Hidden Part Estimation in the Occluded Objects

겹친 물체에서 가려진 부분의 추정

Dong-Uk Cho*, Ji-Yeong Kim*, Heung-Gyoon Ryu**

조 동 욱*, 김 지 영*, 유 흥 균**

ABSTRACT

In this paper a hidden part estimation is proposed for the recognition of occluded objects. The detection process of occluding is made up of counting the number of odd points from the given input image. Also the estimation is performed for hidden parts of the occluded object based on the figure quantity before the feature extraction operation. Finally the effectiveness of this method is shown by various experiments.

요 약

본 논문에서는 겹침이 있는 물체의 인식을 위하여 겹침을 당한 물체의 가려진 부분에 대한 추정을 행하는 방법을 제안한다. 주어진 입력화상에서 정점의 홀수점의 갯수를 셈으로써 겹침의 생성 여부를 알 수 있다. 또한 특징추출을 행하기전에 도형의 형태량에 기초하여 겹침을 당한 물체의 가려진 부분을 추정하여 본 논문의 유용성을 여러 실험에의해 입증하였다.

Ⅰ. Introduction

Computer vision has been drawing much research and work as its application seems to be limitless. Recently, the focus is on the 3 D computer vision and much effort is extended to overcome the inherent limits of information obtainable from gray level data, thereby to recognize the occluded objects. Also there have been various attempts to better utilize the range data so as to distinguish the planar objects from the curved objects[1]-[3].

However in the 3-D computer vision systems, the process of obtaining the range data by the shape from X method[4]-[6] or the range finder method[7],[8] is both time-consuming and inaccurate due to various reasons. Also in one of the major application areas of the computer vision systems, the manufacturing line automation, occlusion is quite common because of physical overlapping and contact among objects. To resolve the occlusion problem, a proper method would be to utilize the range data which much account for the situation correctly but it has the problems ment-

* Dept. of Computer Science & Engineering, Seowon Univ.

** Dept. of Electronic Engineering, Chungbuk Univ.

접수일자 : 1993. 5. 11

ioned above. So more practical method may be found in the utilization of the easily obainable gray level data. But the existing methods try the recognition of the occluded objects without the estimation of hidden parts, which is very prone to false recognition.

In this paper to resolve this difficulty, it is proposed that the estimation on the hidden parts of the occluded objects based on the human psychological tendency about making objects is to be performed before the feature extraction process.

For this, the shape of the hidden parts of the occluded object is estimated using Hough transform[11] and the figure quantity concept[9]. Additionally, the algorithms for the end point detection, vertex modeling, occlusion detection and hidden part estimation are presented in making a complete system. Section Ⅱ describes the existing figure quantity equation and its meaning, and explains the reason for applying in the proposed system.

Section Ⅲ deals with Hough transform. In section Ⅳ, a vertex modeling method to formulate single complete figures. Section Ⅴ explains the proposed occlusion detection algorithm and the shape estimation method for the hidden parts. Finally, the effectiveness of the proposed system is shown the experimental results.

Ⅱ. Human psychology on the figures[9]

Most of the man-made objects are composed of spheres, cylinders, cones and flat surfaces. A report says about 85% of all artificial objects are made up of these primitives[10]. Then the question arises about why human make the object in the way. The one possible answer for the reason may be found in the different figure quantity value of each object established in the human psychology on figures. The psychology says that human feel most comfortable with the objects is their cross section is circle, which accounts for the fact that the cross section of 3 of the above primitive are circle.

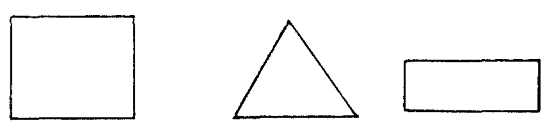
In the case of a circle, as shown in Fig.1, the figure quantity becomes zero and human feel figuratively most comfortable, which is the reason that the cross section of the most man-mad objects is circular. The expression shown below is to compute the figure quantity.

$$G(p) = -\int p(w) \cdot \log p(w)\, dw \qquad (1)$$

where p(w) is the power spectrum expression, which contains the information about the curvature and torsion. The above expression is analogous to the entropy expression of the information theory and it repersents the amount of entropy in the image information, i.e., the value of which is the degree of the curvature and torsion of an object. In the information theory, if the degree of irregularity is smaller, then lower the value entropy. Likewise in the figure quantity concept, smaller figure quantity means that the object is of more ordinary, predictable shape. Geometrically, lower the figure quantity value of an object, smaller the degree of curvature and torsion in its shape.

