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이미지 데이터베이스에서 객체의 타원형 부분의 대칭특성에 기반을 둔 부분객체인식방법

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요 약

이 논문에서 겹쳐지고 잘린 이미지내의 타원형 객체들 가운데 부분적으로 겹쳐져 보이지 않는 외형과 객체 내 영역을 재구성하고 계산하기 위한 방법을 제안한다. 대칭 속성을 이용하여 부분적으로 겹쳐져 보이지 않는 객체를 인식하기 위해서 객체내의 부분인식에 기반을 둔 방법이다. 이 방법은 객체 내에서 대칭축을 이용하여 영역 복사를 통한 보이지 않는 영역을 복원하는 간결한 방법을 제시한다. 이 방법은 통계적 예측보다 대칭 기반의 객체 복원에 의존하기 때문에 부분적으로 겹쳐져 보이지 않는 부분에 대해서 측정된 변수를 가지고 분류 트리를 이용하여 객체 인식를 수행한다. 이는 비록 객체의 자세에는 한계를 가지고 있지만 크기 변경이나 회전, 시각의 변화에서 부분적으로 가려진 객체를 인식하는데 뛰어난 것으로 나타났다.

키워드 : 객체, 이미지, 부분인식, 대칭, 타원

Partial Object Recognition based on Ellipse of Objects using Symmetry in Image Databases

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ABSTRACT

This paper discusses the problem of partial object recognition in image databases. We propose the method to reconstruct and estimate partially occluded shapes and regions of objects in images from overlapping and cutting. We present the robust method for recognizing partially occluded objects based on symmetry properties, which is based on an ellipse of objects. Our method provides simple techniques to reconstruct occluded regions via a region copy using the symmetry axis within an object. Since our method relies on reconstruction of the object based on the symmetry rather than statistical estimates, it has proven to be remarkably robust in recognizing partially occluded objects in the presence of scale changes, rotation, and viewpoint changes.

Key Words : Object, Image, Partial Recognition, Symmetry, Ellipse

1. Introduction

Most existing methods for object recognition are based on full objects. However, many images in electronic catalogs contain multiple objects with occluded shapes and regions. Due to the occlusion of objects, image retrieval can provide incomplete, uncertain, and inaccurate results. To resolve this problem, we propose a new method to reconstruct objects using symmetry properties of objects since most objects in a given image database are represented by symmetrical figures.

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Our approach can handle object rotation and scaling for dealing with occlusion, and does not require extensive training processes. The main advantage of our approach is that it becomes simple to reconstruct objects from occlusions.

We present a robust method for recognizing partially occluded objects based on symmetry properties, which is based on an ellipse within objects. The part-based approach finds a symmetry axis using a reconstructed ellipse in the occluded object.

In experiments, we demonstrate how our method reconstruct and recognize occluded shapes and regions using symmetry. Experiments use rotated and scaled objects for dealing with occlusion. Our method provides a simple method to reconstruct occluded regions via a region copy using the symmetry axis within an object. We also evaluate the recognition rate of the reconstructed objects using symmetry and the visible portion of the occluded objects for recognition. Experimental results show that the reconstructed objects are properly recognized by our method.

The rest of this paper is organized as follows. In Section 2, we briefly review work related to this study. In Section 3, we describe a method to recognize partial objects from given classes. In Section 4, we describe experimental results for partial object recognition. Finally, we summarize this paper in Section 5.

2. Related Work

There have been several research efforts in object recognition for dealing with occlusion. Jacobs and Basri [9] provided an approach, which is focused on the problem of determining the pose of 3D objects. Krumm [10] proposed a new algorithm, which uses models based on training images of the object, with each model representing one pose.

Williams and Hanson [17] described a method for visual reconstruction of visible and occluded forward facing surfaces from image contour. For object recognition, Schiele et al. [15] proposed a method to perform partial object recognition using statistical methods, which are based on multidimensional receptive field histograms. In addition, Rajpal et al. [13] introduced a method for partial object recognition using neural network based indexing.

