# IN SUPPORT OF AN ALTERNATIVE MODEL OF TWO-DIMENSIONAL LINE DRAWING INTERPRETATIONS OF PARTIALLY OCCLUDED PATTERNS

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***ABSTRACT***

*This paper presents some experimental findings in support of a proposed model of two-dimensional line drawing interpretations of partially occluded patterns based on local and global minima. It describes the phenomena of partial occlusion and considers two types of interpretations: mosaic and completion. Some critiques of global minimum principle are discussed and an alternative approach is suggested. Perceptual preference based on the proposed model is tested on selected patterns and the discussion on the results is then presented. Some future works are also suggested.*

***Keywords:*** ***Partial occlusion; coding theory; minimum principle; information load; local and global minima; perceptual preference***.

## 1.0 INTRODUCTION

If we look around, we often see objects which are partly hidden by other objects. Most of the time we can be certain of what exactly is hidden, but sometimes we cannot decide the shape or nature of the hidden parts. This phenomenon has been observed and referred to by many researchers; Chapanis & McCleary [1] called it interposition, referring to two objects at different distances from the observer; Dinnerstein & Wetheimer [2] referred it as phenomenal overlapping, emphasising on spatial relation between the two objects; Kanisza [3] named it amodal completion, focusing on the observer who is completing the figure at the back; Gibson [4] called it occlusion, referring to the front object interrupting light rays coming from the object behind; and Buffart et al. [5] used the term figural completion, anticipating what the figure is seen behind as a function of figural properties of the drawing. In this paper we will use the term occlusion to explain a state which results when one object can be interpreted as partially obscures or occludes the outline of another object as shown in Fig. 1. The object which obscures is seen as in front, and the one which is covered as behind [1].

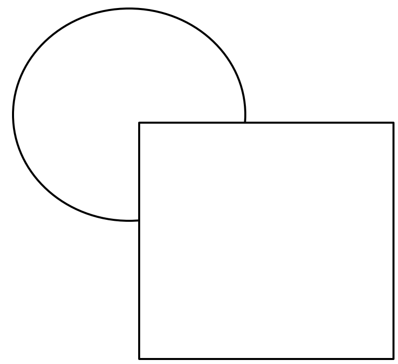


Fig. 1: Figure in partial occlusion

Objects are represented by line drawings. We exclude from our discussion the case of occlusion where the occluding object is fully surrounded by the occluded object as in Fig. 2(a), and we also exclude objects with hole from our work.

Occlusion is not a new phenomenon for man, who most of the time do not have any problem recognising partially occluded objects in their environment, yet researchers are still looking for a reliable model for machines to solve the same problem in a natural way. Many researchers believe that perception tends to result in interpretations characterised by phenomenal simplicity governed by a minimum principle. This phenomenal simplicity can be viewed at either a local or global level. Buffart et al.[5] believe in a global minimum principle which states that there will be a preference for interpretations that are as simple as possible for a pattern as a whole, even if such a globally simple interpretation is incompatible with the simplest description of some part of the pattern, while Boselie [6] and Boselie & Wouterlood [7] suggest that global minimum principle is only operative within the constraint of locally minimal description.

The phenomenon of occlusion gives rise to two instant interpretations, i.e. mosaic and completion. Mosaic is a state where two seemingly overlapping objects are actually sitting side by side in the same plane, they are of equal distance from the observer. On the other hand, completion interpretation suggests that the two objects are positioned in two different planes of sight, one in front of the other, the one that is behind can always be completed to ones interpretation. Helmholtz [8] has pointed out junction point cues as the sole determiner of the relative position of seemingly overlapping objects in space. His view was then refined by Ratoosh [9] by stating that continuity of the first derivative of the object's contour at the point of intersection is the sole determiner where conflicting junction point cues occur in one instance, for example, in Fig. 2(c) we have two conflicting T-junction cues. In other words, the contour which does not turn a sharp corner is seen as in front, as shown in Fig. 2(b). But there are cases, such as Fig. 2(d), the two junction cues may lead to an ambiguous figure. Chappanis and McCleary [1] refute Ratoosh's claim, instead they are of the opinion that overall figural configuration and meaningfulness as well as familiarity, are important cues as well. This view is supported by Dinnerstein and Wertheimer [2].

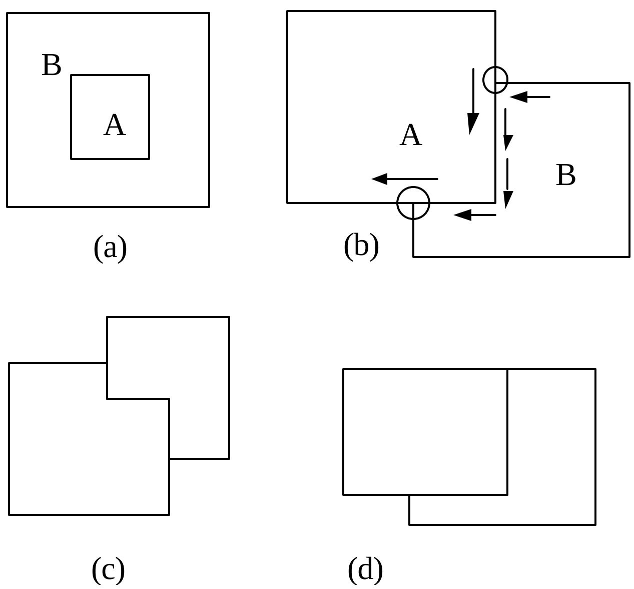



Fig. 2: (a) The occluding object A is fully surrounded by the occluded object B, it looks as though B has a hole in it. (b) A case of occlusion where A is seen as in front of B, the points of occlusion are circled. (c) Existence of two conflicting cues. (d) Existence of two ambiguous cues

## 2.0 HUMAN PERCEPTUAL PREFERENCE

As pointed out by Embong [10], human perceptual preference can be explained in terms of likelihood principle or minimum principle but practical measurement of perceptual preference, so far, has only been shown by advocates of minimum principle using Leeuwenberg's coding model [11]. Leeuwenberg's coding theory assumes simplicity based on global minimum principle, i.e. the minimum principle that applies to a pattern as a whole. Specifically, the global minimum principle states that there will be a preference for interpretations that are as simple as possible for a pattern as a whole, even if such a globally simple interpretation is incompatible with the simplest description of some parts of a pattern [12].

