Decomposition and Construction of Object Based on Law of Closure in Gestalt Psychology

Yi-Chong Zeng
Data Analytics Technology and Applications Research Institute
Institute for Information Industry
Taipei, Taiwan
yichongzeng@iii.org.tw

***Abstract*—People can easily perceive object with incompletion boundary or combination of discontinuous edges. However, common approaches are difficult to segment an entire object without referring to completion contour. This paper introduces a scheme to reify an object based on law of closure in Gestalt psychology. The proposed scheme acquires initial boundaries and edges in advance, and then divides boundary into small edges according to key vertices on boundaries. Applying approximate line and approximate ellipse/circle to two edges, it determines whether two edges are highly related to each other or not. Consequently, path searching is implemented on all edges to find closed loop as well as to construct object with completion contour.**

Keywords—Law of closure; Gestalt psychology; incompletion boundary; discontinuous edge; object construction

I. INTRODUCTION

Human brain can organize perceived objects as patterns, and People easily perceive object with incompletion contour or combination of discontinuous edges. Gestalt psychology attempts to understand human perception, there are laws of grouping in Gestalt psychology [1, 2], including, proximity, similarity, closure, symmetry, common fate, continuity, good gestalt, and past experience. Fig.1 shows three images [3], the representation of objects is highly related to law of closure. The first image consists of black irregular objects placed on white background, and it shows a panda. Similarly, combination of six water-drops represents a peacock in the second image. In the third image, the blue rectangles organize as company's name.

The issue of amodal completion related to Gestalt psychology has been mentioned in many fields. In [4], Gobithaasan et al. presented Log-Aesthetic Curve to solve problem of shape completion. In [5, 6], Hayashi et al. investigated how to segment entire object that portion of object is occluded by the other ones. Their method solved the problems of contour discrimination and contour completion, which represent to laws of symmetry and closure. For occlusion splitting [7], Abbas and Mohamad employed boundary analysis and line drawing to cleave red blood cells.

Common approaches are difficult to segment an entire object without referring to completion contour. This paper introduces a method to implement object reification based on law of closure in Gestalt psychology. The objective of reification is to construct object via combination of discontinuous edges and incompletion boundary. Our method detects key vertices and then divides boundary into small edges. Subsequently, virtual edge is generated to connect two edges as straight line, ellipse, or circle. Implement path tracking to edges to find closed loop, the closed loop is a solution to construct object with completion contour. The rest of this paper is organized as follows: law of closure and the proposed scheme are introduced in Sections II and III, respectively. The experiment results will be shown in Section IV, and the concluding remarks will be drawn in Section V.

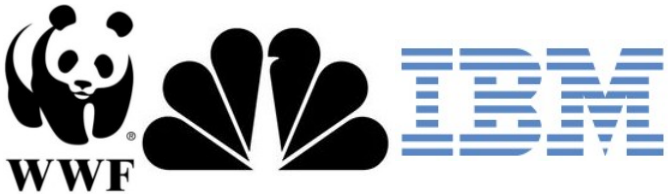

Fig. 1. Three examples represent law of closure in Gestalt psychology

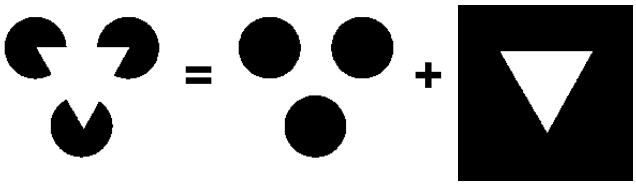

Fig. 2. An example of Gestalt psychology

II. LAW OF CLOSURE

People easily perceive entire object with incompletion information. For an example in Fig.2, a white triangle is placed on three black circles with white background. Using current segmentation approaches, three broken circles are detected easily. However, people can identify three entire circles and a triangle. Human brain tends to ignore gaps and constructs a complete form despite the absence of parts. This refers to the law of closure in Gestalt psychology.

III. THE PROPOSED SCHEME

The proposed scheme consists of four phases, and the detail of every phase is described as follows.

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A. Edge and Boundary Detection

In this work, binary images are analyzed for object detection. The boundaries and edges using morphology operations which is defined as $\mathbf{I}_C=\mathbf{I}-\Phi(\mathbf{I})$. The denotations $\mathbf{I}$ and $\mathbf{I}_C$ represent the original binary image and its boundary, respectively. The function $\Phi(\mathbf{I})$ generate the result by applying erosion operation or dilation operation to $\mathbf{I}$.

