ON A POSSIBLE MECHANISM OF BINOCULAR FUSION

O.V. Levashov
Institute of Control Sciences, Moscow, USSR

Abstract

Described is a possible mechanism of binocular fusion In visual system based on continious estimation of resulting "cortical image" doubling degree during vergence eye movements. The mechanism does not require any search of corresponding sites in pair retinal images. The result of computer simulation of this mechanism are given. A sequence of information processing stages in binocular vision preceding recognition is discussed.

Introduction

It is assumed that corresponding sites of pair retinal images have to be found in order to provide the binocular fusion (I). This procedure seems to be rather complicated for real visual scenes (2). On the other hand some results of the biological experiments show that binocular fusion and stereopsis are possible when corresponding details of pair images have dissimilar shape (1,3.4,5). This suggest that the human binocular fusion mechanism is not based on corresponding sites search.

In this paper a possible binocular fusion mechanism using a continious estimation of doubling degree of image (which is formed in visual cortex by superposition of retinal projections) in the course of vergence is described.

Some information processing stages in binocular vision preceding object recognition

Data available allow to distinguish the following stages of complex spatial scene analysis (i.e. when a number of objects overlapping in the visual field are situated in front, middle and rear plan).

1?^Coarse binooular fusion (plan extraction in depth;

Presumably at first the extraction of the most distinct regions in pair retinal images of similar color or brightness is carried out. Then horizontal disparity of these regions (by their centres or edges) is calculated. After this a divergence or convergence by corresponding angle is carried out. The parts of scene located far farther or nearer than plan extracted are ignored in the further analysis.

All further considerations are concerned with the part of scene located in the region of central vision.

2. Extraction of "subjective contours"

After "plan extraction from the background" (image is obtained which may contain several overlapping projections *of* objects located in the plan extracted), the boundaries among regions of different color, brightness and texture are drawn.

3« Accurate binocular fusion

In the course of further vergence the doubling degree of a part of image obtained is estimated using the extracted "subjective contours". When some marginal doubling degree is attained a command for the eye stop is produced.

4. Stereopsis and extraction of "object irom the baoJcgrouna"

Using the fused part as "zero point" the disparities for the other image points are determined. Disparity distribution is evaluated then and a decision on possible 3-dimansional object shape (or its parts) is made. If the discontinuity of disparity occurs, e.g. when a number of rigid objects is closely located in the plan extracted, some compact (with respect to disparity) set of points (an object) is extracted other being ignored in the further analysis.

The data which support a possibility of existence of these stages in binocular vision are as followsi

- depth perception without "subjective contours" (using disparities of distinctive regions in the stereograms) (1,3, 4,5)i ,
- existence of coarse (qualitative) and precise stereopsis (6)$ inhibitory interaction between information processing channels of crossed and uncrossed disparity (corresponding to different scene plans) (7)|
- reduction of "Mach bands effect" resulting from the "staircase" arrangment of test bands (in depth) (8)i
- preceding of "subjective contours" extraction by the difference in color, luminance or texture to a stereopsis (1,4,9);
- suppression of unfused parts of stereopairs in "binocular rivalry" phenomenon (when they differ in shape significantly) (I);

The 2-nd stage is related to monocular vision and can in principle start simultaneously with the I-st stage.

- using the "narrow slit" detectors (instead of the "edge" detectors) during determination of disparity in vision (10);
- preceding of stereopsis to a recognition (1,11).

In the following only the 3-rd stage of the process will be considered, namely, a mechanism of precise binocular fusion. Assume that the I-st and the 2-nd stages have been accomplished.

A possible mechanism of binocular fusion

When the vergence eye movements In the course of binocular fusion occur, cortical projections from right and left retina are shifted with respect to each other. Assume that a set of "two parallel lines" detectors and "single line" detectors with various orientation and distance between lines in optimal stimulus is available in visual cortex. Then the moment of fusion approaching the set of "double lines" detectors will respond with the distance between the lines contlnlously decreasing. The response of some "marginal set" of the detectors could be a signal for the eye to stop. The marginal distance between the lines depend on eye movement fusion velocity and duration of earring out a stop-command. In the moment the eyes are fixed, the resulting cortical image appears to be fused. A small number of responding "marginal double lines" and a large number of "single lines" detectors responding will also correspond to this moment. A permanent evaluation of cortical image doubling degree during the vergence leads to avoiding the "eye overshoot" in moment of fusion.

A digital simulation of binocular fusion mechanism

The simulation was carried out on a digital computer. Input images were stereopairs of 25x25 (Pig. la) which represented the right and left projections of front view of a cube (subtending an angle of 18). Initially the stereopalrs have been shifted, imitating the "eye fixation" being not in the cube plan. On each step computer shifted one of the stereopairs by one ceil and superimposed both stereopalrs which imitated the cortical projections shift during the vergence. Then the number of double and single lines in resulting image was calculated. This operation was carried out by means of a set of local operators (5x5 in size) which extracted the segments of single

'It is "cortical image" obtained by imposing the retinal projections which bears in mind.

and double lines of various orientations in resulting image (Fig. lb). At each step the ratio of double lines available to single lines was calculated. The relative stereopalrs position in which this ratio was maximal was searched (Fig. I c). Prom this position the stereopalr was shifted by two cells and the resulting superimposed image was printed out (Pig. Id).

