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RESEARCH NOTE

AN AMBIGUOUS RANDOM-DOT STEREOGRAM WHICH PERMITS CONTINUOUS CHANGE OF INTERPRETATION

L. L. KONTSEVICH

Institute for Problems of Information Transmission, Academy of Sciences of the U.S.S.R., Ermolovoy 19, 101447 Moscow, U.S.S.R.

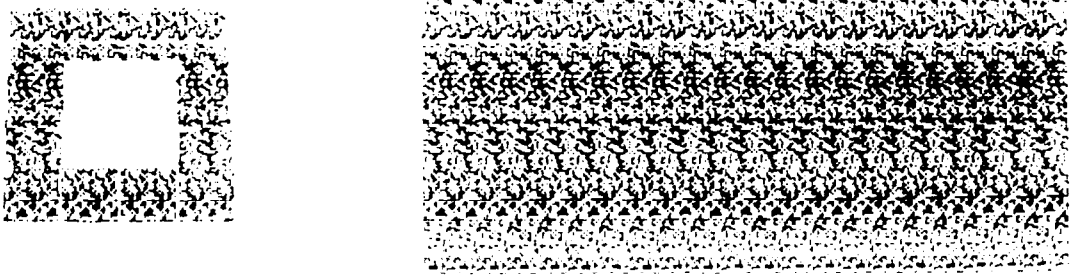
It is not difficult to construct random-dot stereogram (RDS) with ambiguous interpretations. Stereograms which permit two interpretations were described by Julesz (1971). Consideration of these RDS shows that the shift from one interpretation to another is difficult for subjects and it passes through a phase in which fusion is destroyed. Therefore it would be very interesting to create an RDS that permits a continuous change of interpretation.

All the known models of global stereopsis rely on the axiom of continuity (Julesz, 1971; Marr and Poggio, 1979). This implies that if the subject achieves global fusion by means of serial fusion of pattern regions, the following rule will hold: if in RDS some region A is fused and an adjacent domain B with ambiguous interpretation is not yet fused, then domain B will be fused so as to minimise the difference in perceived depth between A and B. The design of the proposed stereogram is based directly on this axiom.

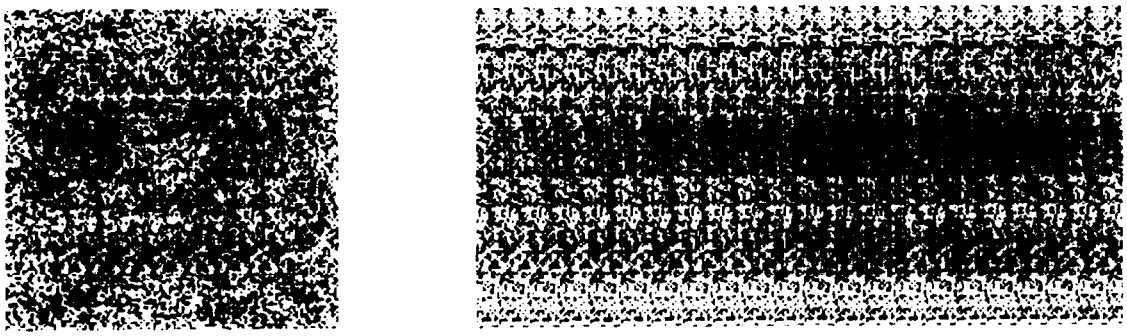
The RDS [see Fig. 1(a)] consists of two parts; one eye views a rectangular pattern while the other views a square pattern. The rectangle has a horizontally periodic texture (12 dots per period) which is random within the limits of one period. The square part consists of 12 square regions 21 by 21 dots each, arranged around the perimeter of a central square. Each square region is the exact copy of some square area from the rectangular part; because of the periodic structure of the rectangle, each square region corresponds not to one, but to many squares in the rectangle. The distance between these square areas in the rectangle is a multiple of the period (12 dots). Fusion of each square region with the corresponding part of the rectangle gives a frontoparallel square surface. If two adjacent square regions are fused sequentially, the second clockwise square will appear deeper then the first (or vice versa, depending on whether the subject uses crossed or uncrossed fusion). Value of the minimal relative disparity between the surfaces of adjacent squares corresponds in linear units to 1 dot of texture. According to the continuity axiom it is such an interpretation that will be chosen. So, regions viewed sequentially are organised into the structure of a spiral staircase. The proposed RDS has two versions; in the first case the squares are surrounded by a white background [Fig. 1(a)], while in the second the background is random [Fig. 1(b)]. Which of these modifications is easier to fuse depends on personal characteristics of the subject.