In Leeuwenberg's model, an interpretation of a two-dimensional line drawing pattern is represented by a series of symbols called primitive code. The primitive code of a pattern is obtained by tracing the contours of the pattern in one direction, starting from one point, noting the lengths and the angles of all contours until the starting point is reached. Lengths and angles with the same magnitude are represented by the same symbol. This is illustrated in Fig. 3. A primitive code can be simplified using coding rules to produce an end code which cannot be simplified further.

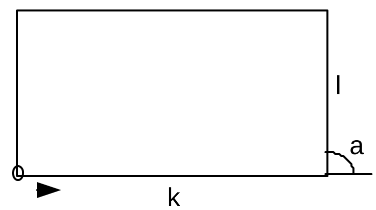



Fig. 3: Tracing a pattern, starting from a point indicated by the small circle and proceeds in the direction of the arrow, yielding a primitive code *kalakala*

Coding theory introduces many coding rules and it suggests that we may select different set of rules to arrive at the same end code. This shows that an arbitrariness is present in the choice of coding rules that are actually adopted in the encoding model. This fundamental problem calls for a more formal differentiation between kinds of regularity. Van der Helm and Leeuwenberg [13] propose that the concept of accessibility be taken as the basis for the choice of coding rules that are appropriate for the encoding of visual pattern. The concept of accessibility implies that regularity and hierarchy in a code of a pattern should correspond directly to regularity and hierarchy in the pattern itself.

Based on the accessibility criterion, Van der Helm and Leeuwenberg [13] have identified three prominent coding rules, they are iteration rule, symmetry rule, and alternation rule. These rules are referred to as ISA-rules. Any primitive code can be reduced to its end code by applying the corresponding ISA-rules. The reduced code is said to be in I-form, S-form, or A-form, respectively. Subsequently, Van der Helm & Leeuwenberg have proposed a new quantification of simplicity that he termed as information new load ($I_{new}$-load) to differentiate it from information load (I-load) used by Buffart et al. [5]. In this paper, for the sake of simplicity, we will refer $I_{new}$-load as I(N)-load. I(N)-load is equal to the number of all different elements over all hierarchical levels in the corresponding abstract chunking of the end code. All different single symbols and different actual groupings of several symbols or chunks are counted. The following examples illustrate the ISA-form and the corresponding I(N)-load, the end codes are obtained by using the algorithm written by Van der Helm [14]:

| | | |
|---|---|---|
| Primitive code: | abababab | |
| End code in I-form: | 4 * (ab), | I(N)-load = 3 |
| Primitive code: | abccba | |
| End code in S-form : | S[(a)(b)(c)], | I(N)-load = 3 |
| Primitive code: | abcba | |
| End code in S-form: | S[(a)(b), (c)], | I(N)-load = 3 |
| Primitive code: | apaqar | |
| End code in A-form: | <(a)>/<(p)(q)(r)>, | I(N)-load = 4 |
| Primitive code: | paqara | |
| End code in A-form: | <(p)(q)(r)>/<(a)>, | I(N)-load = 4 |

For instance, for Fig. 3, the primitive code *kalakala* can be reduced by the S-form to *kS[S[((a)),((l))],(k)]* with I(N)-load=4.

## 3.0 CRITICISMS OF GLOBAL MINIMUM PRINCIPLE

Boselie [7, 15] suggests that global minimum principle is only operative within the constraint of locally minimal description. He gives several examples based on the Gestalt principle of good continuation. According to Boselie, the principle of good continuation, in fact is the formulation of a locally operating minimum principle: a contour whose direction remains constant can be described more simply than the one whose direction changes, or one that terminates and is replaced by another contour. Kanizsa [3, 16] also stresses the role of good continuation in perceptual organisation. He believes that a minimum principle applies only to local regions of a pattern, and that perceptual organisation will not be influenced decisively by the demand for regularity of a whole pattern. However, Boselie [15] has shown that the principle of good continuation is not a general principle of perceptual organisation, and that overall figural goodness is also an important factor.

The debate on local versus global is still going on. For example, one might asks whether you look at local cues first or you look at the object as a whole. Navon [17] supports the global precedence hypothesis, i.e. information at the global level is invariably available prior to information on the local level, e.g. you see the forest before the trees. Kinchla and Wolf [18] suggest that size of the stimulus has a role in determining the speed of processing of local and global level; that there is an optimal size for stimuli, and the forms that are larger or smaller than this optimum are at a disadvantage. Walters [19] thinks that it is possible to use simple local computations to extract quantities that correlate well with the global properties of an image. The result of the computational model suggests ways in which the presence of certain local cues could be used to perform further useful visual processing.

Hoffman [20] concludes that global and local levels of forms are encoded in parallel. The speed of encoding is determined by two factors, i.e. the attention allocated to a particular level (retinal fixation), and the relative quality of information in a display at a particular level. Size is only one of the factors that may contribute to the quality of information. Other factors such as clarity, familiarity, goodness of pattern, continuity of contours, etc., need also to be considered.

From their investigation of the minimum tendencies in perception, Hatfield and Epstein [21] conclude that a global minimum principle which acts as a cardinal principle of perception will not be obtained. They believe that the question of whether the preference for simplicity is adaptive, or whether it results from the fact that the simpler is the more likely, are still very open. One also has to answer the question whether the perceptual system operates in accordance with the minimum principle, and if it does, whether the principle is mirrored in the coding theory.

