Modelling the Process of Assimilation: Computer Simulation of Visual Pattern Recognition

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How computers can help to confirm Piaget's hypothesis

1 Abstract

This work aims at providing an operational model for the process of assimilation described by Jean Piaget, in order to find new concrete evidence to confirm its validity. It has been applied to the visual recognition of simple geometric patterns, and computer simulations have been performed, which exhibited visibly different properties of resilience and selectiveness due to the active nature of the piagetian processes.

2 Introduction

The main obstacles to modelling piagetian assimilation are probably its very generalized nature [1, 3] and the fact it applies to so many different levels. Since 1936 [7], surprisingly few attempts have been made to develop formal models of assimilation. F. Bresson [2] took an important step in that way, but his model has not been completed and confirmed by other works. In the field of artificial intelligence, Grossberg [4] used the concept of *circular reaction* to design a neural network able to reach and grasp objects, with an unsupervised learning algorithm.

3 Towards a model of the process of assimilation

The three main features of the piagetian assimilation process have been expressed as axiomatic properties of what is intended to be a formal model:

1. The cyclic and repetitive nature of the process of assimilation which enables it to be applied whenever possible.

2. Its capacity for generalization, when a pattern of behavior applies to many similar objects.

3. Its capacity for differenciation, which can cause a particular assimilation pattern to split in two when repeatedly in contact with two situations which are similar but not identical.

The sensori-motor assimilation process is based on activity: when a particular scheme assimilates a situation, it is made through a succession of coordinated actions. What are these actions, and how can we model them?

A complex action may be clearly a coordination of perception with more elementary actions. In short, it is also an assimilation scheme, and is itself composed of more elementary assimilation schemes. Therefore, even the smallest 'atoms' of behavior still are irreducible sensori-motor assimilation processes.

For instance, it is well known since Hubel and Wiesel [5] that, in the visual cortex of mammals, some neurons are specifically activated when segments of lines of a particular orientation are projected at a particular place on the retina.

For our computer simulation, we have designed elementary assimilation schemes associated with small oriented segments. For instance, the s_{60} assimilation scheme has been programmed with *ad-hoc* methods in order to have the following properties:

- when a small segment of line with an horizontal orientation of 60 degrees is projected at the center of the retina, the scheme is activated, leading to occular movements between both ends of the segment (Figure 1).
- the level of activity is represented by an upper bounded positive value, in [0,100] for instance. If the segment orientation is not exactly 60 degrees, or if it is not perfectly straight, the activity level will be less than 100.
- if the segment is slowly moved with a mouse on the screen, the eye keeps following it.

In this scheme, assimilation is clearly sensori-motor and is undifferenciated from accomodation. It sees a world of small orientated segments of lines. We consider it as elementary, because we count on its behavior without trying to know how it works.

We shall represent it by the cyclic network of Figure 2, where nodes are intermediate states, and arcs between the nodes are occular movements of positioning. These parts are unseparable, since the scheme is elementary.

The next step is to see how we can combine already formed schemes in order to get more complex assimilations.