As Pig. Id shows, stereopalrs being projections of 3-dimensional object can not be completly fused in none of their relative positions. Simulation results however showed that computer correctly finds the relative position which corresponds to the maximal fusion (in our case - to the front edge cube fusion)•

Conclusion

The binocular fusion mechanism under discussion does not require search of corresponding points in pair retinal images. However it assumes that "subjective contours" are initially extracted by color, luminance and texture differences- Further attempts should be directed toward the study of both subjective contours extraction mechanism (particularly by texture differences) and stereopsis mechanism (which is carried out after binocular fusion of a part of image). The suggested visual system ability to extract "object from the background" binocularly could be taken into consideration in robot visual system design.

'New data which support the hypothesis is obtained recently. Superiority of double parallel lines detectors with angle distance between the lines about 0,5 was found in the visual cortex of a cat (12) (thus indicating the existence of a certain "marginal detectors set").

References

I. B.Juleez, Foundation of Cyclopean Perception, Univ. Chic. Press, Chic. 1971
2. L.Sutro, W.Kilmer, Assembly Computers to Command and Control a Robot, AP PS Conf. Proc, 34,pp. 113-137, 1969-
3. L.Kaufman, C.Pltblado, Further observation on the nature of effective binocular disparities, Am. J. Psychol., 1965, 2a, PP. 366-389.
4. L.Kaufman, J.Bacon, F.Baroso, Stereopsis without image segregation, Vision Res., 1973, 13, pp. 137-147.
5. D.Uitchell, Qualitative depth localisation with diplopia images of dissimilar shape, Vision Res., 1969, 2,991-
6. C.Blacemore, The range and scope of binocular depth discrimination in man, J. Physiol., Load., 1970, 211, 599-62.

7. W.Richards, Disparity masking, Vision Res., 1972, 12, pp. 1113-1124.
8. E.Wist, Mach bands and depth adjacency, Bull. Psychonom. Soc., 1974, 3, pp.97-99.
9. V.Ramachandran, V.Madhusudhan Rao, T.Vidyasagar, The role of contours in stereopsis, Nature, Lond., 1973, 242, pp. 412-414.
10. T.Felton, W.Richards, S.Smith, Disparity processing of spatial frequency in man, J. Physiol., Lond., 1972, 225, pp. 349-362.
11. R.Over, N.Long, Depth is visible before figure in stereoscopic perception of random-dot patterns, Vision Res., 1973, 13, pp. 1207-1209.
12. R. Phelps, Effect of interaction of two moving lines on single unit responses in the cat's visual cortex, Vision Res., 1974, 14, pp. 1371-1375.

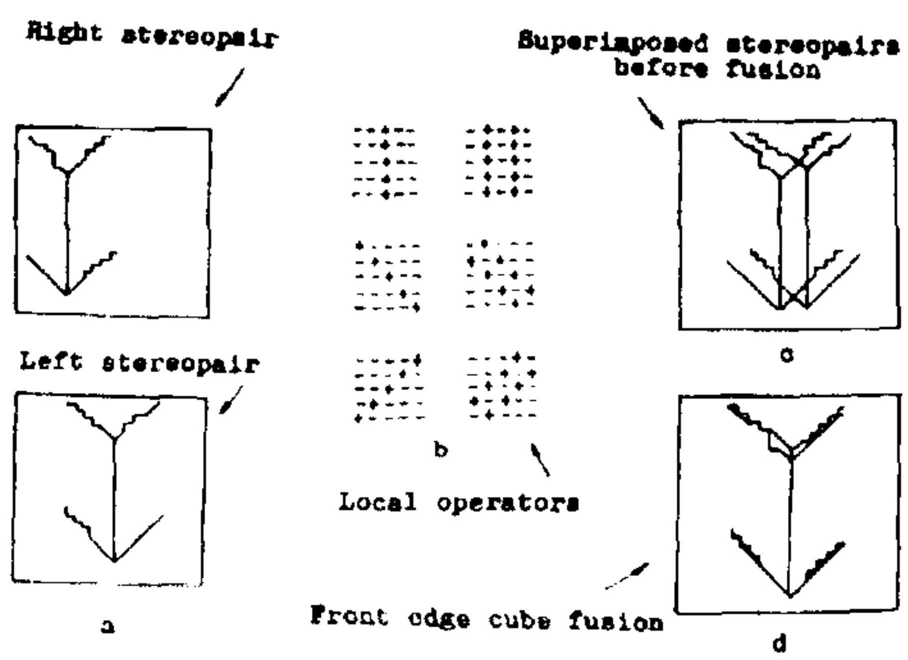

Figure I