Figure 1 shows a typical example.

As noticed in Fig.1 rectangles and squares have different G(p) values. But the line segments of both objects, regardless of their length, have the same G(p) value.



G(p) = 0.874   G(p) = 1.23   G(p) = 1.29

Fig. 1. Figure quantity values for various objects

Ⅲ. Detection of line and circle from image data

As mentioned previously, the cross section of the most man-made objects are circle. Furthermore, the tools used in the workshops and factories figuratively composed of line and circle primitives.

Therefore the correct detection of these primitives is vital for the recognition of the objects. In this paper we use Hough tranform for the purpose.

3.1 Line detection

A line segment in 2 D image of X-Y coordinates is defined as one point in a parameter space.

Fig. 2-(a) shows that any line which passes any point (X_i, Y_i) on a line segment L is defined as :

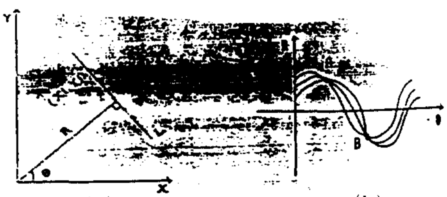


Fig. 2. Line segment in parameter space

$$X_i\cos\theta - Y_i\sin\theta = R \qquad (2)$$
$$(0^0 \le \theta \le 360^0,\ ABS(R) \le SQRT(X^2_{max} + Y^2_{max}))$$

Also Figure 2-(b) shows that all lines passing any point on a line L accumulate to a point(θ, R) in parameter space. For example points A and B are represented as one point as $\theta = \pm 180$, R = ABS (R). If Hough transform is applied to all points in the image, the accumulator array is obtained and after θ-grouping, R-grouping and X-Y grouping processes is performed for the determining of bast line.

3.1.1 Determination of best line

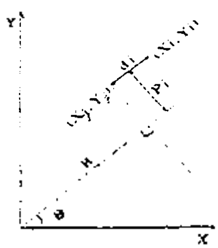


Fig. 3. Best line determination

If N points as the line edge elements from a line segment, then the normal distance from a point (Xi, Yi) to the line of expression (2) is as follows :

$$d_i = R - X_i\cos\theta - Y_i\sin\theta \qquad (3)$$

Therefore the total distance from N points to expression (2) is shown as,

$$D^2 = \sum (R - X_i\cos\theta - Y_i\sin\theta)^2, \quad (i = 1, \cdots, N) \qquad (4)$$

Now, the best line is the one which has the minimum values of θ and R for expression (4)

3.1.2 Determination of end points

If the projected point from a point (X_i, Y_i) to the best line is denoted as (X_j, Y_j), then their values are obtained as

$$X_j = X_i + R\cos\theta - X_i\cos^2\theta - Y_i\sin\theta\cos\theta$$
$$Y_j = X_i + R\sin\theta - X_i\cos\theta\sin\theta - Y_i\cos^2\theta \qquad (5)$$

Also the projection distance, P_i from a given point (X_i, Y_i) in Fig.3 to a straight line defined by θ and R is computed as,

$$P_i = -X_i\sin\theta + Y_i\cos\theta \qquad (6)$$

Similarly corresponding P_i value for the projection point (X_i, Y_i) is

$$P_j = -X_j\sin\theta + Y_j\cos\theta \qquad (7)$$

Now, after the P_i values are sorted, the coordinates decided by the minimum and maximum values become end points.

3.2 Circle Detection and Arc End Point Detection

To detect a circle from the image, the center is located by the principle that a line perpendicular to a line connecting two points on a circle must pass the center. Likewise, by measuring the distance from the center to each point on the circle, the radius is determined. The same method is applied to an arc in determining its center and radius.

As shown in Fig.4, an arc is a part of a circle which satisfies,

$$(X - M)^2 + (Y - N)^2 = R^2 \qquad (8)$$

so, a line connecting any point (X, Y) and the arc center (M, N) is represented as

$$Y - Y_i = (Y_i - N)X/(X_i - M) - (Y_i - N)X_i/(X_i - M) \qquad (9)$$

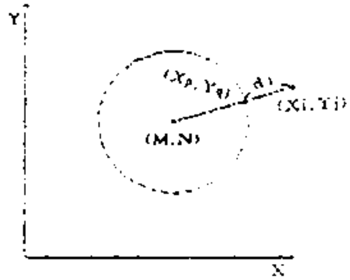


Fig. 4. Determination of the end point of an arc

If the intersection between expression (8) and (9) is denoted as

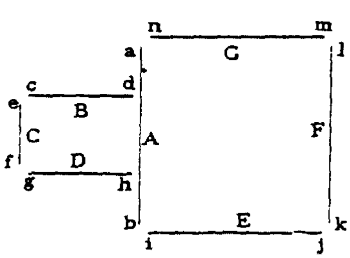
$$d_i = \mathrm{SQRT}[(X_i - X_p)^2 + (Y_i - Y_q)^2] \qquad (10)$$

Now the end point of the arc is determined whose di value is minimum.

