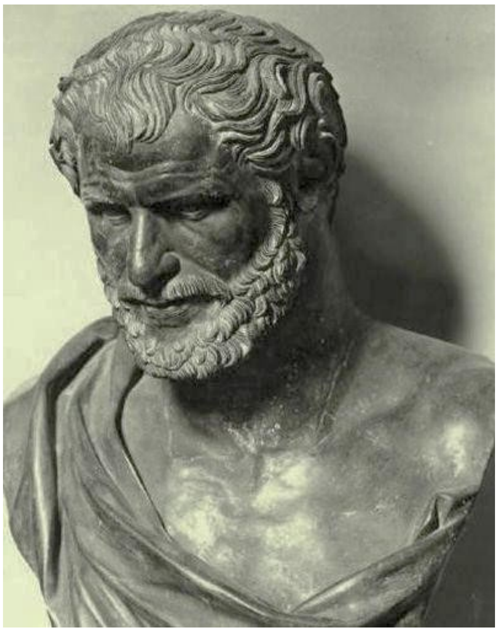
Book Preview

Sergio Beva



Brain Mechanics

It’s a little the working prototype
of an artificial vision system
similar to that of humans,
a little like a model of the human brain.

In this book I propose the project of an artificial brain which imitates the human one. It hinges on neurophysiology and psychophysics and it develop within the groove of classic mechanics. The title and the imagine in the cover leave no doubt about it.
The book discusses:

- how the tangle of electrical excitations produced in the brain on observing the world can be interpreted as the image of this same world;
- how the image can be recognised and how humans can move in the environment;
- how language and grammatical variations are formed.

I have simulate part of human visual processes on the computer, those which do not involve movement; what remains must be considered hypothetical theory.

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Original title: Meccanica Cerebrale.

To be creative we need to be somewhat underemployed in order to give free rein to our thoughts.

To my parents, to whom I owe great liberty.

Preface

The phrases which introduce this book are those of James Watson, co-discoverer of DNA, and Silvio Ceccato, a whimsical man of thought who brought cybernetics to Italy. The first describes my way of life, which has been possible thanks to my parents, to whom this book is dedicated. It aims to be a modest step towards the ambitious purpose of understanding the functioning of the brain or, at least, its rational activities, through mechanization. The first person to recognize that the brain is the centre of the activity of thought in humans and animals was Alcmaeon of Croton. We have only uncertain information about him, including his date of birth. Aristotle said that Alcmaeon was young when Pythagoras was already old. It seems that he dissected animals and saw the nerves that led from the eyes, ears and tongue to the brain. Before him, but also for centuries after, because he did not convince everybody, the seat of cognitive activities was believed to be in the heart and the brain was considered to be an irrelevant organ: the Egyptians didn't conserve the brains of mummies and Aristotle himself thought it served to cool the blood. Like every other science, the study of the brain flowered above all in the last century, thanks to discoveries in microscopy, in chemistry and the revelation of the electric current in a scientific branch called physiology. Then there were the psychologists who studied human and animal behaviour in relation to the brain. Immediately after the Second World War, above all in the United States of America, it was thought that the brain could be simulated with electric calculators, which had just been successfully constructed. The calculators kindled the enthusiasm of many who came to likening them to the brain and calling them electronic brains. The study of the brain and the attempts to simulate its behaviour went on with great intensity. I leave it to the reader to judge if the progress in artificial intelligence is due to conceptual discoveries or rather to the increased power of the calculators. Whether useful or in vain, there has been a great deal of financing in this direction. The latest (2013) which in ten years will provide 1,300,000,000 euros, are two enormous projects, the first is the European Community 'Human brain' project and the second is the USA 'BRAIN' initiative. I have always studied alone, I am a self-taught person and I started to be interested in the function of the brain when I was 19 years old. I did it for purely intellectual interest; what was once called 'for the love of science' and, as I was interested in continuing these studies in absolute freedom, I always paid for them, including the necessary instruments. I don't want to bore the reader with my personal history, which is that of an absolutely ordinary man. At the base of my work is the idea that the brain is an apparatus that permits living beings to navigate their way in their surroundings, anticipating the development of situations in order to profit from them or avoid damage. This is in agreement with the evolutionary theories of Darwin and Wallace. My work is also influenced by the thoughts of Democritus and heavily by those of David Hume. It is linked to the brain and its function through neurophysiology and psychophysics. The model of the brain that I have developed aims to be, as much as is possible, 'human like'. As far as it has been possible for me, and this has happened through visual perception, I have constantly verified the theories I was formulating with programs that function on any type of PC. I agree with Richard Feynmann when he says: what I can't do I'll never understand. As in this text theories on language also appear, I give warning that these have not been experimented. This is not a book on philosophy or psychology, it is substantially a book on physics. In fact a parallel can be traced between the study of the atom and that of the brain: In the first years of the 20th century the physicists perfected the idea of the atom, that the chemists of the 19th century had foreseen, based on experiments with radiations from matter emitted when it was heated. Nobody had ever seen an atom and, as in the physics of the extremely small, even now our ideas are not clear and, in my opinion, never will be. In a similar way as the atom, also the brain can be understood through the manifestation of its activity with psychological tests and with neurophysiological experiments. Unlike the atom, I think that the brain can be understood because its components, neurons, synapses,... are not part of of the microcosm like atomic and subatomic matter. On the contrary the brain can be mapped, in fact we already possess a detailed map of the modest brain of a worm, consisting of a thousand neurons, without, however, succeeding in understanding how it works. My study begins with the perception (I use this word even though it doesn't define well) of how animals manage to survive and get around in their environment without possessing a structural language and therefore it is with the perception that the brain carries out this task. Structured language is an ulterior construction, a faculty of humans, that allows them to improve the predictive activity of the brain but always based on perception. Since, at least in man, vision is the most important sense, in order to understand the human brain, it is necessary, first of all, to understand how the visual system works. Reflecting on evolution it seems to have, in humans and in superior animals, two different functions: The first is that which permits spatial orientation and the second is for recognising objects. If we consider a fly, its eyes seem to have only the first function; food is recognised by the sense of smell or better, the chemiosensorial apparatus. In low-level vertebrates a vast area of the brain is dedicated to the chemiosensorial apparatus and they recognise objects above all from their smell and taste. In humans it is no longer like this: smells and tastes have a marginal importance when recognising objects. I have dedicated myself above all to this second function of the visual apparatus and will set it out in this book. However, I have my own ideas about the other function and will say something marginal about it. Always in the margins I will touch on the mind and consciousness. I wonder if these words make sense and what is their relation to the function of the brain. From this point of view, using language which is not usual for me, I can say that sight is a conscious activity while recognition is an unconscious activity.

Note.

The image on the cover is a photograph of a bust of Democritus, also thought to be of Eraclitus. It was taken from the Italian Wikipedia site.

THE IMAGE IN THIS BOOK, SOMETIMES IN COLOUR, ARE ALSO ON THE SITE www.beva.it which accommodates also the corrections and discussions with readers, which I invite to contact me at the email address: info@beva.it

Chapter I – The World and the Brain

Preliminary remarks

In this chapter I will explain my conception of the physical universe and the brain. It is a chapter on philosophy in which I lay out also the choices and the priorities in my work. They are my opinions and it is not possible to verify if they are true, as it is for every philosophical theory, but they have guided me and still guide me in the projection and construction of an artificial brain whose function, on the contrary, can be verified.

1. A mechanistic model of the brain is needed in a universe that (probably) is not mechanistic.

The brain is connected to the world through the senses. Limiting myself to the human visual system I must ask myself what happens in the brain when I look out of the window and see the mountain with its red rocks, its green woods and the blue sky above. Paradoxically the study of neurophysiology seems to generate further confusion. In fact every image is turned upside down on the retina, it goes on the receptors, cones and rods, which converge in different ways on each single fibre of the optic nerve. Then there are cells that connect them horizontally. I would like to point out that the receptors, that react to the light, are situated under the horizontal cells, amacrine and ganglion, and are not exposed to the light but covered! This observation alone is enough to demonstrate to us how complexity and confusion reign in the visual apparatus and alerts us to the great effort that will be necessary for anyone who wishes to make clear its function. The nerves of the two eyes then meet in the chiasma and then reach the two opposing geniculate bodies (but a portion remains in the same cerebral hemisphere) and go on to the optical cortex. Not to mention the fibres that proceed from the optic nerve to the mid-brain and then from here also go to the optical cortex. During this passage from the eye to the brain the visual information is elaborated (less in man but always more going down the evolutionary scale). It makes sense to me to accentuate the optical cortex: vision occurs in this area. Humans, but also the superior animals who are deprived of this are blind. This does not happen with inferior animals, for example mice without an optical cortex orient themselves in their environment more or less as before this loss. Evidently the role of mid-brain vision is still important for them, while it is almost extinct in humans. I say 'almost extinct' in humans because in my opinion, blind vision, which was discovered in 1973 by Poppel, Held and Frost in cases where the human optical cortex was completely destroyed, is exactly this. Given this, in the cortex, the image on the retina generates disproportionate stimulations and splits into scattered fragments with a form that is in no way similar to the image projected onto the retina and which we can see. Where is the image of my mountain with its rocks, its woods and the blue sky above? Not on the optical cortex and in no other part of the brain. If we say that what we see is on the optical cortex, it does not mean that the stimulation of its cells reconstructs the image on the retina. Those who are used to mathematics would say it is not a bad thing: the points on the retina are in correspondence with the points on the optical cortex; some would call this topographic. Therefore it is easy to go back from these to retinal stimulation, that is the reconstruction of the form projected on the retina. The problem is that this correspondence is not precise; in fact it is not certain that a nerve that comes from the retina arrives at a cell on the optical cortex. The topographic correspondence needs to be considered but this alone would lead to the reconstruction of a blurred and confused image. Rather I consider that what we see is the