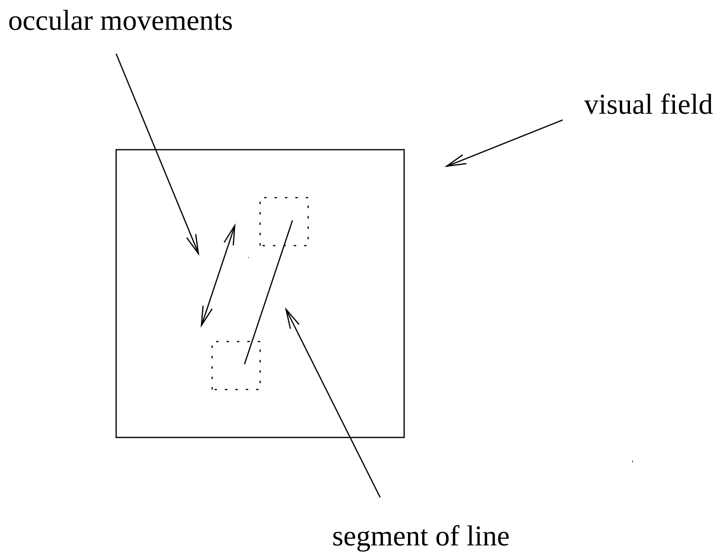

Figure 1: assimilation of a small segment

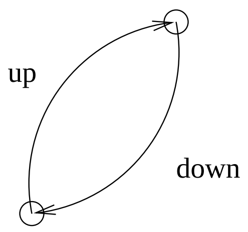

Figure 2: assimilation scheme of a small segment

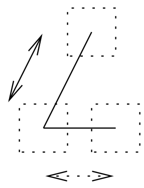

Figure 3: assimilation of an angle

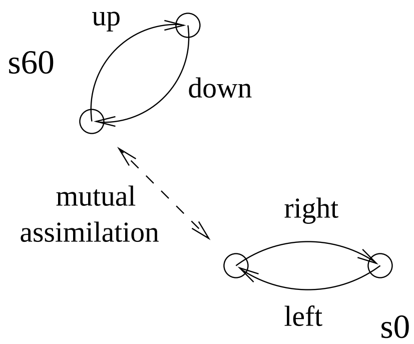

Figure 4: assimilation scheme of an angle

We have programmed a similar assimilation scheme s_0 which is activated when a small segment of horizontal line is projected at the center of the retina.

Let us consider for instance the shape of Figure 3 as being projected at the center of the visual field. Both assimilation schemes s_{60} and s_0 are alternatively activated, since the occular movement *down* of s_{60} makes possible the activity of s_0 and *vice versa.*

The general principle of mutual assimilation will lead these schemes to become parts of the more complex scheme of Figure 4.

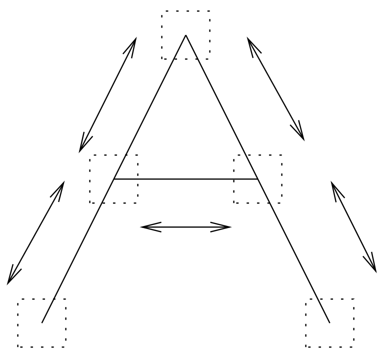

Figure 5: assimilation of the letter A

The activity level of the whole scheme is computed as the sum of the activity levels of its parts. The *mutual assimilation* arrow represents a way for the activity to circulate through both schemes. More exactly, when one of the schemes has an activity level L high enough, the other receives an a priori activity level proportional to L, in order to anticipate the next step in the assimilation cycle.

This mechanism leads to interesting pattern matching properties:

- if the whole pattern is moved, the eye still follows it.
- the more distorted the pattern, the lower the level of activity of the scheme.

Other new properties of selectiveness and resilience appear with still more complex patterns. Consider for instance the scheme of Figure 6, designed to assimilate the shape of the letter A.

The total activity level of this scheme may be as high as 500. When this activity circulates through the network, the anticipation mechanism

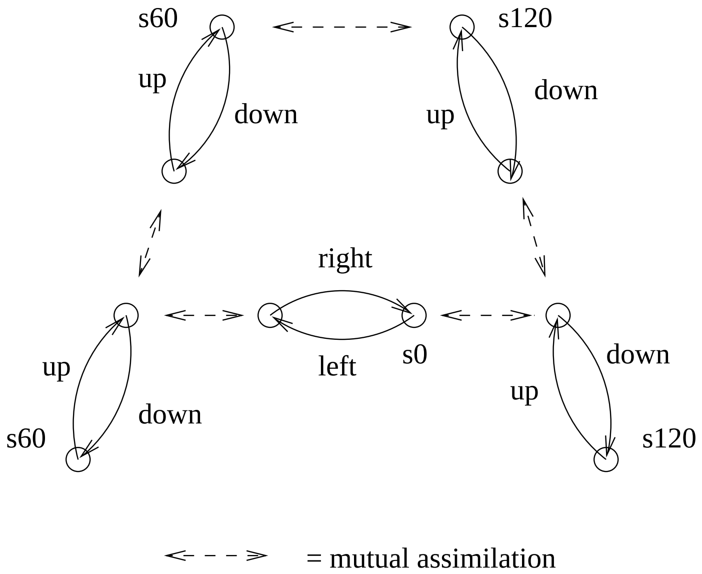

Figure 6: assimilation scheme of the letter A

described previously leads to high pre-activation levels. If we introduce in the visual field some increasing background interference (Figure 7), the activity of the letter A scheme will occasionnaly make possible the activity of some of the interference schemes. In those cases, when multiple and opposite actions are possible, the model chooses the scheme which has the highest level of activity. So in the end, the letter A scheme will overpower all others, and recognition will remain possible.

We can also study the differenciation of two superimposed shapes, for instance our letter A shape and a letter L shape (Figure 9).