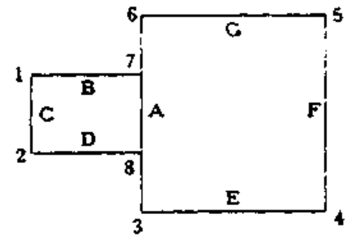
Ⅳ. Vertex modeling

Since the image of every object forms a single closed-loop figure, the vertices are selected such that a single closed-loop figure is formed by the related lines and arcs which are extracted by Hough tranformation. Therefore, the proposed vertex modeling is to arrange the appropriate vertices of an entire object image including the occluded parts from the computed end points of lines and arcs through Hough transformation.

The figure shown below gives an example.



(a) Before Vertex Modeling



1, 2, 3, 4, 5, 6, 7 :

Formulated vertex

(b) Results of Vertex Modeling

Fig. 5. Examples of an vertex modeling

Ⅴ. Detection of occlusion

If we assume that an object is composed of a single figure, then the existence of occlusion must be determined.

5.1 Distinction between occluding and occluded objects

The decision whether there exists an occlusion or not can be made by counting the number of edges originating from a chosen vertex and determining if the number is odd or even. We define a vertex from which the odd number edges as an occluding point. Then, if the number of the occluding points is two or more, then it can be judged that the occlusion has actually happened. For example, as shown in Figure 6 the vertices, a, c, d, f, g, i, j and l are non-occluding points since the number of edges coming out of them are all even. Meantime, the vertices b, e, k and h are occluding points because the number of edges from them are all odd.

Separation of occluding object from a single figure is done by extracting a whole figure which contains all the occluding points. Fig. 6 shows an example.

5.2 Estimation of hidden parts

The hidden parts of an occluded can be determined by considering its surrounding the occlud-

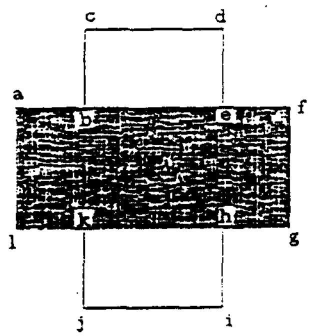
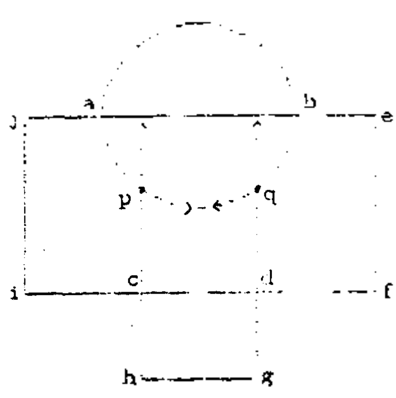


Fig. 6. Extraction of an occluding object

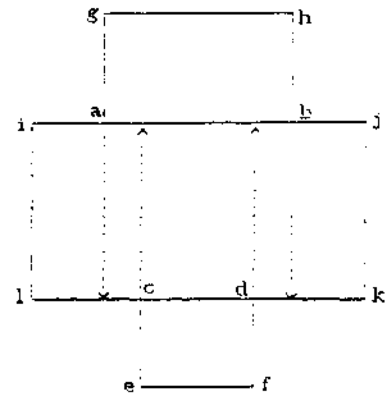
ed points and the vertices of the occluded objects and by establishing a relationship among the vertices, the estimation of the hidden parts of the occluded object is performed. At this time if the estimated line of vertices is formed inside the occluded object region, then the estimation is very likely to be successful.

Otherwise it is definitely a failure case. Fig.7 shows the example.

As shown in Figure 7-(a), if the estimated lines meet each other, the shape estimation for the hidden parts is assumed to be successful (at this time the figure quantity must be the minimum possible value for the chosen configuration). However, if the estimated lines do not meet each other as shown in Figure 7-(b), the estimation process is considered to be impossible and regarded as a failure. In this case, even a human can not properly estimate the shape of the hidden parts.