representation of the information brought by the nerves of the retina, which is already partially elaborated and mostly elaborated by the cortex itself.
Everybody knows that a fly's brain is different from that of a human. Both the human and the fly have two eyes which receive information from the outside world but it is impossible that these two beings have the same vision of the world. The eyes of the fly, already quite different from those of humans, perceive little more than variations of light. However, both for the human and for the fly, what they see is the world. One could say: man is superior to a fly, the world is how humans see it and not how it is seen by these inferior animals. In this way, in my opinion, we fall into an error: anthropocentrism, not different from geocentrism. Who knows what the world is really like, what we see is a mass of information which allows us to foresee the development of situations, relative to our elementary needs, which are satisfied in the environment in which the eye and the brain were formed. We see the trees and the houses but the fly doesn't. Who knows how a hypothetical being, different from us and coming from another planet, would see them, or even only a frog, which has a visual system different from humans or flies. The trees and the houses represent necessary things, who knows what is the reality. Already Democritus 2500 years ago in his 'Book of Shapes' writes that we know nothing that corresponds to the truth of what is around us, a sort of configuration forms in us. However he believed that behind the perceptual illusion there was a reality of atoms that move in the void. About 2000 years later David Hume goes beyond this mechanistic conception, which confuses the world with a mechanistic model of the world and claims that the nature of the world outside the brain is unknown, that what we call physical reality is a mental representation and physical laws are nothing more that recurrent behaviour in this representation. How is this mental representation formed or, in other words, this model? If we look at evolution we see in it enormous suffering and massacres aimed at eliminating the unfit. We are the lucky children of this fight and our bodies, including the brain were formed by a series of events in which we see no philosophic intent aimed at the knowledge of being and its essence. Were we born not to live as brutes but to follow virtue and knowledge? For heaven's sake! This is an unconditional opinion, without confirmation, of the Supreme Poet Dante. Rather the necessity to have an organ, the brain, that can foresee the development of situations in order to benefit from them or avoid damage, is what comes from my observations. It is, or rather, it has taken form, together with the senses that connect it to the environment in which humans live, to satisfy the needs of the living. Transferred to a different setting, the brain will not give the right predictions because neither it nor the senses will be able to grasp the warning signs. The physics of the extremely small is the proof of what I say: the extension of the laws obtained from the macrocosm lead to the theories that are less and less predictive when the studied bodies become smaller and smaller. The results that come from observing the extremely fast are incredible: distance and time, based on all our experiences in the physical world, are different if measured between two subjects in relative fast motion. Personally I doubt that physics can make more progress in this area and it is from the twenties of the last century that each discovery in atomic and subatomic physics only came about thanks to the increased potency of the machines used to observe the world and these discoveries cannot be connected to a theory with predictive power. On the contrary, it is the discoveries that modify the theories and extend them. Only the mechanistic models, both the atomistic ones of Leucippus and Democritus and the pneumatic ones of the Stoics, have brought serious results to physics, or rather in the knowledge of nature. And that is why, since I was nineteen, by now a long time ago, I keep calling my studies 'Brain Mechanics'. I would like to make it explicit that my research is based on a mechanistic model of the brain, mathematical and deterministic. In fact the mechanistic model is suitable for understanding and describing the biological brain because there are no quantic aspects

in its workings: the neurons are composed of a large number of atoms and the electric current between them involves a large number of electrons: we are in the macrocosm, in the area of classical physics, therefore it will be possible to understand the brain in the future, whereas, in my opinion and for the reasons I will elaborate more later, this is not possible for atomic and subatomic physics, never. Having assumed this position, a problem arises: a mechanistic brain cannot make predictions from a world that is probably not mechanistic, given the failures of atomic and subatomic physics………

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Chapter III – The fundamentals of vision

Preliminary remarks

When I was 15 I asked myself how it was possible to see things, how images were formed in the brain. I went to a library and borrowed some books but they did not clarify my ideas. From these readings I remember a beautiful image: according to an Indian sage the world that appears in our brains is like a reflection on a sheet of crystal. Of course it is useless to say that this reflection has not been found on our visual cortex nor in any other part of the brain. However, there are stimulations on the visual cortex that can be related to the stimulation of the retina since they derive from the elaboration of the electrical impulses coming from it. The treatment of the signals coming from the retina is the information that the brain has of the world. It enables us to orientate in the world and recognise its objects. The claim to "see" the image of the world painted by the stimulation of the visual cortex has no sense. I must navigate the world, avoiding holes, dodging obstacles,... and in the brain there is information about the world which allows me to take action. It appears to me as its image. I think this is a conscious activity because it involves a continuous adaptation of the living to the transformations of the world. Instead I think that the work of recognition is subconscious because the object is what it is and is always analysed with the same automatic process, like the work of a gland.

1. Luminance and brilliance

Both the Sun at midday and the full Moon at night allow us to see, in fact it is possible to walk in the mountains and in the fields also in the nights with a full Moon. The illuminance passes from 50,000-80,000 lux during the day to 0.2 lux during the night with a variation of about 300,000 times. It follows that the variation of luminance of the fields, of the roads, of everything to the natural light which reflects the light of the Sun or the Moon is enormous. Therefore also the variation of the illuminance of the retina which receives this reflected light is enormous and remains considerable despite the variation of the area of the pupil, which tends to normalise it. As the discharge of the retinal receptors has a variation of frequency in the order of a thousand herz, I think it has no sense to place this frequency as proportional to the intensity of the retinal illuminance. We must not forget that we are dealing with a biological system, approximate, not with laboratory instruments. In fact,under this hypothesis, the image of an object projected on the retina, brings about a remarkable and highly detectable variation of the frequency of the receptors in the passage between the sunlight of the day and the nocturnal light of the moon. However in the hypothesis that the discharge of the receptors is proportional to its illuminance, two parts of a sheet of paper, one white, one black, that are projected on the retina, would give place in the underlying receptors to discharges more or less of identical frequency, whether they were under the white part of the image of the sheet of paper or if they were under the black part, because the retinal illuminance produced by them would not be so different in relation to the enormous variation between the light of the Sun and that of the Moon. The black part of the sheet of paper, even if it reflects less light than the white one, still reflects a great amount. This is because the average variation of luminance of the sheet of paper in the Sun or in the lunar light is great, while when the sheet of paper is in the Sun, the variation of luminance between the two parts, white and black, is relatively small. If the frequency of the impulses of the receptors were proportional to their illuminance and so determined the sensation of light and dark, the sheet of paper in question, half white and half black, would appear to be a confused mix of light greys when in the sunlight and dark greys when in artificial light. The black part and the white part would not be well defined in both cases. In my opinion the visual system succeeds in resolving this problem, apart from the variation of the area of the pupil, with an apparatus, conceptually constructable, that regulates the sensitivity of the retinal receptors. In my hypothesis, it should act in a very slightly different way in monochromatic vision compared with chromatic vision. Peripheral vision is substantially monochromatic because in the periphery of the retina there are principally rods, insensitive to light frequency. Instead the central vision is essentially chromatic because in the centre of the retina there are principally cones, sensitive to the frequency of light. In peripheral vision (or anyway in monochromatic) there are two regulations.

1) One which measures the illuminance of the retina and acts on the pupil in order to normalise it. In reality the pupil succeeds only in mitigating the enormous variation of the illuminance.
2) The second regulation is aimed at the purpose of permitting the detection of the edges of figures, that is, to generate a significant difference of discharges of the receptors which are found under the white and black of the image projected on the retina of the previous example.