B. Key Vertex Detection

Let Ψ be coordinate set of N vertices on edge of $\mathbf{I}$, and $\Psi = \{(x[n], y[n]) \mid n=\{1, 2, ..., N\}\}$. The definition of curvature [8] is formulated below,

$$k=\frac{x'y''-x''y'}{(x'^2+y'^2)^{\frac{3}{2}}}, \tag{1}$$

where k is curvature. The denotations x' and x'' are, respectively, first-order differential of x and second-order differential of x. The definition is the same as the variable y. The determination of key point detection is defined as,

$$D(x,y)=\begin{cases}1, & \text{if } \left|k_{x,y}\right|>\tau_1\\ 0, & \text{otherwise}\end{cases}, \tag{2}$$

where τ_1 is a threshold to determine key vertex, and τ_1 is set to 1.25×10^{-2} in the experiment.

C. Virtual Edge Generation

In order to determine relationship between two edges, the proposed scheme utilizes approximate line and approximate ellipse/circle to edges. Let $x[n]$ and $y[n]$ be, respectively, coordinates of x-direction and y-direction, and $0 \le x[n], y[n] \le 1$. Approximate line is formulated as $c_1x[n]+c_2y[n]=1$, and two parameters c_1 and c_2 are estimated by,

$$\begin{bmatrix}c_1\\ c_2\end{bmatrix}=\begin{bmatrix}x[1] & y[1]\\ x[2] & y[2]\\ \vdots & \vdots\\ x[N] & y[N]\end{bmatrix}^{-1}\begin{bmatrix}1\\ 1\\ \vdots\\ 1\end{bmatrix}. \tag{3}$$

where N is total number of coordinate. Average error (ε) between original coordinate and transferred coordinate (namely, $x_t[n]$ and $y_t[n]$) is calculated according to,

$$\varepsilon=\frac{1}{N}\sum_{n=1}^{N}\left((x[n]-x_t[n])^2+(y[n]-y_t[n])^2\right)^{\frac{1}{2}}, \tag{4}$$

where $x_t[n]=(1-c_2y[n])/c_1$ and $y_t[n]=(1-c_1x[n])/c_2$. As $\varepsilon<\tau_2$, a virtual edge connects two edges as a line.

Approximate ellipse/circle is formulated as $d_1x^2[n]+d_2y^2[n]+d_3x[n]+d_4y[n]=1$, and four parameters d_1, d_2, d_3 and d_4 are estimated by,

$$\begin{bmatrix}d_1\\ d_2\\ d_3\\ d_4\end{bmatrix}=\begin{bmatrix}x^2[1] & y^2[1] & x[1] & y[1]\\ x^2[2] & y^2[2] & x[2] & y[2]\\ \vdots & \vdots & \vdots & \vdots\\ x^2[N] & y^2[N] & x[N] & y[N]\end{bmatrix}^{-1}\begin{bmatrix}1\\ 1\\ \vdots\\ 1\end{bmatrix}. \tag{5}$$

As $-4d_1d_2<0$, approximate ellipse/circle is available. Similarly, average error between original coordinate and transferred coordinate is computed by (4), and transferred coordinate is defined as follows:

$$x_t[n]=\frac{-d_3\pm\sqrt{d_3^2-4d_1(d_2y^2[n]+d_4y[n]-1)}}{2d_1},$$
$$y_t[n]=\frac{-d_4\pm\sqrt{d_4^2-4d_2(d_1x^2[n]+d_3x[n]-1)}}{2d_2}. \tag{6}$$

As $\varepsilon<\tau_3$, a virtual edge connects two edges as an ellipse/a circle. Moreover, this scheme is capable of examining a single edge whether is a part of ellipse/circle or not.

D. Object Constrution

Two works are implemented during object detection. The first work is to detect ellipse-like/circle-like object. An edge, which is determined as a part of ellipse/circle, is collected in advanced. Moreover, a group of edges connected via virtual edges is collected as well. Drawing approximate ellipses based on the collected edges, ellipse-like/circle-like objects are detected. The second work is to detect polygon with closured contours. Exclude edges utilized to detect ellipse-like/circle-like object, our scheme searches closed loop among the rest of edges and the virtual edges.