(a) success of estimation



(b) failure of estimation

Fig. 7. Examples of estimation

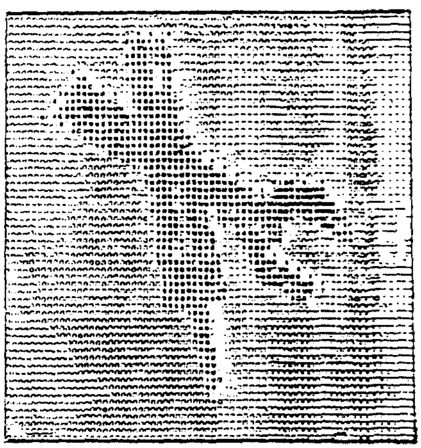
The basis for this estimation process is to form an object of the previously mentioned minimum figure quality vlaue.

VI. Experiment and observation

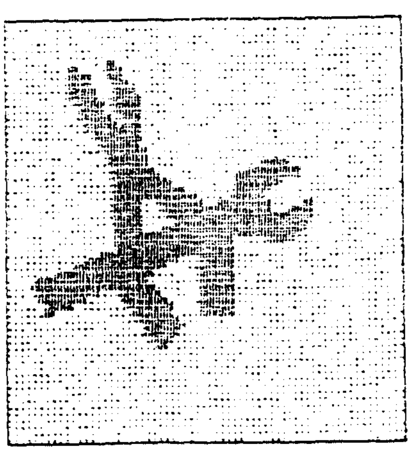
The edge detection is done with Robert operator on a 64×64 image. In the straight line extraction the values projection distance, P_j above 7 are selected. For the P_j values between 4 and 7, initially a straight line is assumed but after attempting to regard it as a circle, an arc or straight line is decided. The end points of each segment are connected to find the true vertices of the figure and a 5×5 window is used to determine the occluding point.

Fig. 8 shows the original input image. Fig. 9 is the result of the line and arc extraction algorithm of Hough transform, for which the edges are detected by Robert operator. Further, Fig. 10 is the result of the shape estimatation process for the hidden parts from image in Fig. 9. The reason for the given estimation comes from the minimum figure quantity as shown in Table 1, i.e., the line segments, h-i-s-r must be regarded as a single line according to the minimum figure quantity value. The same is true for the case of j-k-l-m. This result would be the same even for a human since the most of the man-made objects, with the exception of some very special purpose and use, are of more uniform or constant curvature and of minimum torsion. Consequently, this article exploits the nature of the man-made objects, the shape of which tend to be of more constant curvature and minimum torsion. We find this nature very strong in estimating the shape of the hidden parts in the occluded objects. Further study and research is expected for the cases in which the estimation lines are not formulated.

Even though the experiment has been performed with 64×64 images, thereby the resolution is rather coarse, higher resolution images can be easily handled in estimating the hidden parts of the occluded objects by adjusting the (θ, R) value of Hough transform.

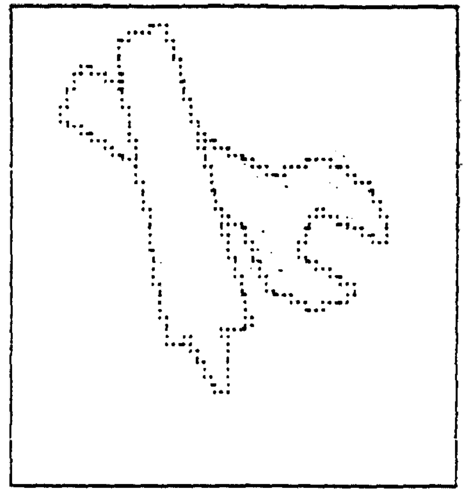


(a)

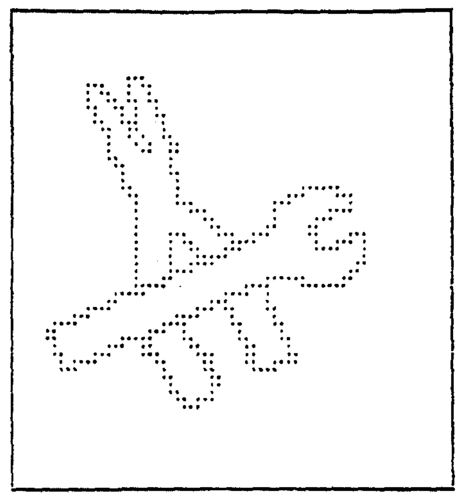


(b)

