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1 The 3 Problems and their Inter-relationship

The 3 Problems: Grouping, Figure/Ground and Recognition, and their Inter-relationship will be discussed in this section.

1.1 Grouping

Grouping is to get a kind of hierachic tree as shown in Fig.(1).

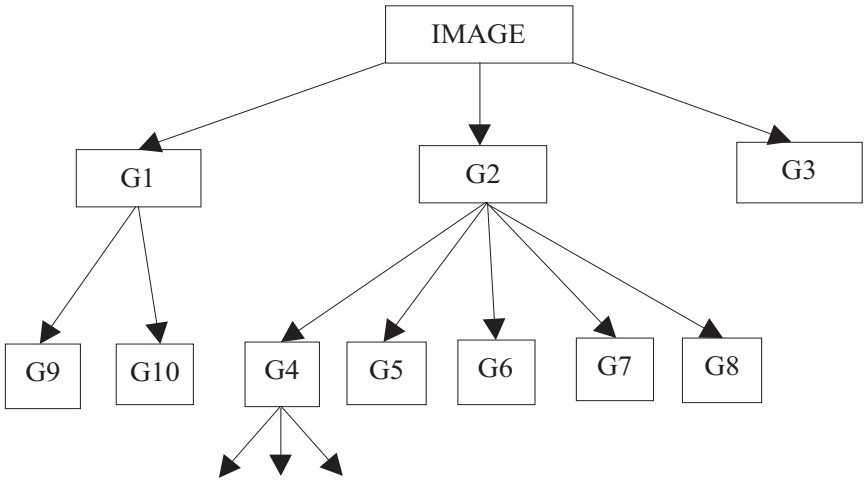
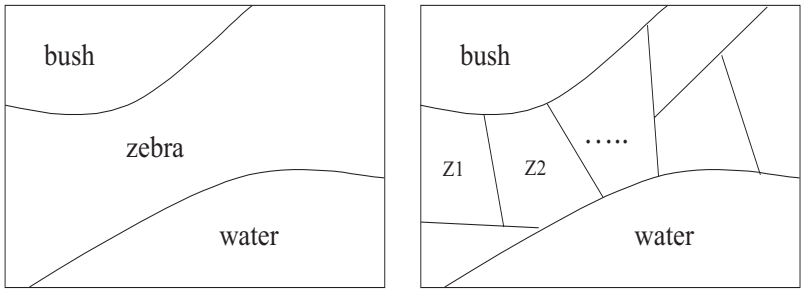


Figure 1: Hierachic Tree

For example, for an image in which there are a number of zebra standing at the side of a river with some bush around them, how to group the image? As shown in Fig.(2), the image

can first be divided into three level 1 groups such as bush, zebra and water. Furtherly, the image of zebra can be divided into a set of level 2 subgroups such as zebra 1, zebra 2, $\cdots$, i.e. Z1, Z2, $\cdots$.



(a) **(b)**

Figure 2: An Example of Grouping

1.2 Figure/Ground

In order to discuss Figure/ground, or depth ordering or surface layout problem, let's first consider a famous example by Rubin in 1915.

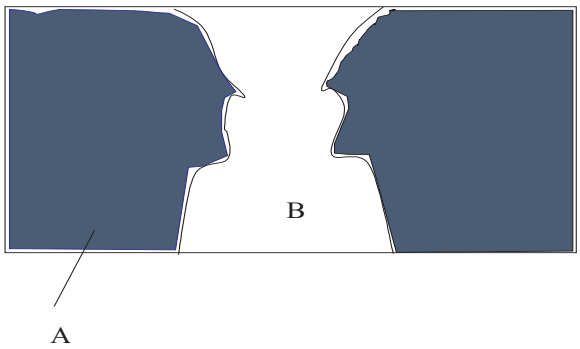


Figure 3: An example of Figure/Ground: Vase/2-face example by Rubin in 1915

As shown in Fig.(3), if the image is interpreted as a vase, pixel B is nearer than pixel A. On the other hand, if the image is interpreted as 2-face, pixel A is nearer than pixel B. Note that the nearer pixel is called *figure* and the farther pixel is called *ground* correspondingly.

1.3 Recognition

Recognition is **Naming Objects**. The task of Recognition is to tell us what kind of shape, what kind of material or what kind of movement the object in the image is. For example, as shown in Fig.(2), you should tell us which is bush, which are zebra and which is water. In a word, here you need to decide which is which. Note that you don't need to do so in

grouping in which the goal is only to divide the image into different groups with different characteristics and you don't care what they are in fact.

1.4 Inter-relationship between Grouping, Figure/Ground and Recognition

Inter-relationship between Grouping, Figure/Ground and Recognition can be represented by Fig.(4).

