Von Neumann's Ideas on the Architeture of The Brain & Related Questions

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"In the above, the frequencies of certain periodic or nearly periodic pulse-trains carried the message, i.e. the <u>information</u>. These were distinctly <u>statistical</u> traits of the message......
Clearly, other traits of the (statistical) message could also be used: indeed the frequency referred to is a property of a single train of pulses whereas every one of the relevant nerves consists of a large number of fibers each of which transmits numerous trains of pulses. It is, therefore perfectly plausible that certain (statistical) relationships between such trains of pulses also transmit information"

ARITHMETIC & LOGICAL DEPTH : PRECISION

vs.

LOGICAL BREADTH

THE LANGUAGE OF THE BRAIN NOT the LANGUAGE OF MATHEMATICS

"We have now accumulated sufficient evidence to see that whatever language the central nervous system is using, it is characterized by less logical and arithmetical depth than what we are normally used to." .....

"Thus logics and mathematics in the central nervous system, when viewed as languages must structurally be essentially different from those languages to which our common experience refers."

John Von Neumann
Computer and the Brain.

Section 3

What the Frog's Eye Tells the Frog's Brain

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Research Laboratory for Electronics
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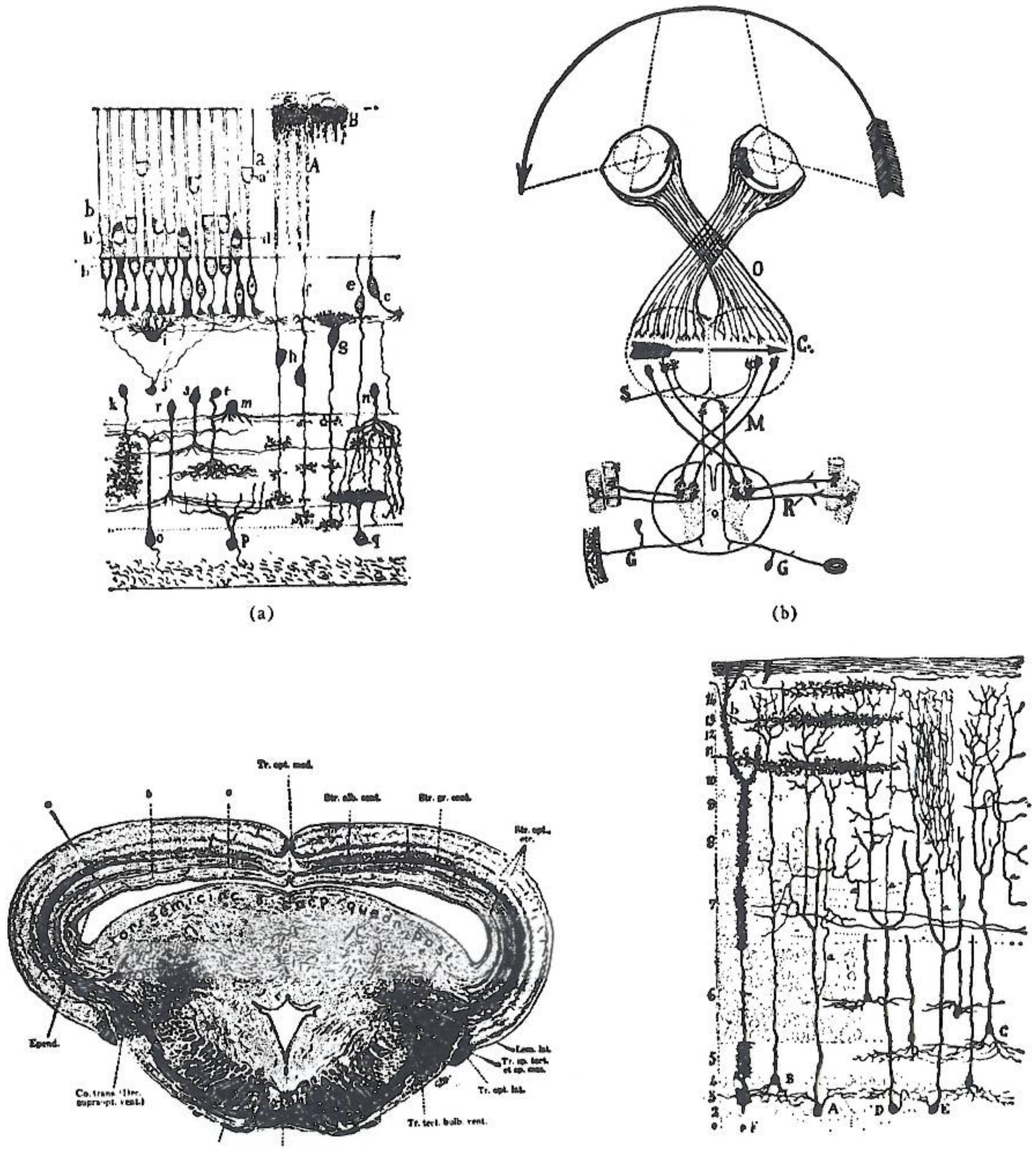
Proc. Inst. of Radio Engr., 1959.