Mechanizing the first regulation is extremely easy, the only precaution is that it must be fast in order that the receptors are not ruined by the excessive light. In the visual system there are cells which act quickly and I think that this is their purpose. The second regulation can be resolved by hypothesising an apparatus of the visual system, that modulates the discharge of the retinal receptors according to the total illuminance of the retina. Its adaption to the light must be slow. I don't know where this hypothetical human apparatus that acts on the pupil can be found, surely it exists: I will reason that it could be located in the eye and that it proceeds in relation to the measure of illuminance of the the retina and acting on the sensitivity of the receptors in a way that summing up their discharges in all the retina in a unit of time, a constant result is obtained, independently of the illuminance of the retina. In other words, probably because of an inhibiting process, the same impulses leave from all the retina every second, whether a lot or a little light enters the eye. The quantity in question is known in electrodynamics as intensity of the electric current, defined as the number of charges that pass through a conductor in time. In this way the discharge of the receptors loses proportionality with the illuminance of the retina but local variations of the illuminance of the retina bring about variations of the frequency of the underlying receptors, which are not proportional to the illuminance and therefore flattened, but the difference between the average value of the illuminance and the local value is therefore remarkable and highly detectable.
Perhaps it is appropriate to give an arithmetical example. In a particular world, lost in the universe, the luminance varies between 100,000 units of maximum luminance and 0 of minimum; in that world the visual system of the people generates discharges with variations of the frequency 1000 hz and 0. An observer looks at a sheet of paper that is half white and half black. The white part has a luminance of 80,000 units while the black part has a luminance of 76,000 units.
In the first hypothesis, of a frequency of discharges proportional to the luminance, the frequency of the receptors under the white will be 80hz and the one under the black will be 76hz. A variation of 4000 units produces the variation of 4hz.

In the second hypothesis, calibrating the emission on the average value, the maximum luminance of 80,000 this time produces a discharge of 1000hz and that of 76,000 units produces a discharge of 0. In this case the difference of discharge is detectable also in a not very sensitive system like a biological one.
Naturally this is a simplification. The proportion between the frequency of the discharge and luminance is completely lost but the variations of illuminance between the various zones of the retina now generate frequency of discharge considerably different. The aforementioned proportion was lost anyway because of the workings of the pupil. All this can be mechanized and constructed and it seems reasonable to me that there is an apparatus somewhere in the brain or perhaps in the eye itself. Perhaps they are the horizontal and amacrine cells that permit the average illuminance of the retina to be measured through spatial integration, that is, the sum of the impulses emitted by all the receptors, and inhibit more or less the sensitivity of the rods. Indeed it seems to me to be a function that can be linked to inhibition and to some neurons, discovered in the visual system, which change slowly the response to intensity of the light. I think the work of these neurons reveals itself when we enter a cinema, only after a short time are we able to see. The discharge, when the eye functions in peripheral vision, is constant on all the retina but I have good reason to believe that a similar regulation happens also when the eye works in central vision, limited to the part of the retina that is involved. The illuminance on it causes a further regulation, starting from the regulation that has taken place in peripheral vision but finer. We will see later that peripheral and central vision are alternatives, they cannot coexist. I want to point out finally that in the models I propose, the information about environmental luminance is obtained from the sensitivity of the receptors in peripheral vision, in central vision and from the apparatus that regulates the pupil. In superior animals the information about luminance is not so important: the visual system is directed above all at identifying images, defining their edges. It seems that information about luminance arrives at the cerebral cortex through another channel and interests a type of cerebral cells which are not those which respond to angles, less important than the first in recognising forms. According to the model proposed, in absolute dark, even if the sensitivity of the receptors is at maximum, there will be no discharge because no photon strikes the receptors. This conclusion is not human like because in humans the retinal receptors always generate a discharge of low frequency, called dark discharge. I am aware of this difference. However I will try a simulation of the function of the visual system in which I must reduce the elements which I think are not essential in order to not get lost in too many details.
Modulating the sensitivity of the receptors in order to make constant the intensity of the discharge emitted by the whole retina, explains the paradox of Hering, which explains why a pile of coal by day emits more light than a pile of snow at night but continues to appear black by day. During the day the sum of the impulses emitted by the retina is equal to those that it emits at night. However, during the day the coal forms a black area on the lighter retina and the sensors below emit low-frequency pulses. At night the pile of snow forms a white area on the black of the retina and the underlying receptors emit high frequency discharges. It doesn't matter how the pupils dilate. This is another problem. The frequency of the discharges is not proportional to the luminance of the pile of coal or snow, because the pupil dilates more or less and the luminance of the image projected onto the retina remains disconnected from the brilliance of the pile. If a minimum of information of the absolute luminance remains in the brain, this ends up brightening the coal during the day and darkening the snow at night. So it should reveal itself as a secondary effect, minimum, detectable in some optical illusions.
Allow me to tell a personal story: once I took my little daughter aged around 8 or 10 years old to visit the Turin Observatory with a group. Amongst other things we were told in a conference that the Moon is black, because it is made of stones of that colour. I didn't notice this but my daughter touched my arm and said, perplexed: "Dad, but the Moon is white". I was wicked and told her to ask the astronomer. The poor man replied with a flood of words without sense. The night sky has a very low luminosity of about 10^{-4}nit, varying according to the hour and the light pollution produced by cities, but it always remains much lower than the 2500 nit of the Moon. The eye adapts to the

low luminosity of the sky, the neuronal discharge stabilizes for that luminosity and the Moon is the luminous particular that interests the underlying receptors which will have a high frequency discharge.
It is important to obtain the revelation of the local variations through a substantial variation of the discharge. In addition when I speak of central or peripheral vision and their alternation, the intensity of the discharge that comes from the eye must be equal in both cases, therefore the expression that must be constant per unit of time from the whole retina must be revised.

2. Inhibition and edges

The edges of a figure are very important, in fact the figure is often recognised by its "silhouette", see fig. 6. In the visual system the edge of an object is that which is often isolated from movement. Within a figure there are other edges, for example the mouth of the human body, which serve to define recognition better. The edges of figures are also picked up by lateral inhibition, which registers them and is visible in the optical illusion known as Mach bands. The following function explains lateral inhibition (not directional) and generates Mach bands, so it can be associated with what happens at the level of the retina and the lateral geniculate body. In my opinion, the role of lateral inhibition non-directional and directional, is connected to the recognition of forms through angles, in addition to the perception of edges, as is normally said.

Fig. 6

Now let's start work on the second aspect. As I had to prove this theory on a computer, I had to write it in a mathematical form and since this book is addressed to the educated reader who is not a specialist, I will not go through the predictable steps or long explanations that will seem banal to those who understand mathematics. Consider a plane (x,y) on which a white stripe is drawn on the left and a black one on the right as in fig. 7b), which shades in the centre between the two colours. Along the straight line u, parallel to the axis x, the luminance of every point on it is as in the diagram (P,u) in fig. 7c). Let's consider now a circle fig. 7a) and calculate the average luminance M on it. As a first case I consider a circle that has a diameter greater than the extension of the shaded area. Let's imagine that its centre runs along the straight line u of fig.7b) to obtain the diagram (M,u) in fig 7d) in which is drawn the average luminance M of the circle in the u points. At a distance from the shaded area (M,u) will coincide with (P,u), instead the inclined part of M will have a slope that is minor than P. In fact, making the circle run from left to right, the average brightness of the circle starts to decrease as soon as its circumference enters into the shaded area while the centre is still in the white part. The difference between the two diagrams (M,u) and (P,u) form the graph (Q',u) in fig.7 e). If we think that the circle is illuminated uniformly, the stimulation of the central receptors is equal to the average stimulation of the receptors around it and the function P-M has a value of zero. If M<P as happens when P is near the shaded area and on the left of R, P-M is positive. On the contrary, when all the circle is in the black area, P-M has a value of zero, but when the centre of the circle is just a little to the right of S and in the black area but the circle is almost half way in the black area and the remaining part in the grey area: the average of its internal brightness is greater than that of its centre. Up to now I have moved the centre P of the circle on a straight line parallel to the axis x therefore it would be better to write P(x,y), M(x,y), Q(x,y), a more correct three dimensional representation would be obtained which, however, does not change what I have said. I will not point out the question of the function to avoid making the discussion too weighty. If I make a sum of the functions M and P-M adding a real multiplier k, I obtain the function:

$$Q=M+k(P-M) \qquad (2)$$

as shown in the diagram fig.7f) which recalls the trend of the brilliance with a very clear abscissa point R and a very black abscissa S which are the Mach bands. The Q function is what we see? Not entirely, I would say but it is a great step forward for the comprehension of the visual process.