## 4.0 AN ALTERNATIVE MODEL

Minimum principle in the context of coding theory assumes simplicity with regards to its globality, interpreting a figure in its entirety. There are cases where human interpretation of a pattern can only be explained, in terms of the encoding model, by locally simplest descriptions, i.e. simplest description for parts of the pattern instead of for the pattern as a whole entity. This phenomenon is known as local effect. Actually local effect is natural if we consider that the cause of the effect has greater appeal to the perceptual system. According to Leeuwenberg & Boselie [22], a minimum principle has to be limited to some local stimulus, if local effect did not exist, the perceptual system had to postpone the organisation of incoming information till it dies, because in principle each forthcoming input can lead to a better organisation of all input received till then. This would imply that stimuli never get organised at all. They conclude that the local effect phenomenon shows that a global minimum principle is constrained by locally minimal description.

Given a pattern in occlusion, we think the first decision a man will take is to decide whether it is really an occlusion or a mosaic. The question then is whether local - global interaction plays its role at this stage or later. If it is a case of occlusion, then the next step would be to decide on how the pattern is completed, probably based on local properties. Other than line continuation, Embong [23] has pointed out junction types interpretation as another important local factor and subsequently he has proposed a new strategy in line drawing interpretation of partially occluded patterns based on local as well as global properties. By considering both properties concurrently, he claimed that local effects can be minimised. Based on this strategy we have written an algorithm which can be modeled as in Fig. 4. Deliberation on the model has been done in [23]. In brief the model has suggested that cues for completion be checked before any decision based on information load alone is done.

We have tested the model using patterns drawn from two sets of figures that have been used in two different experiments, i.e. Boselie's [15] and Buffart et al.'s [5]. The reason why we choose to use those figures is because their interpretation preferences have been tested by the respective authors in their experiments. Furthermore, we think the set of figures is enough to represent the kind of occlusion involved in two-dimensional line drawings. However, some of the patterns have been modified slightly to suit our purpose, and a few patterns have been added. We exclude patterns with curvy boundary and adhere strictly to patterns with straight lines. Since we are not testing on the effect of orientation, for patterns with different orientations we only choose the one in its most natural orientation. The success of our approach is measured on how close the system's preference is to the subjects' preference as recorded in the two experiments. Of course our basic assumptions is that the subjects' preferences stay the same over the time.

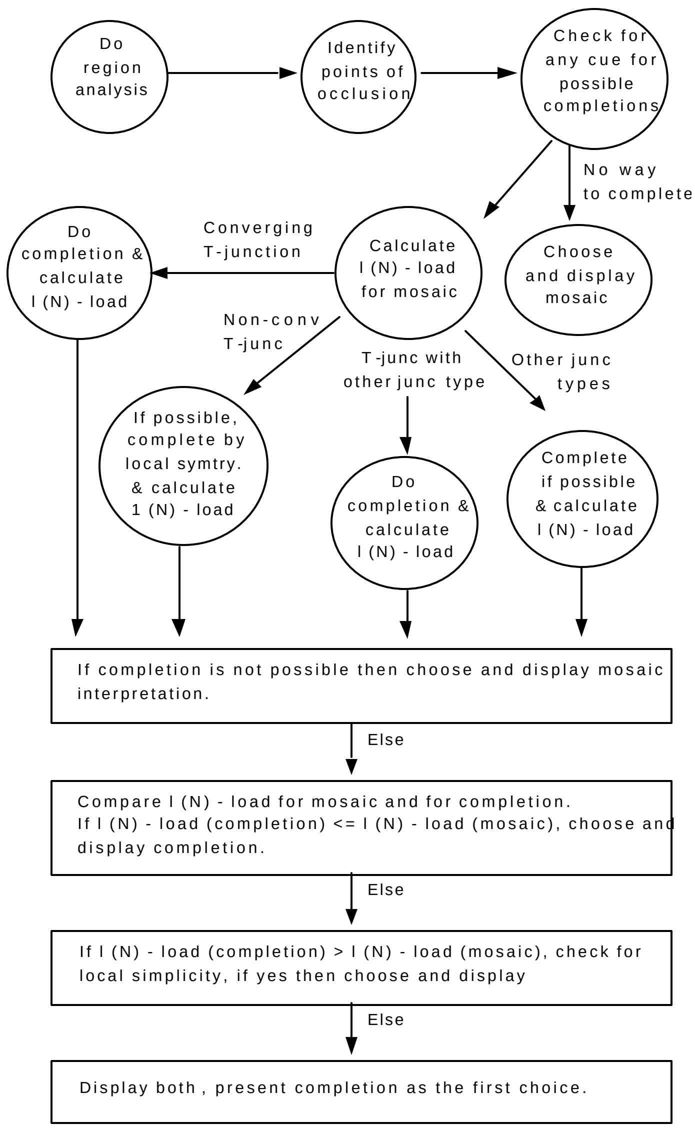
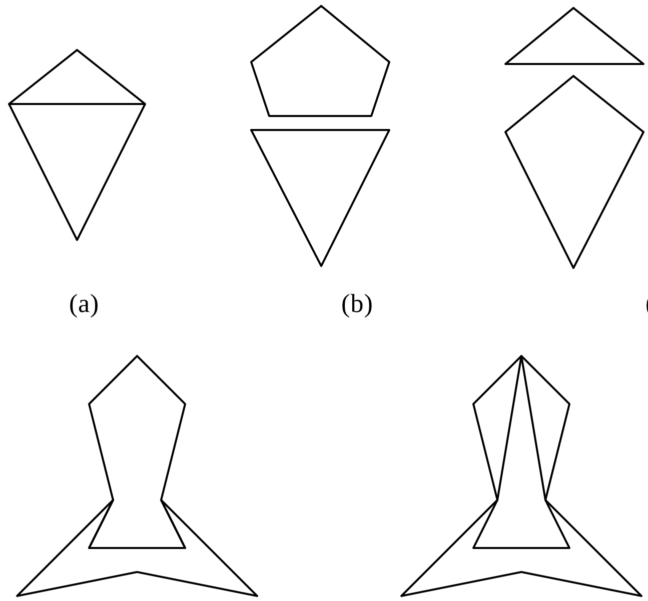