If, by chance, one of the letter schemes is first activated, its actions will be successively chosen, and it will soon overpower the other, which will be seen as a kind of interference. If one of both schemes is preactivated by a

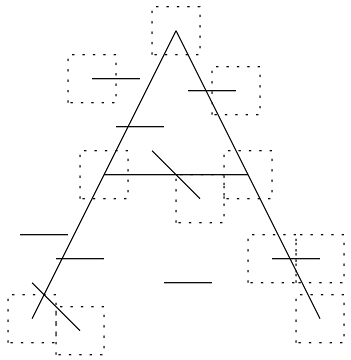

Figure 7: background interference

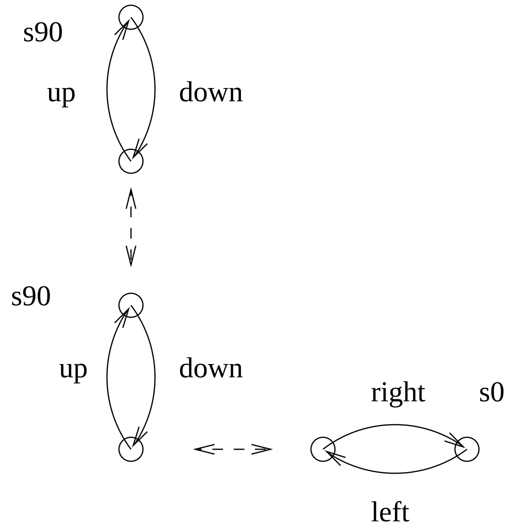

Figure 8: assimilation scheme of the letter L

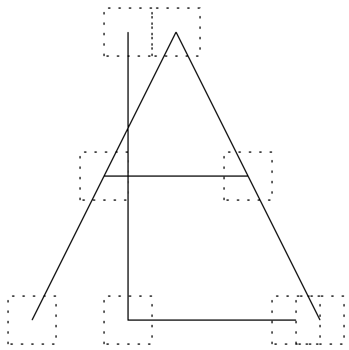

Figure 9: superimposed shapes

higher assimilation, its recognition will no longer be indeterministic.

Finally, let us consider the assimilation scheme of a triangle (Figure 10).

If we project the image of a triangle at the center of the visual field, and if we separate progressively the three corners, it will still be recognized as a triangle (Figure 11), with a smaller activity level.

It can be imagined that this initial assimilation could be confirmed and reinforced by processes of a higher level.

It would be interesting to see whether other optical illusions could be explained by the active way by which the shape is reconstructed by occular movements.

4 Conclusions

We have been able to prove that piagetian methods can be successfully implemented in formal models, and simulated at certain levels of perception. They have visibly demonstrated how information is sought through the occular activity of the subject.

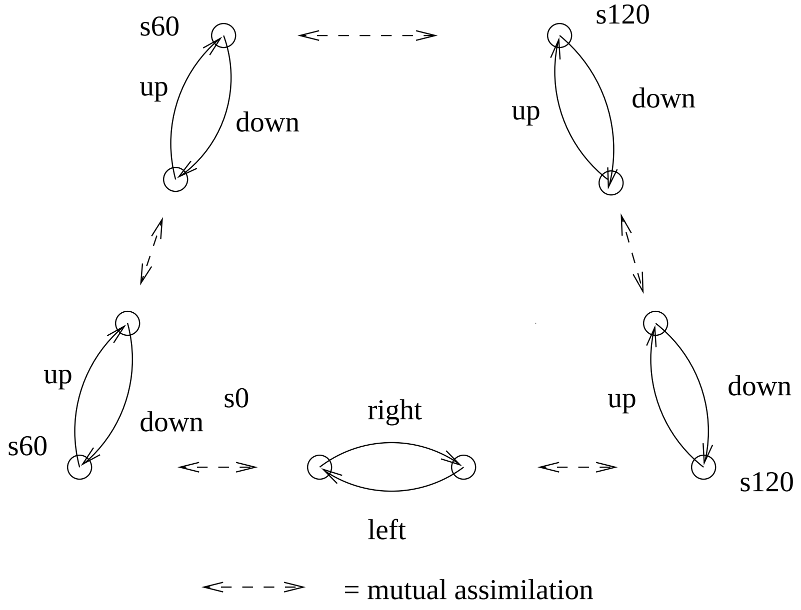

Figure 10: triangle scheme

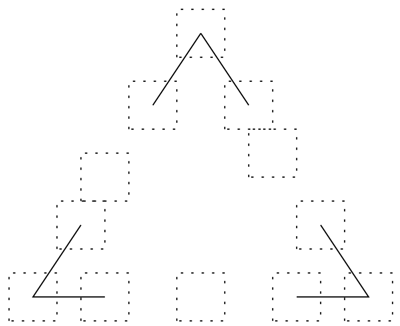

Figure 11: suggested triangle

The next stage would be to enable the model to extend its capacities towards a certain degree of learning, and then perhaps apply it to other aspects of sensori-motor intelligence. We could simulate the mutual assimilation process between arm movement schemes and occular assimilations, in order to study the construction of arm-eye coordination. This would provide convincing evidence for the validity of Piaget's hypotheses.

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