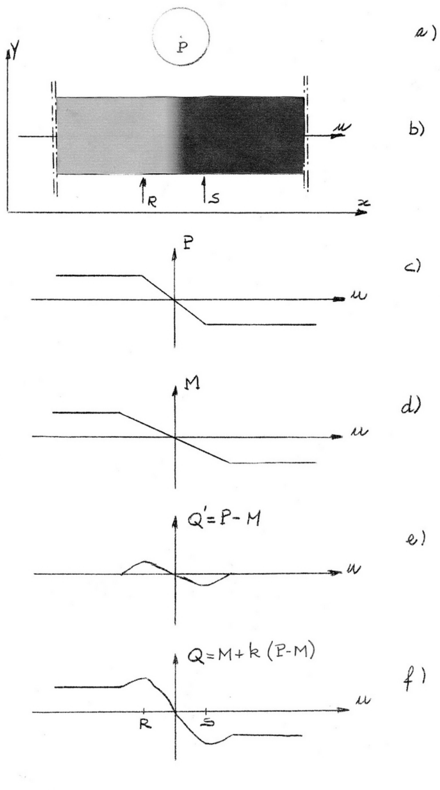

Fig. 7

It is true that the Mach bands do not always appear to sight but only in the case of large shaded areas, more precisely we could say that the diameter of the circle of convergence is less than the extension of the shaded area. In this case the function of Q explains the phenomenon well, it has the same behaviour of brilliance.

We observe Q', fig. 8 e) which presents two distinct extremes connected by a coincident segment with the axis u. In this area, in fact, the slope of P and that of M are equal, differences are found only at the end and beginning of the shaded area. If, instead, the shaded area is narrow, that is, less than the circle of convergence, the direction of Q' is that of fig. 7 e). Consequently the directions of Q are respectively in the fig. 7 f) and 8 f). There does not seem to be a direction of brilliance described by Q in fig. 7 f). In order to be more sure, in fig. 9 I studied the direction of the function Q where the drawing does not have shaded areas but the luminance passes, with a step from a high value to a low value, from white to black. Also in this case Q presents two variations AB and A'B' which are not perceived. For now the function of Q can be considered adherent to the visual perception only in the case of a large shaded area.

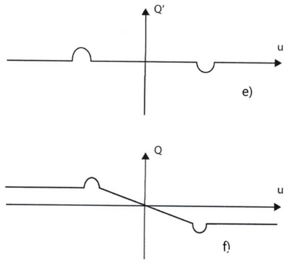

Fig. 8

In the case of the fig. 7 f) and 9 f) Q cannot be considered like brilliance because there is no adherence with experimental facts. I want to present this problem, which will be resolved later. Lastly I would like to say that I have considered the shaded areas with linear and monotonous direction. It maybe that other directions produce other effects which can be the arguments of psychophysical experiments for further verifications of this theory.

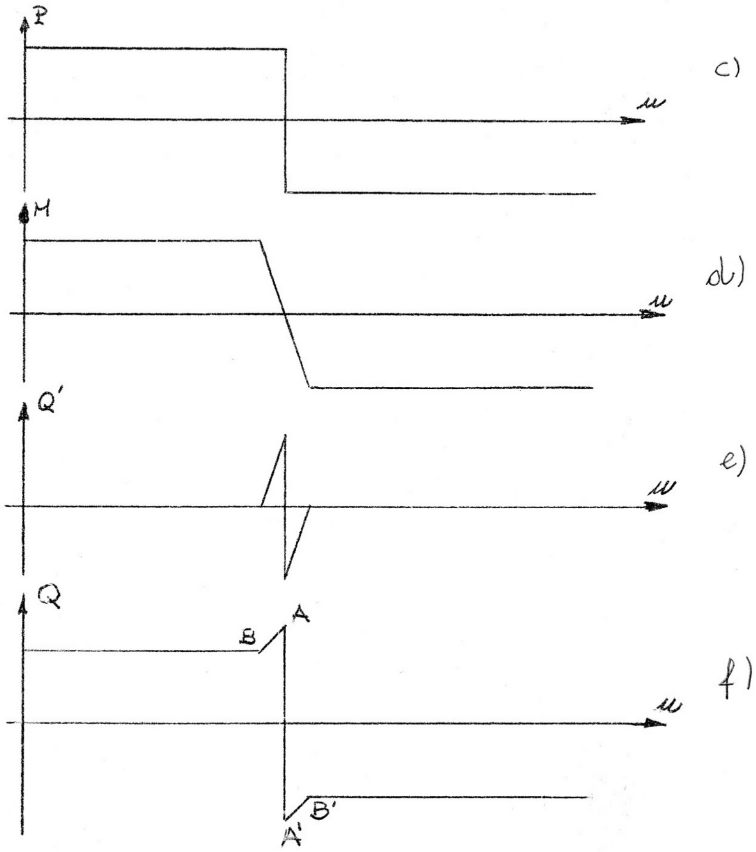

Fig.9

The function of Q is to identify edges? I have already said that not all the points are on the straight line u but on the plane (x,y), therefore the function of P in reality is P(x,y) and its value depends on the point on the plane. It is similar to (1) and the parallel applies with the relief map I have used to explain it. Anyone who has a little experience with the processing of computerized images knows that the figure appears as a table with many numbers, each of which represents the position (x,y) and the brightness z=P(x,y) of an areola. Together these variously illuminated areoles form the image. More technically it can be described as a matrix of pixels. With this data the computer must succeed in distinguishing an object from the background or, and it is the same thing, find the edges of an object in order to establish the distinction between it and the environment in which it is immersed. Initially the threshold was tried, that is, only the points below a certain brightness were tried, assuming that the object was less bright than the environment. These are the small numbers on the table. For this it is enough to order the computer to eliminate the higher numbers up to a given number which is called the threshold and the computer does this. However, the result was a failure, in fact there is no certainty that the object is dark and the background is light. Furthermore, even if this were the case, the computer considers the shadow of the object, which is dark, to be part of the object. Inverting the roles of light and dark and putting mobile thresholds, the results did not improve. This technique was explored in the early days of studies on computerized images, now it is only used for rough industrial applications. I have written the preceding lines to introduce the matter and to make understandable the difficulties that are met carrying out actions that are apparently simple, like distinguishing an object from its background. An educated person, not of this field, who reads these pages must be able to understand them. Whoever wishes to know more can find everything about edge detection (the extraction of outlines) and on segmentation (the isolation of an object from its background) in books on image processing. In order to detect the edges, which means isolating the figure from its background, there is not only the threshold, there are many other methods. In literature the problem is faced using above all gradients and sometimes Laplacians. I tend to adhere to brain function, noting above all that movement isolates the object from its background by activating the phasic Y cells on its edges. I believe that the gradient thus obtained is coarse, a trace to follow and to improve, cultivating the idea of lateral inhibition. In fact children's toys are brightly coloured and attract their attention by moving. Having said this, I believe that the edges of figures are formed slowly in the brain through progressive memorizing and refining. Therefore movement is welcome, strong contrasts are welcome, they are very useful in simplifying the progressive construction of edges inside the brain.

Given this, I propose that there must be an edge where the function Q'=P-M is different from zero. Whoever has tried with a computer will see that in this way a very "thick" edge is extracted. What I want to say is that it shows up as a stripe and not as a line (see fig.12a). In other areas of the image a disturbance called salt and pepper emerges, that is, points where Q' has a different value and marks where there is no edge. These problems are not resolved by filtering Q' with a threshold because in that way there is the risk of eliminating tracts of valid edges. The remedy is to try to simulate the directional inhibition which requires, as a first step, to observe the presence of a gradient of Q between R and S (rif. Fig. 7f). Since I have tested the following theory on the computer, I have preferred to not apply the definition of gradient based on partial derivatives that come from university reminiscences, because they are not suitable for a real surface. The gradients, if they deal with perfect geometrical inclined planes would be parallel as in fig. 4b). In our case it is not so, as it is not so on a mountain side, with holes and rocks. However, as on a mountain side, also in this case, the gradients are generally orientated in the same way, in the direction from high to low. This is on the edges of the figure; instead in the marks, distributed zones which are not edges, the function of Q' is different from zero but its gradients do not have precise orientation. To capture the gradient I have considered a circle, fig. 10, much smaller than the matrix of pixels, which contains the whole image, and I have calculated the sum of the values of P respectively in the shaded semicircle and the white one, then I found the difference and I noted it down in the first column of a table of two columns and in the second I wrote the angle of AB. Then I rotated AB some degrees and repeated the operation until I had formed a flat angle. The maximum, in absolute value (because the direction is not important) of the difference makes it possible to understand the direction of maximum slope of the inclined plane and from now on we will call this gradient. In this way an average of the irregularities of the surface Q is obtained giving the maximum inclination. I hypothesize that around this detector, when it indicates a gradient, a vast field of directions spreads out which influence the other detectors to capture gradients parallel to this.