Fig. 4: The process flow in the interpretation strategy



(a) (b) (c)

(d) (e)

Fig. 5: (b) and (c) are two "possible" interpretations of (a). (b) is considered to be an imaginative interpretation because it is purely the "imagination" of the perceiver to perceive the top triangle as an occluded regular polygon. Interpretation (c) of (a) is an example of a full completion, i.e. the lower triangle is completed to the full extent of the region. (d) can be interpreted as (e), this is another example of imaginative completion.

The main difference in our approach as compared to the two earlier experiments is that our model does not enumerate all kinds of logical interpretations, instead it goes straight to suggest feasible interpretation. The decision is shaped during the process of determining which interpretation is most likely, mosaic or completion, not after exhaustive search through the enumeration of all probable interpretations. The decision process in our approach, therefore, is closer to human way of arriving at their preferences.

## 5.0 EXPERIMENTAL RESULTS AND DISCUSSIONS

Patterns are grouped into two categories:

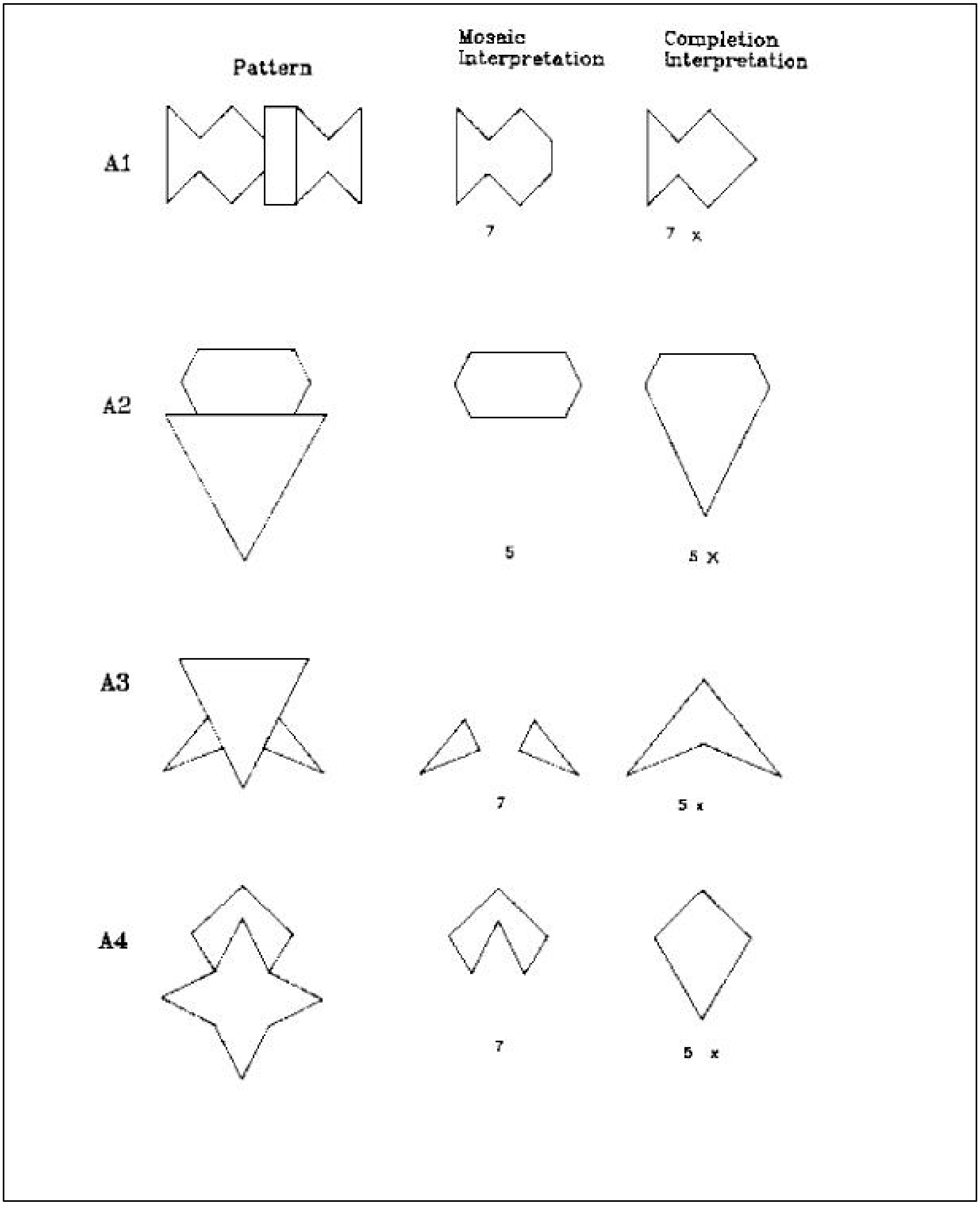
(A) Pattern which has some cue for completion.