The vision system of the frog needs to be studied with the motor system in an integrated way.

Main objective: Survival

The frog does not seem to see, or at any rate, is not concerned with the detail of stationary parts of the world around him. He will starve to death surrounded by food if it is not moving. His choice of food is determined by size and movement.



(a) (b) (c) (d)

Figure 1.

Fig. 1. (a) This is a diagram of the frog retina done by Ramon y Cajal over 50 years ago. The rods and cones are the group of elements in the upper left quarter of the picture. To their bushy bottom ends are connected the bipolar cells of the intermediate layer, for example, f, g, and h. Lateral connecting neurons, called *horizontal* and *amacrine* cells, also occur in this layer, for example, i, j and m. The bipolars send their axons down to arborize in the inner plexiform layer, roughly the region bounded by cell m above and the bodies of the ganglion cells, o, p and q, below. In this sketch, Ramon has the axons of the bipolar cells emitting bushes at all levels in the plexiform layer; in fact, many of them branch at only one or two levels.

Compare the dendrites of the different ganglion cells. Not only do they spread out at different levels in the plexiform layer, but the patterns of branching are different. Other ganglion cells, not shown here, have multiple arbors spreading out like a plane tree at two or three levels. If the terminals of the bipolar cells are systematically arranged in depth, making a laminar operational map of the rods and cones in terms of very local contrast, color, ON, OFF, etc., then the different shapes of the ganglion cells would correspond to different combinations of the local operations done by the bipolars. Thus would arise the more complex operations of the ganglion cells as described in the text.

(b) This is Ramon y Cajal's diagram of the total decussation or crossing of the optic nerve fibers in the frog. He made this picture to explain the value of the crossing as preserving continuity in the map of the visual world. O is the optic nerve and C is the *superior colliculus* or *optic tectum* (the names are synonymous). (c) This is Ariens–Kapper's picture of the cross section of the brain of a frog through the colliculus, which is the upper or dorsal part above the enclosed space. (d) This is Pedro Ramon Cajal's diagram of the nervous organization of the tectum of a frog. The terminal bushes of the optic nerve fibers are labelled a, b, and c. A, B, C, D and E are tectal cells receiving from the optic nerve fibers. Note that the axons of these cells come off the dendrites in stratum 7, which we call the *palisade* layer. The endings discussed in this paper lie between the surface and that stratum.

Detectors

Let us compress all of these findings in the following description. Consider that we have four fibers, one from each group, which are concentric in their receptive fields.

Suppose that an object is moved about in this concentric array:

(1) The contrast detector tells, in the smallest area of all, of the presence of a sharp boundary, moving or still, with much or little contrast.

(2) The convexity detector informs us in a somewhat larger area whether or not the object has a curved boundary, if it is darker than the background and moving on it; it remembers the object when it has stopped, providing the boundary lies totally within that area and is sharp; it shows most activity if the enclosed object moves intermittently with respect to a background. The memory of the object is abolished if a shadow obscures the object for a moment.

(3) The moving-edge detector tells whether or not there is a moving boundary in a yet larger area within the field.

(4) The dimming detector tells us how much dimming occurs in the largest area, weighted by distance from the center and by how fast it happens.

All of the operations are independent of general illumination. There are 30 times as many of the first two detectors as of the last two, and the sensitivity to sharpness of edge or increments of movement in the first two is also higher than in the last two.

Conclusions

What are the consequences of this work? Fundamentally, it shows that the eye speaks to the brain in a language already highly organized and interpreted, instead of transmitting some more or less accurate copy of the distribution of light on the receptors. As a crude analogy, suppose that we have a man watching the clouds and reporting them to a weather station. If he is using a code, and one can see his portion of the sky too, then it is not difficult to find out what he is saying.