Think, for example, that a detector has captured a vertical gradient (rif. Fig.11); the field that it generates causes the other detectors along the direction AB (which is horizontal) or in its immediate vicinity to be sensitized to catch the vertical directions of any stimulated detectors. On the contrary, outside this zone the same field causes the detectors to inhibit the capacity to catch the vertical gradients Fig. 11 a. If we consider various optical illusions, I can say that the field is vast and decreases little moving away from the detector that has generated it. Furthermore I think that the effect of sensitizing the detection of the gradient interests a narrow and long strip straddling AB and for the rest the vertical direction is inhibited. I think that with psychophysical experiments it is possible to define a function f(ρ,θ) quantitatively . Obviously the situation does not change if the gradient of the detector is not vertical but anyway is rotated. Incidentally this last observation is not perfectly human like because neurophysical experiments show that the speed of the expansion of the lateral inhibition depends on the direction considered.

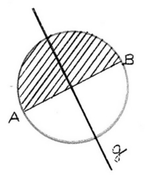

Fig. 10

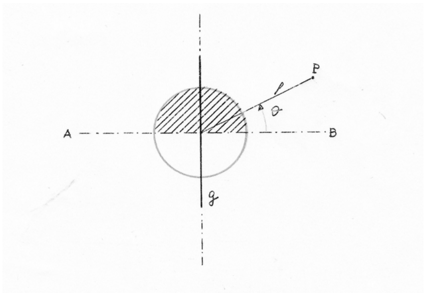

Fig. 11

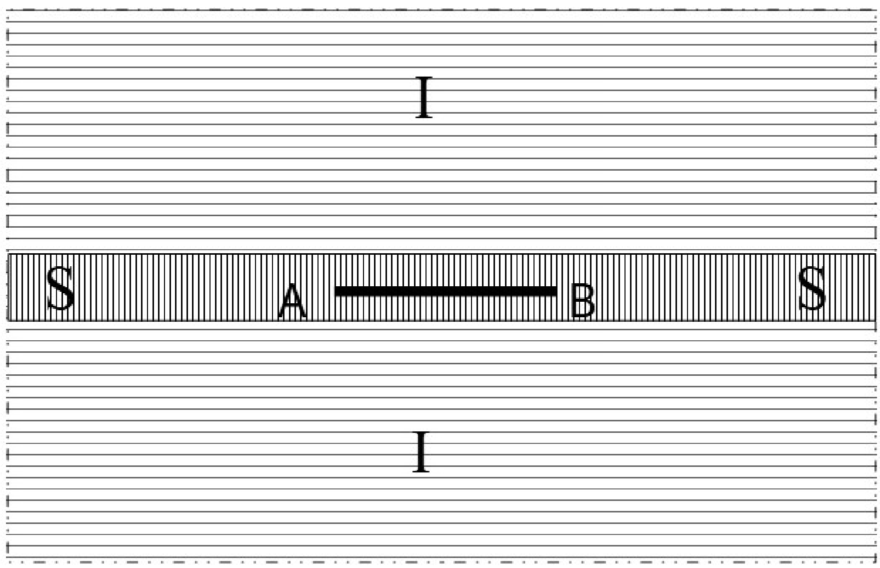

Fig. 11 a)

Zone of the inhibitory field generated by the detector which has got AB diameter. S: strip sensitized to detect vertical gradients. I: area inhibited to detect vertical gradients.

I am aware of this, I believe it is impossible to simulate exactly, at least with current knowledge, an apparatus that is so complex and little known like the visual system and I prefer to remain on essential lines. The directional fields sum up, even if it is necessary to remember that they are not vector fields and while for two vectors, being opposites means having opposite orientations, for two directions, being opposite means being perpendicular. However, also with very broad hypotheses on the sum of directions we can say that some gradient detectors, for example, vertical, aligned or with the diameters AB (fig. 10) on the same straight line generate fields that add up, producing a line (or narrow strip) to be defined quantitatively, of an intense horizontal field that magnifies the sensitivity of the underlying detectors to capture vertical gradients. This line, which I will call privileged line or privileged strip (lp) extends also where there are no gradients. Instead outside this strip and therefore around it the field is such as to inhibit the detection of vertical gradients. The directional inhibition agrees with and perfects the non directional inhibition. I have kept them separate because it seems to me that this is the scheme of the visual system and also simulating the former reduces the calculations of the computer.

Fig. 12 a) Fig. 12 b)

The transport of neurophysical evidence on directional inhibition also in this case finds confirmation in the tests carried out on the computer, it produces a thinning of the outline (ref. Fig. 12 b) and explains many optical illusions.
The first psychophysical evidence comes from the close parallel lines that disturb vision and produce strange optical effects because their gradients, lined up one in front of the other, inhibit each other. It is said that the zebra's coat has this design to confound the sight of predators……
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Chapter IV - Peripheral vision and central vision

Preliminary remarks

On considering the problem of isolating an object from its background I noticed further characteristics in the visual system. In order to understand them I have developed a model which explains the optical illusions that the brain produces. A structure of layers comes out that tends to keep constant the information coming from the isolated object. The idea of the repeated convergence of the optic nerves in a single nerve fibre comes from neurophysiology. The model that I propose develops this idea.

1. The model of isoconvergence. An outline of peripheral vision and central vision.

The dimension of the image of an object that forms on the retina sometimes is not connected to the dimension with which that object is seen. There are many optical illusions that make things appear big or small, independently from their dimension on the retina. The same reader can experiment this: put on a table two identical glasses, one at a metre from the eyes, the other at two metres. For an elementary law of optics the image of the two glasses on the retina show one glass half the size of the other glass but the two glasses appear equal!this fact is known as constancy of the form (see fig. 35). This is true if I observe the glasses one after the other but if I stand in line with them and, for example, and I concentrate my vision on the one nearest to me, I notice that the other, now blurred, seems to be reduced by half following the laws of geometrical optics. However, in the first case, the optical illusion remains.

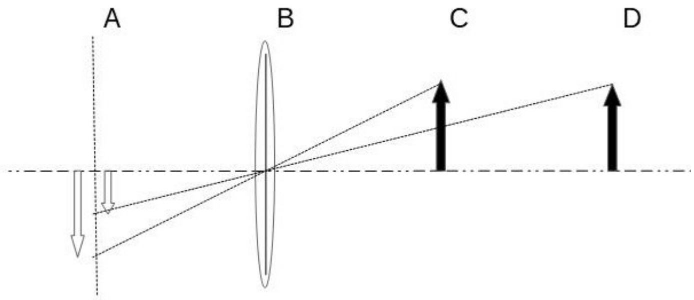

Fig. 35 A: retina, B: crystalline C,D: glasses

It is known that the receptors of the retina (cones and rods) converge differently on the fibres of the optic nerve. Without making claims to precision one can say that at the centre there is often, also only one receptor on an optic nerve. Going towards the periphery convergence increases and the sensors that converge on the same fibre of the optic nerve are always more. What is more it is known that the figures appear out of proportion in the visual cortex and that the part which falls in the centre of the retina occupies an enormous portion of the cortex while the part of the figure that falls on the periphery of the retina occupies a minimal part of the cortex. The model that I propose takes this into account. I will call it a plan model or an isoconvergence model, it will not be confused with the layered model, which elaborates the information coming from a single plane of the layered model in several layers of the layered model. Considering the nerves that come from the retina fig. 36: the circle indicated with 0 is the centre of the retina, a zone of minimum convergences of the receptors on the fibres of the optic nerve and the annuli 1,2,3,... are areas of convergence growing always greater. As the receptors, cones, rods have more or less the same area, the fibres of the optic nerve will be denser in the centre where they are subject to a lower convergence of the receptors and more rare in the periphery where convergence is at its maximum.