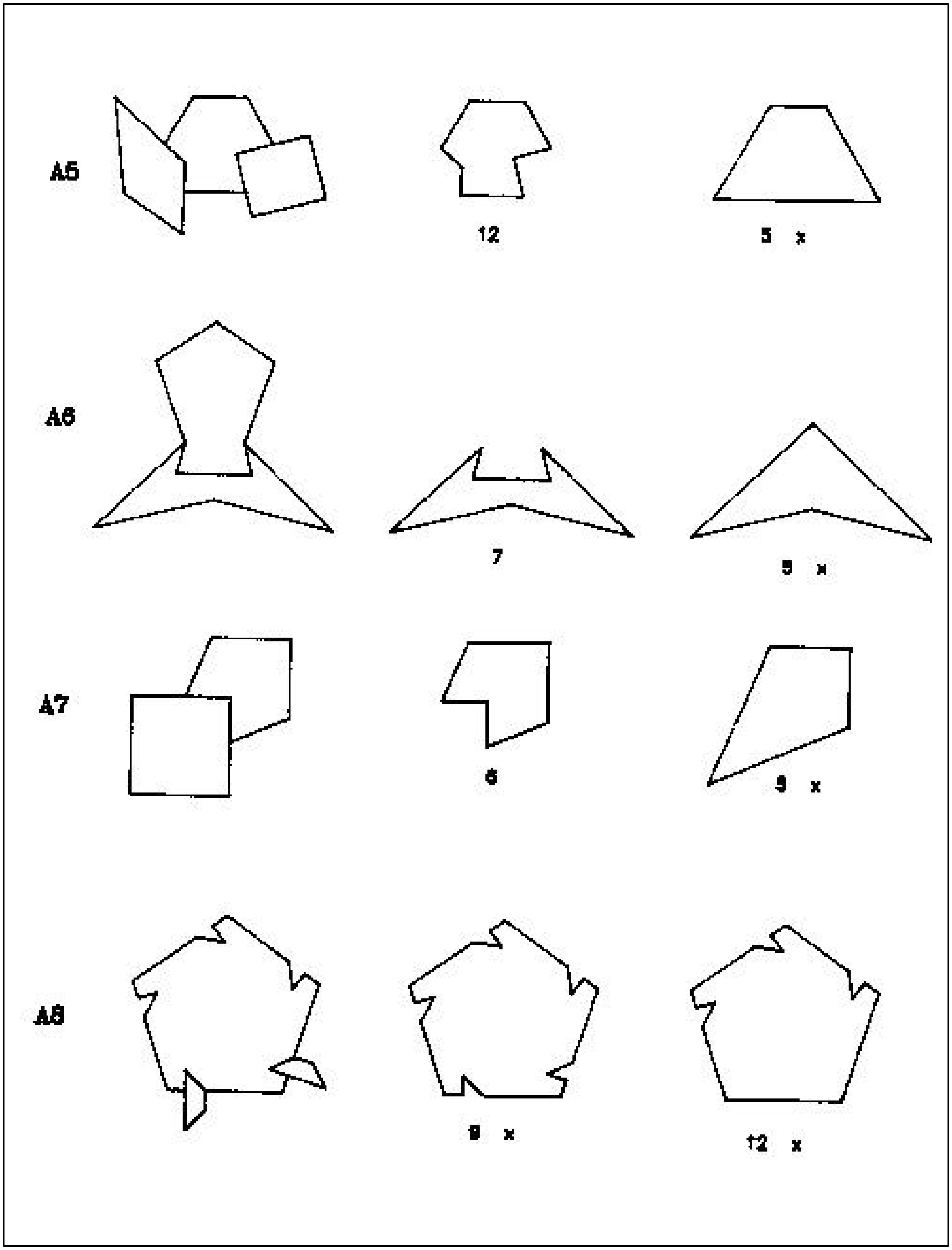
(B) Pattern which has no cue for completion.

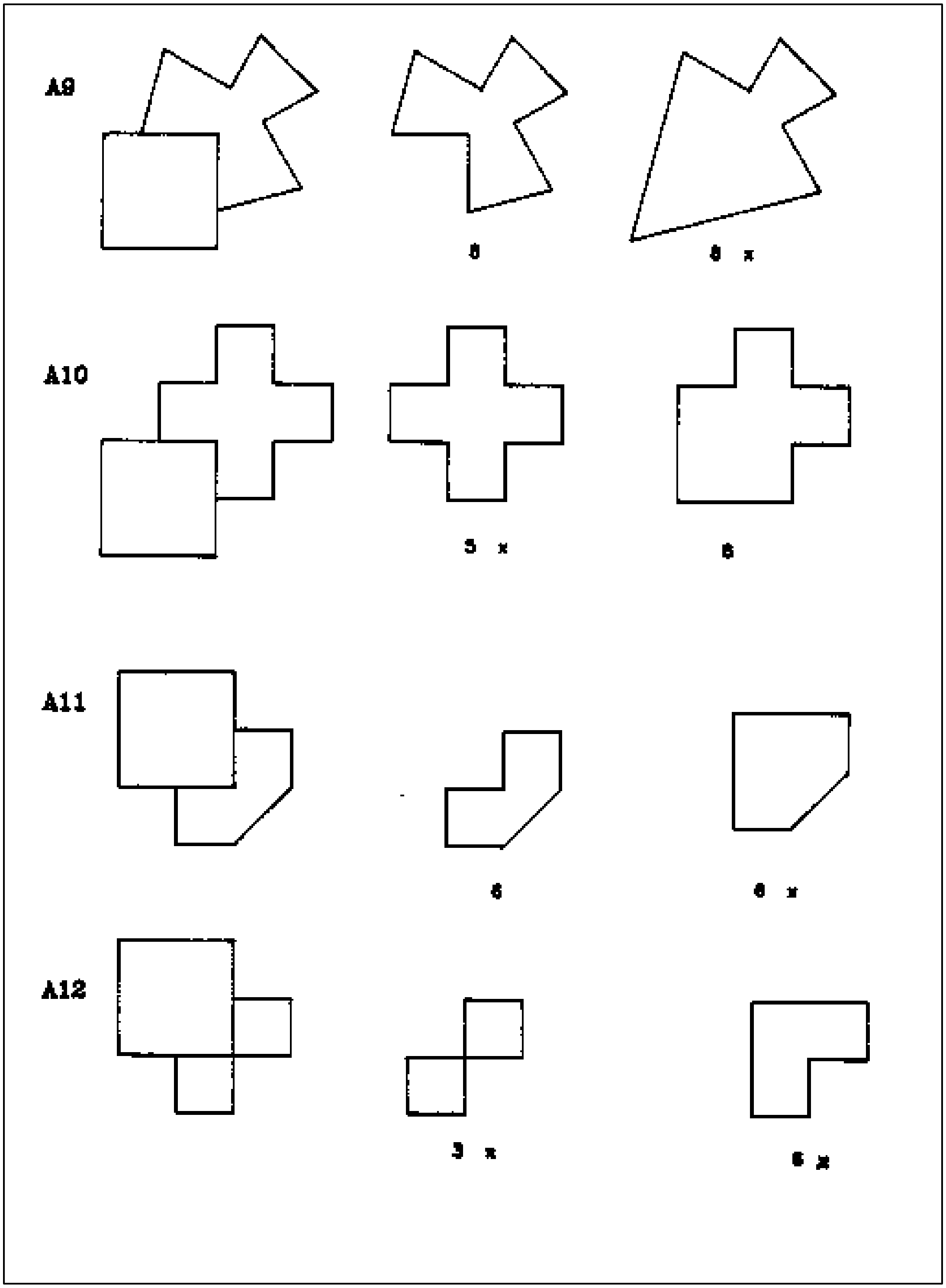
For the pattern in the (A) category we show both the mosaic interpretation and the completion interpretation. Alternative interpretations are not that many because we have already excluded cases of "full" completion, and furthermore we do not cater for imaginative completion. These are illustrated in Fig. 5. Only the interpretation of the occluded regions and the system's preferences are shown (Fig. 6). For the pattern in the (B) category there is only one preference, i.e. for mosaic, thus we just show the mosaic interpretations (Fig. 7).