A number of more recent works have used edges for object recognition. Mikolajczyk et al. [11] generalize Lowe's SIFT descriptors to edge images, where the position and orientation of edges are used to create local shape descriptors that are orientation and scale invariant. Carmichael's [2] approach uses a cascade of classifiers of increasing aperture size, trained to recognize local edge configurations, to discriminate between object edges and clutter edges; this method, however, is not invariant to changes in image rotation or scale. David et al. [6] uses model and image line features to locate complex objects in high clutter environments. Finding correspondences between model and image features is the main challenge in most object recognition systems.

In appearance-based object recognition, Leonardis and Bischof [1] handled occlusion, scaling, and translation by randomly selecting image points from the scene and their corresponding points in the basis eigenvectors. Rao [14] applied the adaptive learning of eigenspace basis vectors in appearance-based methods. Ohba and Ikeuchi [12] were able to handle translation and occlusion of an object using eigenwindows.

Current methods for dealing with occlusion have been based on template matching, statistical approaches using localized invariants, and recognition of occluded regions based on local features. In this paper, we propose the unique methodology in object recognition for dealing with occlusion based on symmetry properties through the ellipse reconstruction of an object.

Even though there have been several efforts in object recognition with occlusion, current methods have been highly sensitive to object pose and scaling. In addition, many object recognition methods assumed that they have known occluded regions of objects or images through extensive training processes. However, our method is not limited to recognizing occluded objects by pose and scale changes, and does not require extensive training processes.

3. The Proposed Method

The following sections describe how to reconstruct and estimate occluded shapes and regions of objects. We discuss the object reconstruction and the parameter estimation methods to find the best matching class of input objects using the classification tree method [4]. We extracted shape parameters from reconstructed objects using RLC lines, such as roundness, aspect ratio, form factor, surface regularity. [5]

The basic assumption is that most objects are represented by symmetrical figures and they have an ellipse within an object. We can simply detect an ellipse using a tool.

First, we reconstruct an ellipse in objects, and then we reconstruct the occluded region of objects using symmetry property. In this section, we discuss how to reconstruct an elliptical portion of an object, and how to estimate partially occluded objects based on the reconstructed ellipse using symmetry.

Some researchers have provided methods for elliptical object detection using geometrical properties [8,18] and the Hough transform [19]. A working environment for this study is electronic catalogs, which include objects like pans, pots, cups, and plates. These objects can be represented by circles, ellipses, truncated cones, cylinders, and combinations of these objects. Among these features, we focus on the ellipse of objects to reconstruct occluded shape of an object using symmetry since most objects contain an ellipse. The main idea of the method is to reconstruct the ellipse so as to reconstruct the partially occluded object.

In the following section, we describe procedures for the reconstruction of an ellipse as well as the whole shape of an object.

3.1 Reconstruct Ellipse

In this step, we describe how to reconstruct an ellipse since we use an ellipse to reconstruct the shape of an object. We assume that an ellipse is a part of an object, and it is a partially occluded. We reconstruct the occluded ellipse based on the following equations. The symmetry axis of the reconstructed ellipse allows reconstruction of the contour of the occluded object. Therefore, ellipse reconstruction is the primary step to perform reconstruction of occluded objects. The main point of this section is to find (x_i, y_i) points of the occluded shape and region and restore an ellipse based on these points.