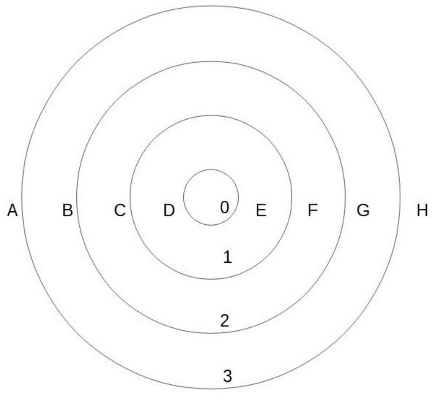

Fig. 36

The blind spot is not a part of the model and I will leave it out. In fig. 37 I propose a model of a section of the retina. The plane 0 corresponds with the circle 0 and signals start from every one of its nerves, …………….
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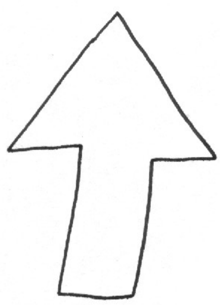
Chapter V – The topological recognition of forms

Preliminary remarks

A classical method for recognizing forms is to utilise certain particularities of them like having points in certain positions, having straight edges in certain positions of their perimeters, present holes in certain zones, having a certain ratio area perimeter...., each one of these features can be seen as a dimension of a space and a specific form, defined by the value of its features, it is seen as a vector in this space. Then it is possible to say that two forms belong to the same class if the vectors that form them do not differ beyond a certain size. I was nineteen and thought this approach was weak because it resulted in a thicket of complex mathematical formulations instead of paying attention to what were the features that could describe the forms. The ones that I saw in use were "ad hoc", functional for one class of objects but not in general. I spoke to professors about this but they told me that I was posing a problem that was not essential. They were in love with mathematics and couldn't see the void underneath. In my opinion, instead, whoever wished to recognise all the forms had to understand what were the features that would make it possible to reach this goal.
I don't like thinking about details and, even though I was not rich, neither was I oppressed by economic reasons to construct and sell machines that were useful for specific industrial uses. I started from far behind, I could do it, at that time I had really a lot of time in front of me. Also time for discussing politics and religion, time for walking alongside the river Po, in the Langhe, the afternoons and evenings seemed endless. Time for love, time for looking at the sky and the stars, the view blocked in part by the Saint Anastasia chapel, smell the perfume of the fields, listen to a dog barking in the distance. Naked, beautiful in our youth, happy with what we could give ourselves. We didn't feel these same sensations again in the same place after fifteen years. Alone and unhappy, stupidly we tried to find them again. I smile to think how little I was inhibited. You too have made these comparisons.
It didn't work.
It was the last time.
However, all this never distracted me from my studies of the brain, much less my official studies of physics, to which I devoted marginal efforts: I philosophized a lot to have a framework of reference to guide me and I didn't let myself fall into the misguided search for an immediate result. I came to the conclusion, as I have already stated, that we cannot know the world external to the brain, but the brain must be able to make predictions. How is it possible to design senses that connect the world and the brain if nothing is known of the world the senses want to explore? There is no possibility of reasoning. In fact, nature has provided through natural selection, forming senses (and the brain) suitable for this purpose and they succeed in making these predictions (with good possibility). In humans the main sense is sight and predictions start with recognising forms which, in my opinion and in agreement with Piaget, occurs first in a topological way and then it is refined in a syntactic way. Always in my opinion, the first way is typical also of superior animals: The term topological, which I use because Piaget used it, is not to be understood in the extended sense that it has taken on in mathematics, but rather in its intuitive and primogenital significance of the geometry of a sheet of rubber or geometry of the continuous. Indeed also this meaning must be limited: the brain must recognise as belonging to the same class those figures that a child less than three years old says are similar. In the following paragraphs
I will try to mechanize this idea of similarity: For those who are not experts in the processing of images on computers I will say that the devices for studying forms are carried out connecting a video camera to a computer which, limited to the vision of black and white, transforms the image on a screen to many small adjacent and ordered squares, each one of which has a shade of grey. In parallel, we speak of a matrix (table) of pixels (small squares) each one of which has a position,

defined by its coordinates and a value, a level of grey. If the same object is rotated, transferred or moved further away from the video camera, it produces different images and, in parallel, a different matrix of pixels. How can the computer recognise that the object is the same if the matrix of pixels is different? For as long as it deals with rotating, transferring or reducing (provided that it is in scale), it is not difficult to make the computer understand that it is dealing with the same object. These transformations are said to be linear and are known in mathematics, it is enough to apply them to the programmes but if two objects are slightly different, like two letters of the alphabet in a different typographic style, there is no general way, only a series of ad hoc artifices that function for the Latin alphabet but the same artifices don't function for the Arab alphabet. This is a problem that has persecuted artificial vision since the end of the 1940s. Reflecting on this argument, as I was nearing my 28 years, an idea came to my mind that even now I place at the base of my system for recognising forms. I thought about an arrow like the one in fig. 51, its rotation, its change of position and its reduction in scale would not have influenced its angles, therefore if I used these to describe the figure, I would save the heavy calculations necessary for following the linear transformations. This was no small thing, furthermore, because the idea was valid for linear transformations, why not try it out, with appropriate improvements, at the base of a general recognition of forms? I looked for correspondence to these ideas of mine in literature on the subject and found that Attneave considered angles essential for recognising forms. Attneave's "cat" in fig. 52 is famous. It is unmistakably a cat and all the information comes from the angles. I then found the work of the neurophysiologists Hubel and Wiesel and knew I was going in the right direction.



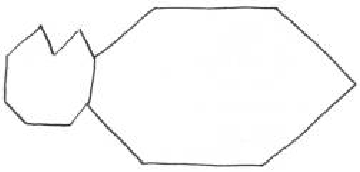


Fig. 52

Fig. 51

I noticed that the angles of an arrow drawn on a sheet of rubber pulled in unpredictable directions, change their values and if they exceed a certain limit, together with the change of the values of the angles, the drawn figure loses the form of an arrow in the sense that a child would no longer recognise it as such. The limits of the deformation of the figure so that it generates another that is similar are limits on the variation of its angles. This does not contrast with the function of the brain because Hubel and Wiesel discovered that cells that respond to bars of light of a determined inclination continued to do it until the inclination of the bars varied between 10 – 15 degrees, beyond this approximation other cells responded. Furthermore the cells that responded to a bar continued responding if the bar was moved within a certain limited area. I applied this idea to the computer. I can say that more or less after I had extracted the edge (the perimeter) of the figure, I measured its angles in the order that they were found on the perimeter and then I compared them with other, similar series, taken from previous figures. I memorized them on a table until I found, if it existed, the one that corresponded or rather the one that had angles within the aforesaid approximations equal to the one present on the computer. I immediately understood that in the two figures, that a child considers to be similar, there were different details and because of this their order of angles was different and that the computer would not succeed in recognising the equal parts and establishing that the two forms belonged to the same class. It was necessary to eliminate the details that had little importance and get to the "essential forms", that is a series of angles and positions that were identical for all the similar figures. The expression "essential forms" is not empty rhetoric, as it may seem, it will be defined operationally. For this I constructed a "layered model", layer after layer the figure lost its unimportant details and came closer to the essential form. In the first years of the 1980s I used and, allow me, invented a method of representation of a hierarchic type of information, now (in the year 2019) it is very popular and goes by the name of "deep learning". Two problems arose 1) How to make the computer distinguish the unimportant details of the form and 2) within the heirachic representation of information, always more abstract, layer by layer, how could the computer chose the "essential form". For the first problem it was natural to resort to angles. I realised that it was possible to define the power of an angle and that this was also the measure of the importance of the detail of the figure. In the layer model, little by little the less powerful angles of the figures were eliminated. The figure was schematized until it reached its "essential form" and beyond because the process continued and reached, if the starting figure was closed, the form of a triangle, the most general of the closed figures, whatever initial form it had. About the second problem, the choice of the layer to be considered as containing the essential form could take place only through the teaching or the experience of the machine and, as will be seen later, it can be mechanized.

From the 1940s of the last century much has been discussed of neuronal networks, of perceptron, that were not very different from the neuronal networks, principally about the recognition of forms. In all these devices connections between "neurons" that were rewarded or depressed based on teaching were foreseen. This approach gave unsatisfactory results and for decades the argument was shelved, to be taken up again about twenty years ago, more or less in the same terms but using calculators that were much more powerful. I think that the fundamental idea of perceptron is correct but incomplete: the problem is always the same, the lack of definition of the features. To recognise forms, the features, at least the principal ones, in my opinion, are the angles and in order to define the essential form I have applied the idea of the neuronal network, rewarding the features that are equal in each class of forms.

The neuronal (or neural or neuronic) networks function well with the particular features of a class of images, with angles it should function for each image. The purpose, the hope is to achieve a "general purpose" system of recognition, as already said, that is "human like". I am not saying that angles are the only characteristic that make it possible to achieve the recognition of forms but I think it is basic. Other features such as colour, dimensions can be useful for the recognition of forms but in a subordinate position to angles. This is limited to the sense of sight because in humans smells and tastes,... that come from the other senses are also subordinate…………….

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The value of the threshold of power of the angles of the line increases progressively and with every increase the typical values of the line are registered on a table, which constitutes a matrix. I have called "layered model" all the matrix of the table which contain information about the edges of the figure which is progressively generalized. The information contained in the layers is hierarchical. I have called "contraction" the operation with which I eliminated angles, contracted the lines that were obtained and also the numerical tables equivalent to them. Finally I called the set of contracted lines "configuration". Fig. 55 shows four different forms of the capital letter R of the Latin alphabet. The forms could be different, the result would be the same. In figure 56 the result of the procedure is shown, applied to the form bottom left of fig. 55. It follows alphabetical order from the letter a) where there is the original form to the letter o) where there is the triangle that all the closed forms are reduced to. As can be seen the form, contraction after contraction, loses more details, that is, it acquires more generality until it becomes a triamgle. The figs. 56 h), 56 i) and 56 l) are particularly interesting because they represent the essential form of "R" and are common to all the "R" that a child would say are similar.