IV. The Experiment Results

Fig.3(a) shows three of tested images in the experiments, and Fig.3(b) displays the corresponding curvature maps. It obviously illustrates that key vertices appear at the white pixels and the black pixels. The detected key vertices and the edges were numbered on the original images as illustrated in Fig.3(c). Therefore, Fig.3(d) and Fig.3(e) depict the approximate lines and the approximate ellipses, respectively.

The covering objects (dark-gray patterns) and the covered objects (white patterns) are displayed in Fig.4(a), and the residual is shown in Fig.4(b). In the 1st image of Fig.3(a), the proposed scheme decomposes the entire objects into two pieces. In the 2nd and the 3rd images of Fig.3(a), black object covered white object, that resulted in a part of white object vanishing. Our method not only constructs covering object but also covered object as illustrated in Fig.4(a).

V. Conclusion

In this paper, we propose a scheme to implement object reification based on law of closure in Gestalt psychology. The proposed scheme is capable of constructing and decomposing object with combination of discontinuous edges and incompletion boundary. The experiment results demonstrate that our method accurately detects covering object and covered object with completion contours.

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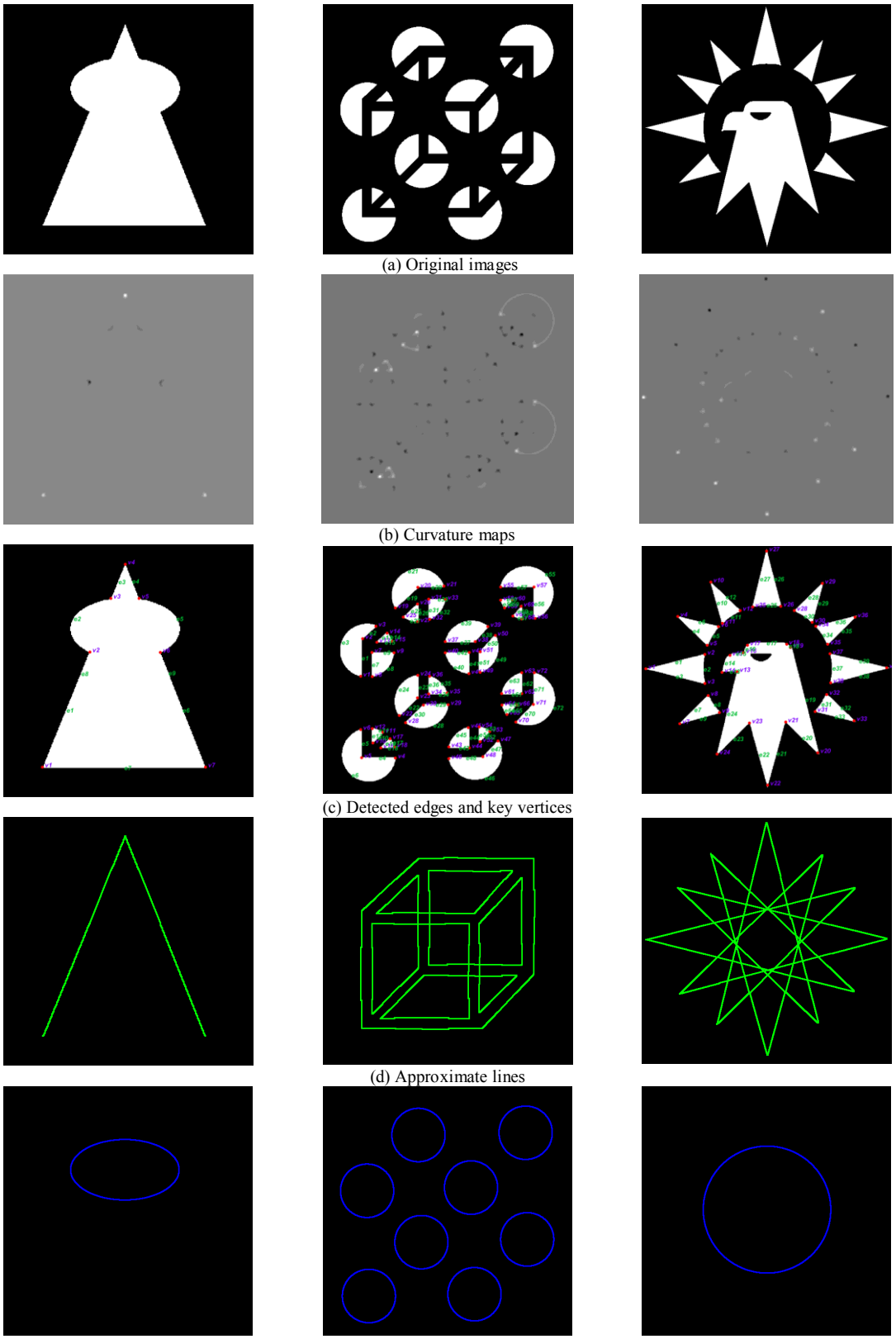