For the patterns with no cue for completion the result is always a mosaic. Since there is no need to calculate the information load for the interpreted patterns, we just display the mosaic preference. The result shows that 100% of the system's display match the preferences shown by the subjects. According to the minimum codes employed by Boselie [15], coding theory predicts 3 out of the 6 patterns (50%) as mosaic, 2 patterns (30%) as completion, and 1 pattern (16.7%) as ambiguous.

For the patterns with some cues for completion, every possible means of completions based on local simplicity such as line continuation, local symmetry and junction interpretation is persued. If the completion based on local simplicity is compatible with the one based on global simplicity then the completion interpretation is preferred. If it is otherwise, i.e. the mosaic interpretation is globally simple, then we have to determine whether the mosaic interpretation is also locally simple or not. If the mosaic interpretation is globally as well as locally simple then mosaic interpretation is preferred over completion. If this is not the case then we have some form of ambiguous interpretation preference. The system has the choice to display both interpretations, but we hold to the opinion that completion interpretation based on local simplicity has more appeal than a mosaic interpretation which is globally simple but has no local significance [15]. Therefore we choose to present the completion interpretation as the first choice.


Pattern
Mosaic Interpretation
Completion Interpretation
A1
7
7 x
A2
5
5 x
A3
7
5 x
A4
7
5 x


A5
12
5 x
A6
7
5 x
A7
6
9 x
A8
x
12 x


A9
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6 x
A10
5 x
6
A11
6
6 x
A12
3 x
6 x