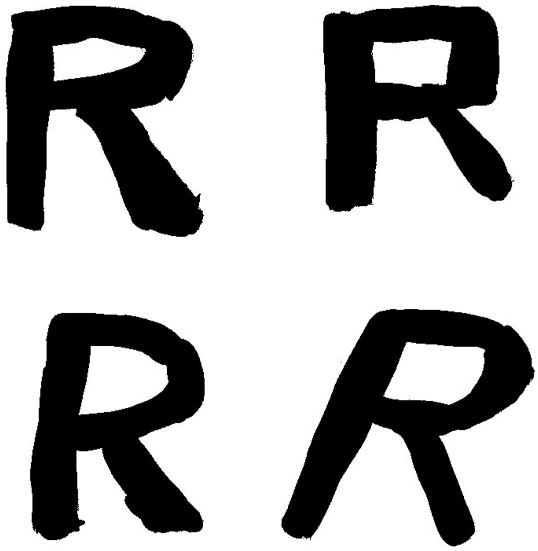

Fig. 55

The figure 56 appears from all the similar "R" with 6 angles two concaves and three convexes and 6 sides. The value of the angles and the measure of the sides are not equal, they vary according to the shape of the initial "R" but the computer must recognise them as equal, even in these approximations. This will be the argument of the following paragraph, for the moment it comes spontaneously to me to point out that the successive contractions are characterized by lines with sides that become longer and longer and angles that are more and more accentuated. The method of contraction can be seen as the opposite of the method of "smoothing". In order to complete the picture I include the results of the processing of the other three forms in fig 55. The essential forms are indicated with a white dot.
Also fig. 57 has its essential form, in fact it has 6 angles indicated with a small circle. I would like to point out that an identical essential form for all the similar forms is a goal that cannot always be reached, like the identity of the configuration after the essential form.In the following paragraph I will discuss how the figures can be recognised also with configurations that are not perfectly equal

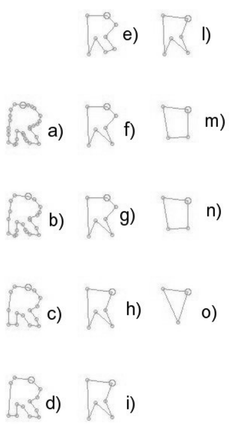

Fig. 56

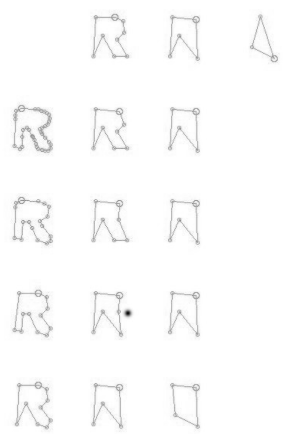

Fig. 57

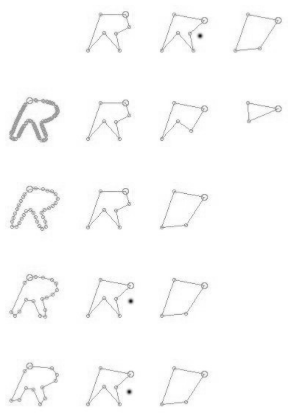

Fig. 58

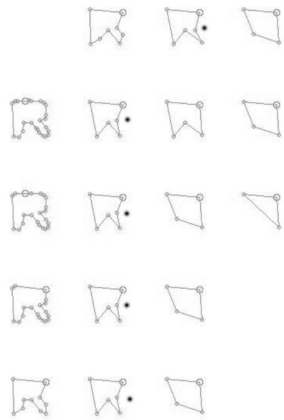

Fig. 59

3. Recognition and learning

In this paragraph with the words " recognition of forms" I mean the capacity to recall two similar forms with the sense that a child of three would give to this expression. As a child would say that the four forms of fig. 55 are similar, the machine must learn, also seeing only one of them, to recognise the others as similar to the first. if the name "erre" has been given to it, the machine must be able to remember this when the others are presented to its visual apparatus. This result can be obtained comparing the contracted lines. For recognition it is essential to remember the observations of Hubel and Wiesel, according to whom the same simple cell of the visual cortex responds to an angled bar within a certain approximation and within a certain area. According to this criteria, the contracted lines of the figs. 56, 57, 58 and 59, marked by the black dot are "equal" and in reality come from similar forms, to which could be given the same name. Since the machine captures this similarity, we are on the track of a human like recognition. I won't bore the reader with mathematical demonstrations that I carried out and which have led me to conclude that a description of forms through angles and their position, the configurations, that is, the hierarchical structure between contracted lines is extremely important for recognising the figure. It is enough to think that from two essential forms that are perfectly equal, going down through the process of contraction, further equal contracted lines and therefore equal configurations. It is not like this if the essential forms are only approximately equal like the essential forms of R. In fact the corresponding angles, despite being in approximations, are more or less powerful and are contracted one after the other. Information is taken from the successive contracted lines, especially on the proportions of the figure which escape an analysis of the sole preceding contracted line. It is obvious that mathematics is a tautology and therefore all the information is already in the essential form in the value of its angles, in the length of its sides. At the limit it is all in the form and all the process of contraction could be thought in another way. I follow models that help my intuition. Closed this parenthesis, it is necessary to learn how to compare contracted lines. In order that the comparison between two contractions resulting from different figures is made easy it is necessary that the figures are normalized. In fact for recognition not only the angles are important but also their position. The operation of normalizing was discussed in detail in Chapter IV. I

4. The neuronal network. Fragmentation of the figure.

While testing my ideas on the computer, I wrote a programme which simulated a classical neuronal network. Nothing exceptional. This made averages between similar figures, the distances between vertexes, the bisectors, the values of the angles, the depth of the layer of the angle in question and attributed a persistence to the angle. Persistence is a characteristic that is different from power. The power of an angle depends on its acumen and the length of its sides, independently of the number of times in which it occurs. Persistence makes it possible to cancel an angle, if it is relatively little in respect to the number of times the figure has been seen and recognised, furthermore normalized persistence in respect of the number of times that the figure has been seen and recognised supplies further criteria to define the connection between the angles of the current form and the memorized form. I called "residual form" the memorized form, refined by averages with a consequential strengthening of the persistence of the angles and their cancellation………