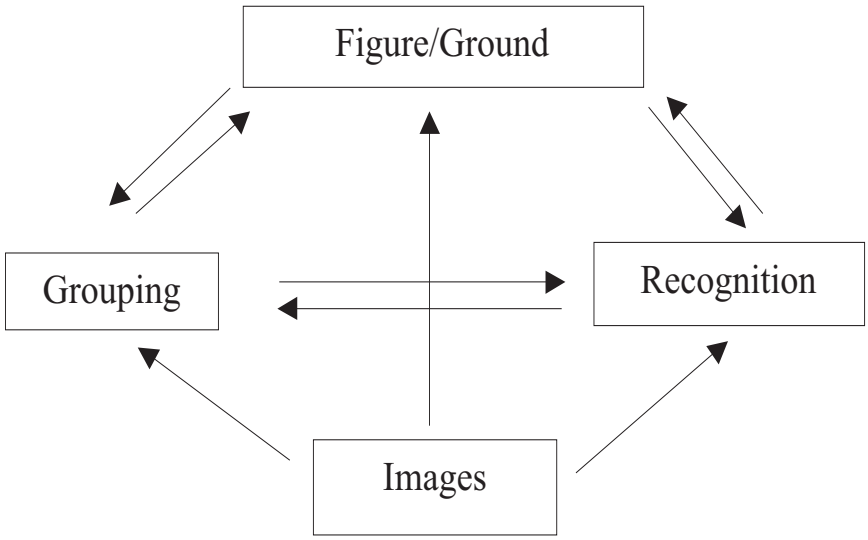


Figure 4: Inter-relationship between Grouping, Figure/Ground and Recognition

For example, you can either do recognition after grouping or do grouping after recognition. As shown in Fig.(5), you can first divide the image into two parts, i.e. the images which are inside the ellipse and those which are outside of it. Then you can recognize that the inside part is a face and so on. This is the technique of recognition after grouping. In other way, you can first find that there is a familar face in the image. Then you can group it as face part and non-face part. This is in fact the technique of grouping after recognition.

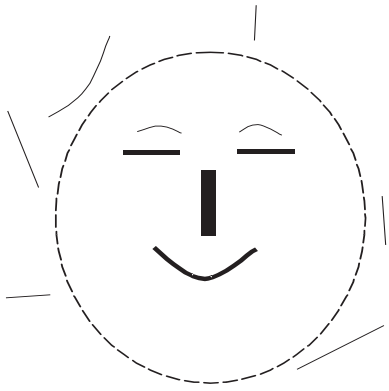


Figure 5: An example image of face

Note that the tool used in the inference between different parts is the **Probability Inference**. The reason is that conditions are changing all time so that no rule will be always right.

2 Principal Factors that lead to Grouping, Figure/Ground and Recognition

In this section, principal factors that lead to grouping, figure/ground and recognition are discussed. First let's consider principal factors that lead to grouping.

2.1 Principal Factors that lead to Grouping

Boundaries of image regions are defined by a lot of attributes such as:

- Brightness and color
- Texture (texture is often defined as a repeated pattern)
- Motion, e.g. bird flys in the bush. With single black and white image, it is hard to tell which is the bird. But the motion of the bird provides us a cue to pick it out from its "camouflage".
- Stereoscopic depth: Human vision system is born to use the stereoscopic feature. With built-in knowledge of disparity between left and right eyes, we can tell the depth of $0.4mm$ when the objects are placed in 1 meter ahead of us, referred to the notes of CS280.
- Familiar configuration: it is the familiar configuration from our own knowledge, e.g. table from a sheet of paper, moon from ballon, etc.

Principal factors which lead to grouping are:

- Similarity of (Brightness, color, texture, disparity, motion)
- Proximity
- Good continuation of boundary contours
- Closure
- Symmetry and Parallelism
- Familiar configuration

we will discuss it separately in the folowing section.

2.1.1 Similarity of (Brightness, color, texture, disparity, motion)

As shown in Fig.(6), most people will percive two groups, i.e. one group of red dots and another group of green dots. This is an example of similarity in color. As to the similarity in motion, recall the example of bird flys in the bush, points that move together can be grouped together.

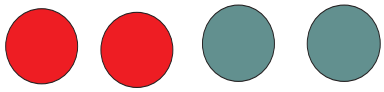


Figure 6: An example of Color Similarity

2.1.2 Proximity

Figure 7: An example of Proximity

As shown in Fig.(7), most people will percive two groups, i.e. one group of red dots in the left side and another group of red dots in the right side. Why do we percive this as two seperate groups of black dots? The insight of this and other factors which lead to grouping comes from ecological statistics. In computer vision, we are given an image and trying to deduce the world that has highest probability of giving rise to that image. This can be considered as a Bayesian view, find the most probable interpretation in the context of prior world knowledge. Statistically, the probability of two pixels are in the same object decreases when the distance between the two pixels increases.

2.1.3 Good continuation of boundary contours

Most objects in the world have smooth continuous boundaries. Objects in our world do have sharp corners, but the probability of an object being smooth is much higher, as shown in Fig.(8). The question to ask is how often is the tangent of a contour continuous vs. discontinuous. Again this is a statistical justification.

2.1.4 Closure

Most objects in the world appear to be enclosed in their contour, as shown in Fig.(9). However, there are cases where they are separated, e.g. the sky in Fig.(10) which is separeted by the tree. But again, the probability of the object being enclosed by its contour is much higher and hence we can use closure as a factor for grouping.