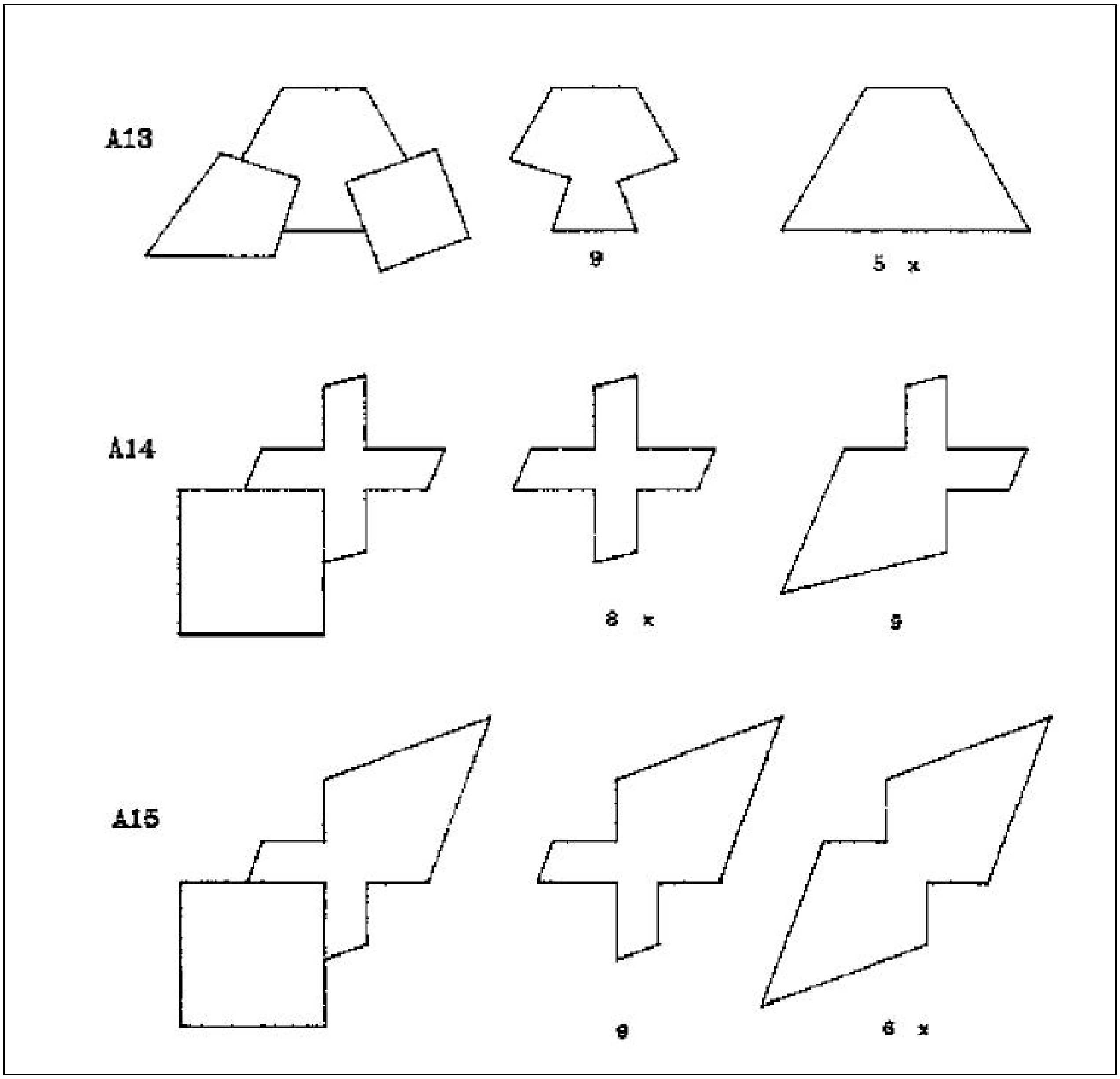


Fig. 6: The number beneath each interpretation is the respective I(N)-load. The x means that the particular interpretation is displayed by the system as its preference