If the center of the ellipse is *(a,b)*, the equation of the ellipse with radius r_1 and r_2 is as follows:

$$\frac{(x-a)^2}{r_1^2} + \frac{(y-b)^2}{r_2^2} = 1 \quad (1)$$

In order to reconstruct an ellipse, we use the equation of a circle with center *(a,b)* and the foci on the x-axis with coordinates *c*. In addition, we describe equation (3) for many pairs of (x_i, y_i) in an ellipse. Furthermore, we assume that we can extract r_1 and r_2 from the occluded ellipse. We use points *a* and *b* for the occluded ellipse on r_1 and r_2 lines.

$$(x-a)^2 + (y-b)^2 = c^2 \quad (2)$$

$$\sum\left(c^2 - \left((x_i - a)^2 + (y_i - b)^2\right)\right)^2 \quad (3)$$

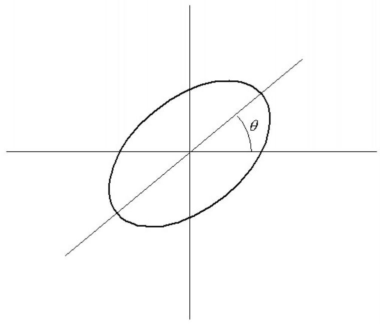
$$\varepsilon_i = c^2 - \left((x_i - a)^2 + (y_i - b)^2\right) \quad (4)$$

Find *a,b,c* that minimize

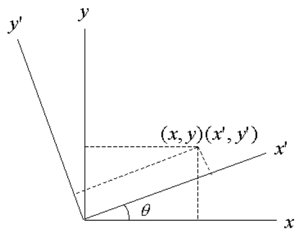
$$\sum \varepsilon_i^2 = f(a,b,c) \quad (5)$$

3.2 Geometrical Transformation

In terms of the geometrical transformation, we discuss the 2-D rotational transformation in this section. When the pose of an ellipse is distorted, we cannot use the above equations to reconstruct an ellipse. An example of a distorted ellipse is shown in (Fig. 1).



(Fig. 1) After rotation of a coordinate system



(Fig. 2) Rotation of an Ellipse

Rotation and transformation coordinate systems are easily accomplished with matrices. For instance, a simple rotation about the origin of an *x-y* axis to a new set of axes *x′-y′* through an angle *θ*, as in (Fig. 2) can be computed with a matrix that transforms point *(x, y)* into *(x′, y′)* whereby the *x′-y′* coordinate system is a simple rotating angle *θ* is as follows: $\begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}$

The original points are rotated by an angle *θ*, as defined by equations 6 and 7.

$$x' = x \times \cos\theta + y \times \sin\theta \quad (6)$$

$$y' = -x \times \sin\theta + y \times \cos\theta \quad (7)$$

We apply *(x′,y′)* to above equations 2, 3, and 4 to reconstruct rotated *(x,y)* points of an ellipse.

$$(x' - a)^2 + (y' - b)^2 = c^2 \quad (8)$$

$$\sum\left(c^2 - \left((x_i' - a)^2 + (y_i' - b)^2\right)\right)^2 \quad (9)$$

$$\varepsilon_i' = c^2 - \left((x_i' - a)^2 + (y_i' - b)^2\right) \quad (10)$$

Find *a,b,c*, that minimize

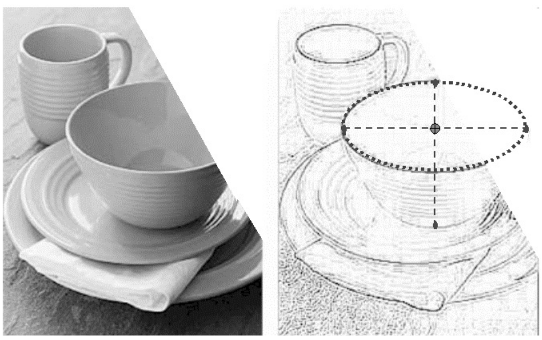
$$\sum \varepsilon_i'^2 = f(a,b,c)' \tag{11}$$

The equations can be solved numerically using common nonlinear equation functions in mathematical tools such as Matlab. Using the above equations based on the visible part of an ellipse, we can reconstruct an ellipse with *a*, *b*, and *c*. From the above discussion, we showed how to reconstruct a partially occluded ellipse in objects.