Fig. 8. Input image



(a)

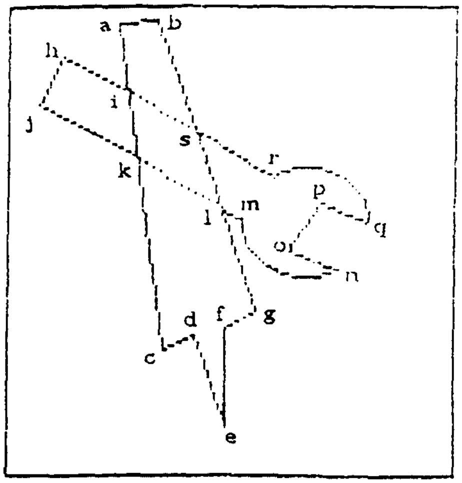


(b)

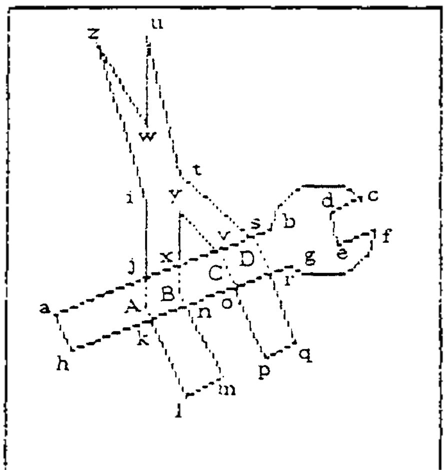
Fig. 9. The extracted results of the line and arc by Hough transformation

Table 1. Result of estimation of the Fig. 10-(a)

Relations of Estimation	Figure quantity
h-i-s-r(same line)	h-i : 2.68 s-r : 2.68 h-i-s-r : 2.68
j-k-l-m(same line)	j-k : 2.68 l-m : 2.68 j-k-l-m : 2.68



(a)



(b)

Fig. 10. Estimated image

Table 2. Result of estimation of the Fig. 10 (b)

Relations of Estimation	Figure quantity		
A j i(same line)	j i	:	2.68
	A-j-i	:	2.68
A-k-l(same line)	k i	:	2.68
	a-k i	:	2.68
B x-y(same line)	x-y	:	2.68
	B x-y	:	2.68
B n-m(same line)	n-m	:	2.68
	B n-m	:	2.68
C v-y(same line)	v-y	:	2.68
	C v y	:	2.68
C o p(same line)	o-p	:	2.68
	C o p	:	2.68
D s t(same line)	s-t	:	2.68
	D s t	:	2.68
D-r q(same line)	r-q	:	2.68
	D r q	:	2.68

Ⅶ. Conclusion

A way of estimating the hidden parts of an occluded object is proposed. Circles and lines are detected by Hough transform and the concept of the ifgure quantity is utilized in the estimation process. Further research on the cases where the estimated lines do not meet in the estimation process is required.

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▲**Dong-Uk Cho** (Regular Member)

1983. 2 : Department of Electronic Engineering, Hanyang University (B.S)

1985. 8 : Department of Electronic Engineering, Hanyang Gradnate School(M.S)

1989. 2 : Department of Telecommunication Engineering, Hanyang Graduate

1982. 12~1983. 5 : Researcher Research Center, SindoRicoh Co,

1987. 9~1993. 8 : Instructor, Hanyang University

1989. 9~1991. 2 : Assistant professor, Dongyang Junior College

1991. 3~to present : Assistant professor, Seowon University

Interest Field : Computer Vision, Fuzzy Theory & Neural Network

▲**Heung-Gyoon Ryu** : Vol.12, No.1E

▲**Ji-Yeong Kim** (Regular Member)

He is an associate professor of computer science and engineering at Seowon University, Chongju since 1989. His research interests include system performance evaluation, computer vision and tele-measuring and controlling system.

Before joining Seowon University faculty, he wae the Chief Research Scientist at the Central Research Center at Oriental Precision Company Ltd. for 2 1/4 years. Before then he was an assistant professor of computer science and engineering at Auburn University, Auburn, Alabama for a year.

He received M.B.A in MIS and M.S and ph. D in computer science all from the state University of New York at Binghamton NY, in 1977, 1979 and 1984 respectively. He is a member of the IEEE Computer and Communication Societies and the ACM