Section 4

Hierarchical Image Segmentation

Problem of curve inference from a brightness image is a difficult task since brightness data provides only uncertain and ambiguous information about curve location.

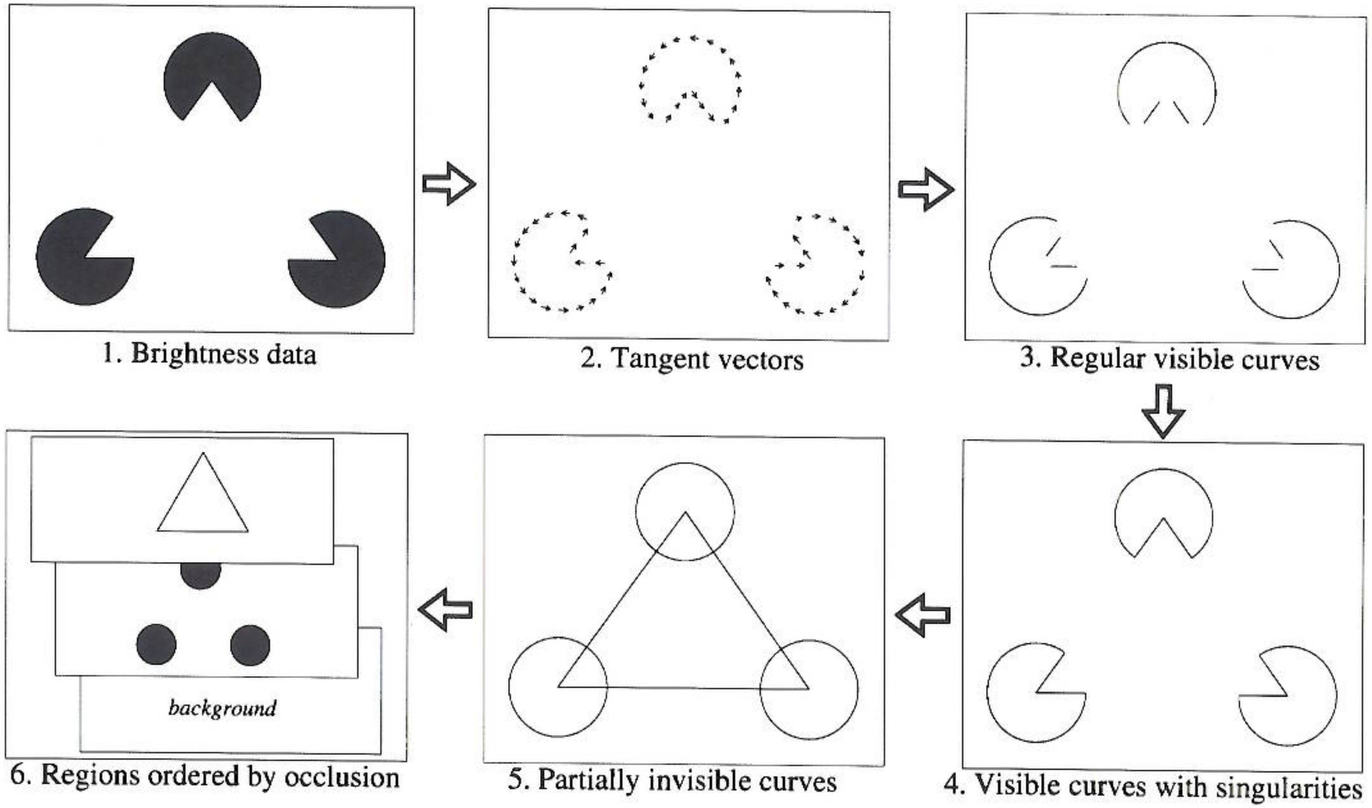


Figure 2. Hierarchy of edge representations for image segmentation. At the highest level the data is represented as a white triangle floating on top of three black disks (Kanizsa, 1979).

Need to use global information.

Singularities

See later section for Stratified Manifolds.

Why is Development so Illogical ?

Sidney Brenner

Structure to Function Map ?

Neural Circuitry to ⟶ Motion Control of the ~~Map~~ Nematode

How would one model the Nematode as an Organism ? Multiple Views !

How do we "glue" together heterogeneous functional elements ?

Vision & Motion Control ?

New Mathematics ? New "Sheaf" theory. ?

Information Theory for Communication and Coding of Neural Signals.

How is geometry, motion "coded" in ensemble of neural signals?

Communication & Action.