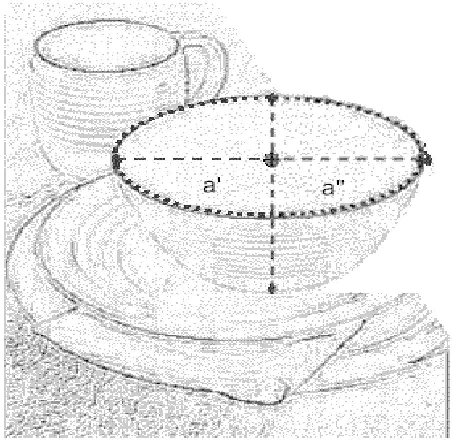
3.3 Detect the symmetry axis in an Reconstructed Ellipse

After reconstructing an ellipse, we should find the symmetry axis from the reconstructed ellipse. A line through the foci intersects the ellipse at two points, known as vertices. This line segment joining the vertices is called the major axis and its midpoint of is called the center of the ellipse. The line segment through the center, perpendicular to the major axis, and with endpoints on the ellipse is called the minor axis. In addition, major and minor axes are symmetry axes of an ellipse.

- A symmetry axis of the reconstructed ellipse could be a symmetry axis of a partially occluded object as shown in (Fig. 3). Mirror symmetry can be used to reconstruct occluded shapes and regions of an object across a symmetry axis as shown in (Fig. 4), which shows region a' = a" from the mirror symmetry.
- Re-compute shape measurements using RLC lines from the reconstructed shape of an object. Re-compute shape parameters based on shape measurements.
- With the estimated parameters, we apply to a classifier to find the class.



(Fig. 3) Reconstruct the ellipse from the occlusion and detect the symmetry axis from the ellipse



(Fig. 4) Reconstruct object using the mirror symmetry from the reconstructed ellipse

So far, we discussed how to reconstruct partially occluded objects based on one of the individual parts of an object, which is an ellipse. In addition, we have experienced the power of the symmetry for reconstruction of objects.

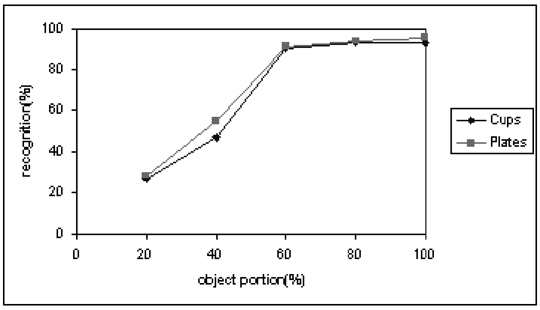
4. Experimental Results

In the sections, we evaluate and describe the results of partial object recognition by our proposed method. We have selected 190 partially occluded objects of images from electronic catalogs on the Internet as well as manipulated images. We assume that occluded objects have more than 50% visibility of objects, and images of catalogs contain partially occluded objects. Our approach and experiments are limited to cups and plates since we use roughly-rounded or elliptical objects. More precisely, the database contains 32 objects from different viewpoints and images of 97 objects comprising image plane rotations and scale changes.

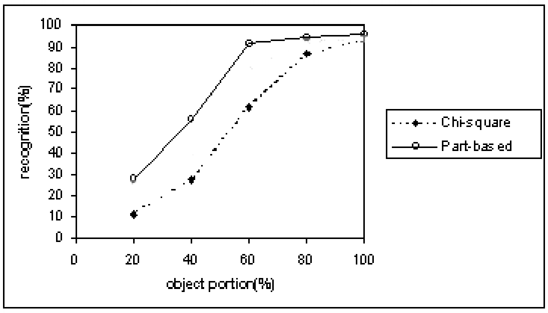
In this section, we examine the robust method for part-based partial object recognition using symmetry properties. There are some limitations of the shapes of objects, and our method may or may not apply to all objects in our image database since the shapes of objects vary.