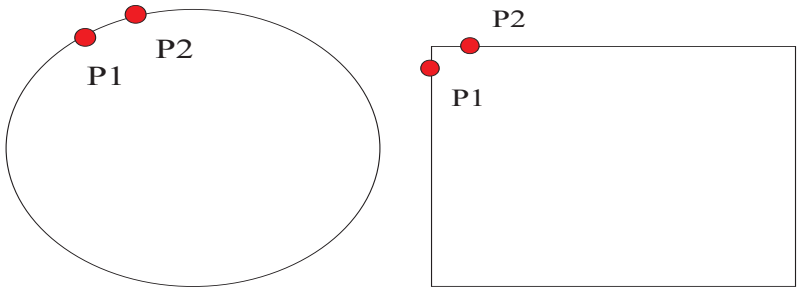


Figure 8: Examples of continuation and discontinuation of boundary contours: (a) contour with good continuation (b)contour with discontinuation

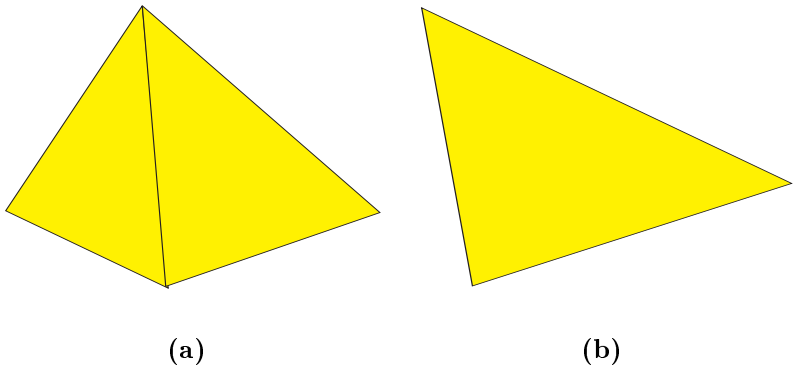


Figure 9: Examples of closure: (a) contour enclosed in its closure (b)contour which is not enclosed in its closure

2.1.5 Symmetry and Parallelism

As shown in Fig.(11), most people will percive that L1 and L2 are parts of the same object due to symmetry. Again this is a ecological statistic as most of objects in the natural world exhibit symmetry. The two types of symmetry seen the most often are Rotational Symmetry (symmetry around an axis like a limb, i.e. your arm) and Bilateral Symmetry (i.e., the left and right sides of human body).

2.1.6 Familiar configuration

As shown in Fig.(12), most people will interpret this as a face. This is duo to high level knowledge that humans use.

2.2 Principal Factors that lead to Figure/Ground

2.3 Principal Factors that lead to Recognition

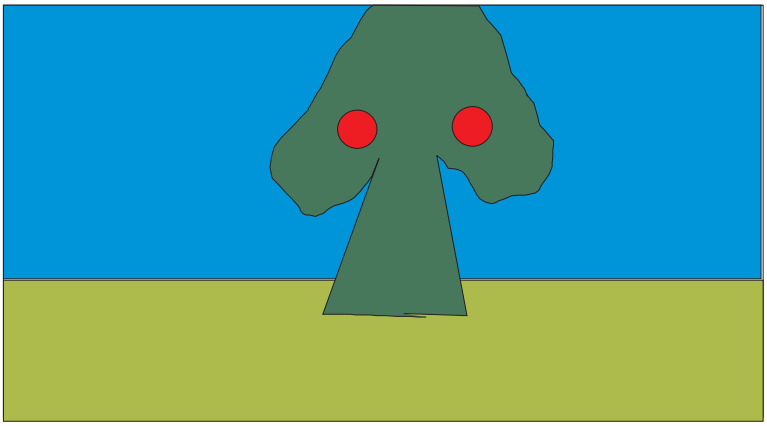


Figure 10: An example of Symmetry

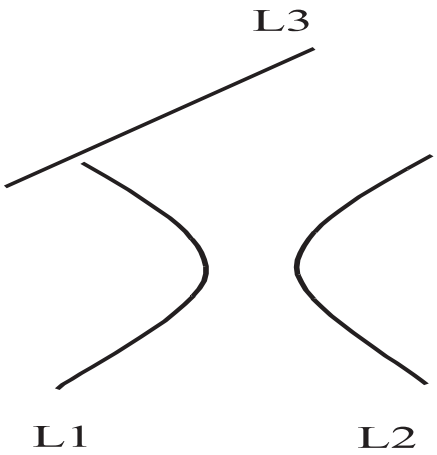


Figure 11: An example of Symmetry

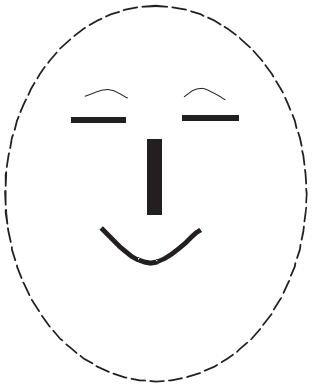


Figure 12: An example Image of Familiar configuration