2(x_2)$ are fields at the source plane and the two detection planes, respectively. $x_0$, $x_1$, and $x_2$ are the transverse coordinates of the light source plane and the detection planes, respectively. $T_1(x_1)$ and $T_2(x_2)$ are the transmittance functions for the reference and test objects, respectively. Here the bucket detection is performed between the arms.

The light fields $E_1(x_1)$ and $E_2(x_2)$ at the detection plane are related to the field $E_0(x_0)$ at the source plane by the Fresnel diffraction integral,

$$E_j(x_j) = \int E_0(x_0) h(x_j, x_0) dx_0,$$

with $j=1,2$. And $h(x, x_0)$ is the impulse response functions,

$$h(x, x_0) = \frac{1}{\sqrt{\lambda z}} \exp[-i \frac{\pi}{4} + ikz + i \frac{k}{2z}(x-x_0)^2] T(x),$$

Where $k$ is the wave number, $\lambda$ is the wavelength, and $z$ is the distance from the source plane to the detection plane, respectively.

The intensity of the bucket detector can be written as

$$I_j = \int I_j(x_j) dx_j = \int E_j^*(x_j) E_j(x_j) dx_j, \quad j = 1,2,$$

thus the intensity correlation between the two detectors is written as

$$\langle I_1I_2 \rangle = \langle I_1 \rangle \langle I_2 \rangle + \int \int |\langle E_1^*(x_1) E_2(x_2) \rangle|^2 dx_1 dx_2,$$

Where $\langle I_1 \rangle$ and $\langle I_2 \rangle$ are the intensity averages of the two bucket detectors.

Assume the source field $E_0$ to be spatially complete incoherent

$$\langle E_0^*(x_0) E_0(x_0) \rangle = I_0 \delta(x_0 - x_0'),$$

$I_0$ is the constant light intensity. Thus the average intensity of the detector is

$$\langle I_j \rangle = \int \langle E_j^*(x_j) E_j(x_j) \rangle dx_j = \frac{I_0}{\lambda z} S_j,$$

Where $S_j = \int |T(x_j)|^2 dx_j$ is the light translucent area of an object. When $z_1 = z_2$,

$$\langle E_1^*(x_1) E_2(x_2) \rangle = I_0 T_1^*(x_1) T_2(x_2) \exp[i \frac{k}{2z}(x_2^2 - x_1^2)] \delta(x_2 - x_1).$$

And so
\[ \int \left| E_1(x_1) E_2(x_2) \right|^2 dx_1 dx_2 = I_0^2 \int |T_1(x_1)|^2 |T_2(x_2)|^2 dx_1 = I_0^2 \int |T_1(x_2)|^2 |T_2(x_1)|^2 dx_2 \]  

(8)

Defined the coefficient \( K \) as

\[ K = \int |T_1(x_1)|^2 |T_2(x_2)|^2 dx_2 = \int |T_1(x_1)|^2 |T_2(x_1)|^2 dx_1 , \]

(9)

the second-order correlation function between the two detectors is

\[ \langle I_1 I_2 \rangle - \langle I_1 \rangle \langle I_2 \rangle = I_0^2 K . \]

(10)

Thus

\[ K = \frac{\langle I_1 I_2 \rangle - \langle I_1 \rangle \langle I_2 \rangle}{I_0^2} , \]

(11)

and

\[ 0 \leq K \leq 1 \]

(12)

From Eq. (9), when \( z_1 = z_2 \) and the test object is identical to the reference object, \( K = 1 \). While when the two objects are orthogonal or different completely, \( K = 0 \). Thus this model based on an optical theory provides a theoretical way of realizing object recognition.

When performing target recognition, rotate the reference target object for multiple measurements, and if the maximum value of the measurements is 1, the object to be detected is exactly the same as the reference target. The size of the \( K \) reflects the same degree of the object to be detected as the reference object.

4. Conclusion

In this paper, an appropriate model is established by using optical principle, and a method for target recognition is provided by coincidence measurement. The results show that the same degree of the object to be detected and reference object can be determined by measuring the intensity-dependent fluctuation of the two detectors. The next step can be related to experimental validation.

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