If the RDS is viewed from a near distance, the subject's attention cannot cover the entire pattern. His glance traces the steps of the spiral staircase one at a time, from near to far or vice versa. Sometimes, if the RDS is viewed far from the subject, the entire pattern can be perceived in a simple fixation. In this case one turn of the staircase is seen completely and there is no further change of depth. None of the subjects could see more than one turn of the staircase at once. Below we shall discuss only the sequential tracing.

During the tracing of the staircase one eye views sequentially the square regions of the RDS square part; the other eye moves in a spiral-like trajectory over the rectangular part, cycle by cycle sliding to the margin of the rectangle. If this eye meets the rectangle borders, fusion is automatically destroyed; however, if the border is far enough, this eyes motion cannot continue indefinitely: at some moment the motion in depth stops with pain in the eyes, an involuntary succade and destruction of fusion. This happens when the physiological



(a)



(b)

Fig. 1.

limit of the eyes' vergence angle is achieved. This fact allows use of the proposed stereogram for evaluation of this limit and for training patients with strabismus.

The proposed stereogram is rather difficult but after some trials most of the subjects (15 from 18) could fuse it. Those who achieved successful fusion can be divided into two categories:

(1) for 3 subjects the relative depth difference of sequential turns was evaluated in accordance with the geometry of RDS (illustrated in Fig. 2). It is interesting to note that all of them were myopes;

(2) for 12 subjects each sequential step had a different depth during sequential tracing, but

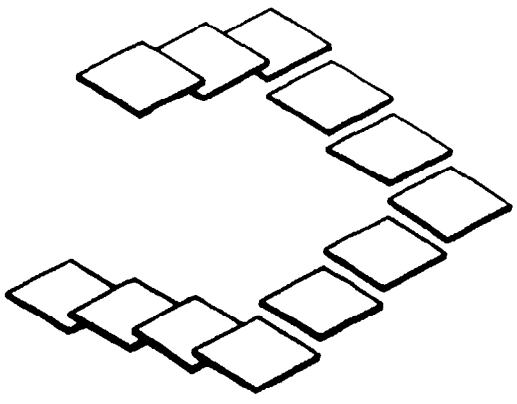


Fig. 2.

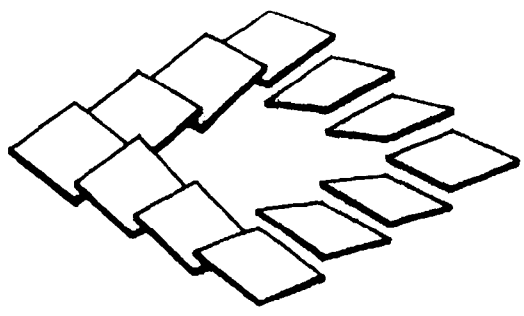


Fig. 3.

the distance between successive turns changed slightly or not changed at all. There appeared a sense of paradox similar to that with Penroses' triangle (Penrose and Penrose, 1958). This sense disappeared after two or three tracing turns, when a consistent stable interpretation of the whole pattern was formed (illustrated in Fig. 3). The peculiarity of this interpretation is that it does not reflect precisely to the real geometry of the RDS.

The described phenomenon can be explained by individual parameters of short-term memory for depth in different subjects. For the second type of interpretation slight deviation of interpreted depth from the precise estimation is permissible. In the first type they must correspond precisely. In some sense the described interpretations may be thought of as analogous to absolute and relative pitch in music.

The discovered phenomena reveal an interesting property of the binocular system, which not only fuses the RDS, but also interprets it in such a way that this interpretation is compatible with human experience.

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