We experimented with shape reconstruction based on a part of an object, an ellipse, using mirror symmetry. This experiment is limited to cups and plates since we only try to restore the ellipse among parts of objects.

In terms of an ellipse reconstruction, we have performed the experiments to reconstruct the ellipse, which was occluded. In terms of an object reconstruction, we detect a symmetry axis in a reconstructed ellipse and then we reconstruct an object using mirror symmetry.



(Fig. 5) Object recognition in the presence of the occlusion of objects based on the part - ellipse



(Fig. 6) Experimental results with occlusion

〈Table 1〉 The visibility of object recognition in the presence of partial occlusion

Methods	Visibility	Training processes
Appearance matching techniques using adaptive masks	90%	not required
Probabilistic technique using Chi-square	72%	required
Probabilistic technique using local measurements	34%	required
Part-based approach using symmetry	54%	not required

〈Table 2〉 Summary of Object Recognition Methods for dealing with Occlusion

Methods	Occlusion	Scale changes	Object Pose	Rotation
Bischof et al. [1]	Yes	Yes	No	No
Edwards et al. [4]	Yes	Yes	No	Yes (limited)
Ohba et al. [12]	Yes	No	Yes	No
Jacob et al. [9]	Yes	No	Yes	No
Rao [14]	Yes	No	Yes	No
Krumm [10]	Yes	No	No	No
Part-based method	Yes	Yes	Yes (limited)	Yes

After the reconstruction of occluded objects based on ellipses, we have classified objects to evaluate. A visible portion of approximately 54% is sufficient for the recognition of objects as shown in (Fig. 5). In other words, if we can restore the ellipse of an object, we have a high possibility of reconstructing the occluded objects.

In the following sections, we evaluate our method compared to other object recognition methods, which can handle occlusion. There are many efforts in object recognition for dealing with occlusion. The visible portion of objects required to recognize occluded objects are shown in <Table 1>. <Table 1> shows a simple comparison between our method and other existing methods. The probabilistic method based on local measurements requires small portions of objects to recognize the whole objects, but it required extensive training processes to recognize occluded objects [3,16,15]. Our method shows good visibility of partial object recognition and does not need extensive training processes.

In order to measure the influence of occlusion and compare its impact on the recognition performance of the different methods, we performed an experiment as follows: (Fig. 6) summarizes the recognition results for different visible object portions. For each test object, we varied the visible object portion from 20% to 100% and recorded the recognition results using Chi-square divergence and our method.

The results show that our method clearly obtains better results than Chi-square divergence. Using only 50% of the object area, almost 80% of the objects are still recognized. This confirms that our method is capable of reliable recognition in the presence of occlusion.

<Table 2> summarizes the various object recognition methods. The table indicates whether the methods can handle occlusion, rotation, pose, and changes in the size of objects in the database. Unlike the other methods, our method can handle scale change, object pose, and rotated objects with occlusion, even though our method has minor limitations of object poses. Although, we have some limitations, the approach has been shown to be remarkably robust with respect to partial occlusion.

5. Conclusion

In this paper, we have discussed how to estimate parameters and to reconstruct the occluded shape of partial objects in image databases. In order to reconstruct occluded shapes, we used symmetry, which provides powerful method for the partial object recognition. Unlike the existing methods, our method tried to reconstruct occluded shapes and regions within objects, since most objects in our domain have symmetrical figures. However, we have limitations in the shape of objects and the occluded region of objects. Another minor limitation of our method is that a method is sensitive to the pose of an object. For example, if we cannot see an ellipse due to the object's pose, we cannot recognize the object. After estimation, we have applied inputs, which include estimated parameters, to the existing classification trees, to get to the best matching class.

All experiments are performed based on the classifier in earlier work. In experiments, the results show that the recognition of the occluded object is properly reconstructed, estimated, and classified, even though we have limited to the size of samples, and this approach is suitable for solving the partial object recognition problem.

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