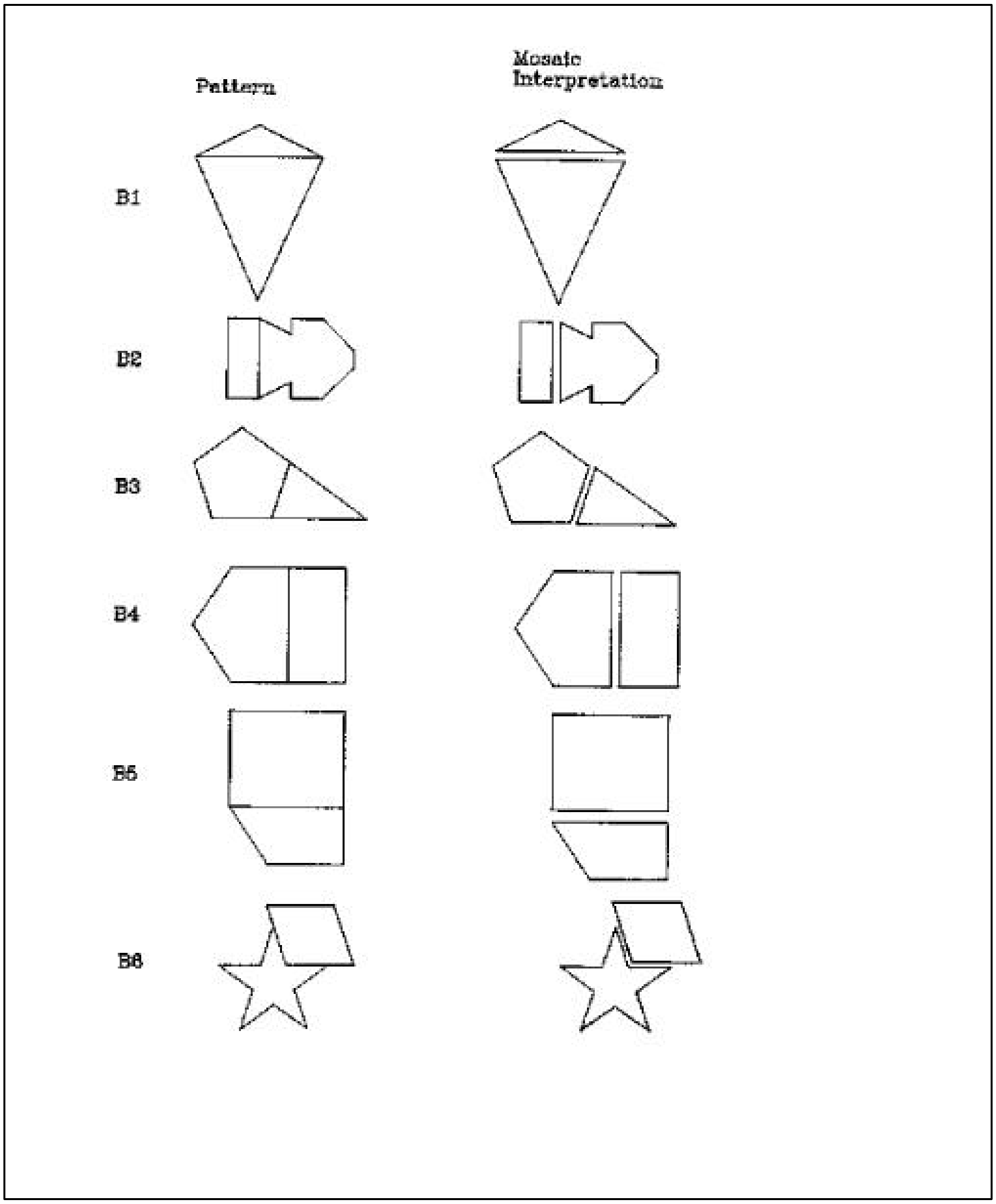


Fig. 7: Patterns with no cue for completion

Out of the 15 patterns with cues for completion as shown in Fig. 6, 13 interpretations (86.7%) match the subjects' preference, while the other two (13.3%), i.e. patterns A8 and A12 are displayed as ambiguous. In the two instances the mosaic interpretations are globally simple but not locally simple, and the completion interpretations are locally simple but not globally simple, hence the system marked it as ambiguous; both interpretations can be displayed but completion interpretation takes the first priority. According to Boselie's experiment, 100% of the subjects prefer pattern A8 as completion. For pattern A12, 42% of the subjects in Buffart et al.'s [5] experiment prefer mosaic interpretation and 54% prefer completion. This pattern is actually ambiguous; the two small squares can be interpreted either as two separate regions or as an L-shaped region which is accidentally occluded by the bigger square at such an angle that two of their sides are aligned with each other. In the same experiment, Buffart et al. present another pattern which is similar to pattern A12 but the two small squares are different in size as shown in Fig. 8, the preference shown by their subjects was reversed, 49% for mosaic and 46% for completion. The percentage (almost about 50-50) actually supports our system's preference for ambiguity. From the above result, it shows that for patterns with cues for completion almost 94% of the system's displays match the subjects' preferences, whereas according to the minimum codes employed by Boselie [15], coding theory only made nine (60%) correct interpretations; it predicted 4 patterns (26.7%) as ambiguous, and 2 patterns (13.3%) were wrongly interpreted.

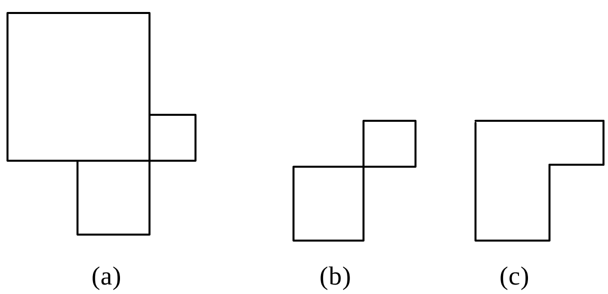


Fig. 8: (a) can be interpreted as (b) or (c). 49% of the subjects in Buffart et al.’s [5] experiment prefer (b) and 46% prefer (c), this shows that there are some ambiguity in (a)

## 6.0 SUGGESTIONS FOR FURTHER RESEARCH

Many aspects of line drawings and occlusion phenomena have not been included in our discussions. We have not addressed in detail the effects of context and high-level knowledge. We have not specifically considered figures with holes, curvy figures, three-dimensional figures, multiple figures, and multiple occlusion, and we have not examined in particular the effects of other factors like colour, size, and orientation on perceptual preference.

Figures with holes probably add an additional dimension to the problem. There arises a need to differentiate between a hole in a region and an occluding object positioned in front or on top of the region. For example, in Fig. 9, A and B can be interpreted as a hole in the respective square, or they can be interpreted as smaller squares occluding the bigger squares. The problem needs to be addressed further.

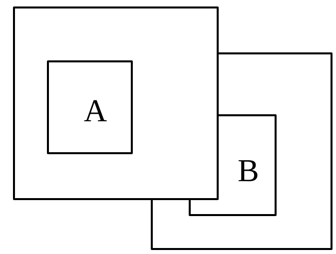


Fig. 9: A and B can be interpreted as holes in the pattern or as smaller squares occluding the respective bigger squares

To be useful to the real world situation, extension of the problem from two-dimensional line drawings to three-dimensional figures needs three-dimensional environment and involves more variables like adjacent consistency and verticality. Currently much researches in three-dimensional figures are more concerned with scene recognition, we think more work should be devoted to the interpretation of three-dimensional objects in partial occlusion.

Most of our discussions were devoted to figures consisting of only two regions or objects. This should be extended to multiple figures, i.e. figures consisting of more than two objects. Multiple figures will give rise to occurrence of multiple occlusion and compound occlusion. These occurrences are illustrated in Fig. 10. Further works need to be done to address those cases.

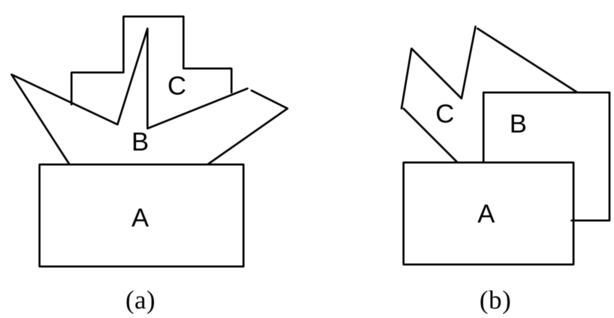


Fig. 10: (a) Multiple occlusion, where A occludes B and B occludes C. (b) Compound occlusion where A occludes B and both A and B occlude C

The effect of colour, size, orientation, and many other factors of visual preference has to be investigated in detail. This calls for further and continuous research by the experimental psychologists and computational vision researchers. The challenge is far from over. We have seen that stimulus pattern tends to be perceived as a simple structure. In the process, probably more than one perceptual factors are detected, they might be seen to complement and support each other, or there exists conflicting factors which could lead to conflicting perceptual hypothesis. How do we decide which factor is dominating? Even among basic factors and visual principles put forward by the Gestaltists, it has not been determined conclusively "which dominate what". Investigation in this direction is still inconclusive, and very much is yet to be researched. The result of further psychological findings will be the basis of future computational model of perceptual preference.

## 7.0 FINAL REMARKS

Perception is active. It is an interaction between the perceiver and the stimulus through the environment. Each has its own role in the perceptual process but the perceiver (human) is and will always be in the commanding position. Man is encouraged to study and understand the processes involved, and probably will succeed up to a certain degree in translating the understanding into some forms of mechanical processes implemented in a certain machine. But our understanding of the perceptual processes is very limited indeed and probably we will never be able to know the details of the actual processes. Yet there are always space for the seekers of knowledge to know more.

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