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7. The literal memory

I think that in the auditory system there are two types of memory: one which we will call pyramidal memory and a second which I will call literal memory, the argument of this paragraph. Let us suppose to have memorized the words of the Italian vocabulary, let's say in 5000 cells. In these conditions (without interruptions) we recite: The glory of he who moves everything through the universe penetrates... Saying "The" I excite the cells that have these phonemes in the line of characteristics, it is the same saying "glory", "of",... these word cells have in their indexes, which I suppose have respectively the values of 12, 23,75, 132, etc... The cell number 12, has it line of the characteristic excited by the phonemes "The", is excited by the pronounced word, but its excitation vanishes after a little time, to be specified with quantitative considerations, which I suppose are sufficient for memorizing the indexes of the words "glory" and "of" but not the rest of the phrase. When "glory" is pronounced the cell which has the phonemes of "glory" in the line of characteristics is excited and the cell will memorize the indexes of the words "of" and "he"; then the excitation of "glory" will fall away and will not be capable of memorization anymore. Pronouncing the word "of", the cell which has this characteristic will be excited and will memorize the indexes of "he" and "who", etc,... Essentially each excited cell memorizes the indexes of the words ahead. If a word cell X is strongly excited by the indexes of the phoneme cells, which it has in its line of characteristics, it becomes capable of memorizing for a certain period of time. Since in that time other word cells are stimulated, the X cell memorizes their indexes in a line of memorization. If the reading is repeated in order to learn a poem by heart, the programme controls and finds that in the memory zone of the cell "The" there is a line with the indexes of the same words which are being pronounced now and strengthens the power of the registration. If we want to remember a passage, when the registrations have been memorized, pronouncing only the word "The" the emission of a more powerful line of memorization of the cell may occur but if "The glory" is pronounced, the cell of the word "The" of the index 12 is excited and the cell of the word "glory" of index 23 too, but most important of all is that the index of the word “glory” will be the stimulation which will make the line of memory of the cell "The" containing "glory of" emit. Therefore the cell 23 of the word "glory", if excited strongly, emits stimulated by the indexes which come from the cell "The" for which it emits "of who" or better still, the indexes 75 and 132. From now on instead of speaking of indexes I will use words because this gives a more immediate result. It should be noted that "The" has emitted "glory of", the cell "glory" has emitted "of who" and therefore the cell "of" is excited by two emissions originating from the brain cells not from the decoder activated by a speaker. The excitations of the decoder are powerful, those of the brain less, however, if "The" and "glory" are pronounced very rapidly the two "of" emitted (glory OF, OF who!) interest this cell summing up their effects and taking it to a sufficient level of excitation and to the emission stimulated by its line which contains "he who", etc... Therefore having said two words in order, the memory of the text starts. It doesn't matter if the two words are the first or if they are to be found at any point of the memorized passage, what is important is that they are in order and they start the memory of the words that come after. All this does not have a quantitative value: it is an example. The word memorized in the line of a cell could be 4, as 3 cellular emissions of the same word could be needed to take the cell to a sufficient level of excitation. In fig. 69 there is an example of the function of a stimulated emission. The cells are 4. In the first line of the table there are their indexes. The last is the line of characteristics which contains the phonemes of the word that belong to that cell. In the second line there are the memories of the poem memorized in every cell, together with many others, indicated by the dots on the third line. To simplify the discourse, in the second line I have put the names of the cells while the indexes are memorized in them. Therefore instead of writing in the first cell "glory of" it would be correct to write 23, 75, if we want to be even more precise with their persistence. Under the table, in the first line there are the words spoken by an external speaker, each one of which is enough to strongly excite the cell. In the second line there is the emission of cell 12, the one of the word "The", that is "glory of". Cell 23 is excited twice: from the word "glory" pronounced and from the index number 23, the first time strongly because it is a signal that comes from hearing and the second time more weakly because it is the emission of cell 12. The two excitations sum up and a very strong excitation comes from them. The cell 75 "of" is excited by the emissions of 12 and cell 23, they are weak stimulations but if summed up they are sufficient to make it emit in its turn. As there is the index of the cell 132 "he" in the memory of cell 23, the emission of the line of cell 132 which contains the index of "he" will be stimulated. It is the same for cell 132 "he", excited by the emissions of cells 23 and 75 and their emission is stimulated by "who" present in cell 75 which make "who all" emit. At this point the process takes place and is maintained. I would like to point out again the two functions which each word has (or better the index of its cell has, which, however, contains the same information). In this development, for example "he" emitted by cell 23 excites cell 132 and stimulates the emission of the part of memory "he who" of cell 75. The word "he" emitted by cell 75 in the part of memory also excites cell 132 and makes it able to emit, naturally in a regime of stimulated emissions.

12	23	75	132	indexes
glory of	of he	he who	who everything	memory zone
......	......	......	......	memory zone
......	......	......	......	memory zone
......	......	......	......	memory zone
the	glory	of	he	charact. zone

the	**glory**			pronounced word
	glory	of		emission from cell 12
		of	he	emission from cell 23
			he	emission from cell 75
strong	**very strong**	sufficient	sufficient	cell excitation

Fig. 69

In this type of memory it is necessary that the cell remains excited, that is, it is able to memorize, while the successive cells are excited. Therefore it doesn't seem to me that literal memory can concern the phrase cells and even less the period cells, unless it is expected to keep them stimulated with a voluntary act and a device suitable for this purpose. However it could concern the phoneme cells, more than the word cells for which I have developed the example. The literal memory is substantially asemantic, it could be formed by asemantic words.

8. The pyramidal memory

The name pyramidal memory suggests how it is formed even in a long text, with phonemes as a base, then syllables, then words, then phrases,... up to the last cell, at the top of the pyramid. Proof is necessary but I believe that the pyramids are not very high. Furthermore I think that how the pyramidal memory is formed, by the phrase plane, whose cells have the indexes of the word cells as characteristics, does not happen as for a word cell, whose stimulation is (also) the work of an automatic attentional device. The phrase cell, for example, must be maintained in a stimulated state for a relatively long time and therefore a wilful act is necessary. Keeping a cell stimulated voluntarily is a big leap in quality: up to now I have only spoken of automatism and I think that the existence of this possibility and the device that carries it out contribute more than any other apparatus, to explain the difference between the thoughts of animals and those of humans. A difference already detected by Descartes. In order to memorize the line of characteristics of a phrase it is necessary to voluntarily keep the cell stimulated while the words which substitute the phrase are pronounced and the beginning and end of the phrase must have clear temporal pauses, superior to those between the words. During the formation of the phrase, in pyramidal memory, the words must already be formed, because the characteristics of the phrase cell are the indexes…..

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Alphabetical Index

actuators..161
agent..136
agglutinatived..139
Alcmaeon of Croton..4
antagonist cells..67
articular zones..123
atomic commands...141
brilliance..23
candle..28
cause and effect...17
cause of the transformation..136
chemiosensorial apparatus..7
Chomsky..141, 178
chromatic constance...70
cones..19
configuration...108
constancy of the form..79
contour line...25
contraction..108
control device...141, 172
cortical visual apparatus..154
dark discharge...36
Darwin...5, 15
Democritus...5, 11, 136
direction..26
Enroth-Cugell..20
ergative...137
Ernst Mach..154
excited..147

field.....27
Fourier.....143
frequency.....19, 30
Frost.....10
function.....25
Galileo.....136, 179
ganglion.....20
Gestalt.....153
gradient.....26
graphemes.....142
Held.....10
Heraclitus of Ephesus.....157
Hering.....67
Hubel.....21
Hume.....5, 12, 136
illuminance.....29
illumination.....29
index.....130
intensity.....30, 34
intuition.....168
isoconvergence model.....80
isolating.....140
James Watson.....4
Lamark.....15
Land.....74
layered model.....80, 104, 108
Leibniz.....179
Leonardo da Vinci.....53
lines characteristics.....131
literal memory.....162
luminance.....23, 29
luminous flux.....28
luminous intensity.....28
lux.....29
Mach.....23
Mach bands.....38
magnitude.....26
Markov.....143
meaning.....157
memory cells.....130
memory zone of a cell.....131
Michelangelo.....53
model.....12, 133
Mondrian.....74
nit.....29
paradox of Hering.....36
parsing.....139
patient.....136
pauses.....146
persistence.....120
phoneme.....145
phonemes.....142

plan model........80
Poincaré........168
Poppel........10
privileged line........47
privileged strip........47
pyramidal memory........162, 166
Raffaello........53
relative persistence........122
residual form........118
retina........19
Richard Feynmann........5
Robson........20
rods........19
route of primary vision........56
sentence........145
Silvio Ceccato........4
similar........120
similarity........28
spectrums........143
spontaneous emission........147
stimulated emissions........148
syllable........145
topological transformation........28
vector........26
versus........26
W cells........20
Wallace........5
Wiesel........21
word........145
X cells........20
Y cells........20
Yarbus........182
Young........67
…………………
…………………
…………………

Contents

Brain Mechanics........1
Preface........4
Chapter I – The World and the Brain........9
Preliminary remarks........9
1. A mechanistic model of the brain is needed in a universe that (probably) is not mechanistic........9
Chapter II – Connections........19
Preliminary Notes........19
1. Elements of neurophysiology and bases of the model for interpreting the human visual system........19
2. Mathematical Elements........25
3. Elements of physics........28
Chapter III – The fundamentals of vision........31
Preliminary remarks........31

1. Luminance and brilliance..31
2. Inhibition and edges..37
3. The isolation of the object from the background.................51
4. The formation of the visual image.......................................55
5. Some references to the theories of colour and
neurophysiological connections..67
Chapter IV - Peripheral vision and central vision.........................79
Preliminary remarks..79
1. The model of isoconvergence. An outline of peripheral
vision and central vision...79
2. Dimensions of the objects. Near objects and far objects…..88
3. Comparison between figures and optical illusions..............91
Chapter V – The topological recognition of forms.....................100
Preliminary remarks..100
1. The power of angles...106
2. The layered model...107
3. Recognition and learning...111
4. The neuronal network. Fragmentation of the figure..........120
5. Notes on the search for objects..129
6. The structure of the visual cells...130
Chapter VI – The mechanization of language............................132
Preliminary remarks..132
1. Voice recognition...142
2. The structure of the linguistic area of the brain.................144
3. Spontaneous and stimulated emissions..............................147
4. The formation of the object...150
5. The formation of words..156
6. Level A. Actuator cells..160
7. The literal memory...162
8. The pyramidal memory..166
9. Relations between the pyramidal memory and the literal
memory...168
10. The control device..172
11. Understanding the written text...179
Appendix I – Complements...182
1. Learning by differences...182
2. Some examples...184
A reasoned bibliography...188