(a) Original images

(b) Curvature maps

(c) Detected edges and key vertices

(d) Approximate lines

(e) Approximate ellipses

Fig.3. The experiment results of key vertices and edges detection: (a) original images, (b) curvature maps, (c) detected key vertices (red dots) and edges, (d) approximate lines, and (e) approximate ellipses.

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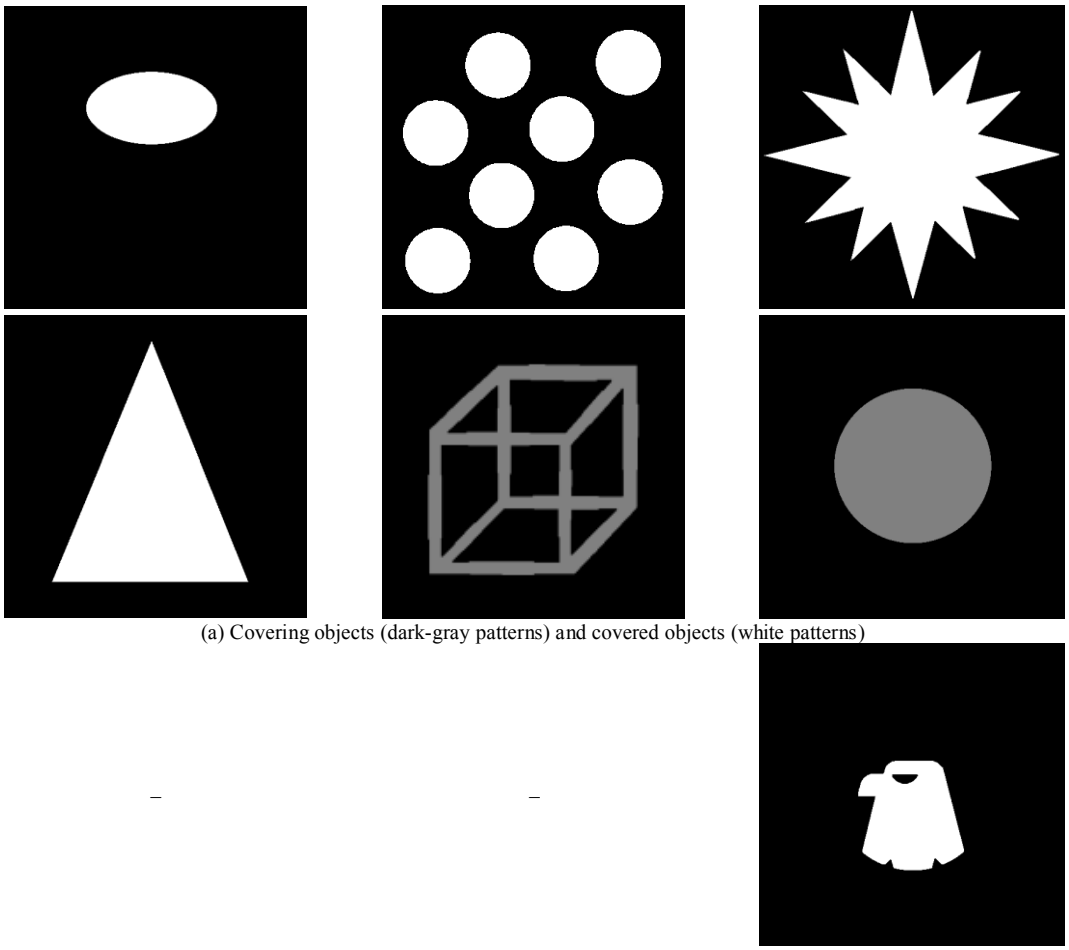

(a) Covering objects (dark-gray patterns) and covered objects (white patterns)

(b) Residual

Fig.4. (a) Covering objects and covered objects, and (b) residual.

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