A new method to analyse the perception of size

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ABSTRACT

In living bodies, the correct perceptual representation of size constancy requiresthat an object's size appear the same when it changes its location with respect to the observer. At the same time, it is necessary that objects at different locations appea to be the same size if they are. In order to do that, the perceptual system must ecover from the stimuli impinging on the individual, from the light falling on the retina, a representation of the relative sizes of objects in the environment. Moreover, at the same time, image perception is related to another type of phenomena. It corres ponds to the well known perceptual illusions. To analyze these facts, we propose a system based on particular arrays of receptive points composed by optical fibers and dummy fibers. The structure is based on the first layers of the mammalians primary visua l cortex. At that part of the brain, the neurons located at certain columns, respond to particular directions. This orientation changes in a systematic way as one moves across the cortical surface. In our case, the signals from the above-mentioned array are analyzed and information concerning orientation and size of a particular line is obtained.

With this system, the Mülle -Lyer illusion has been studied and some rules to interpret why equal length objects give rise to different interpretations are presented.

Keywords: Illusion, perception, size perception

1. INTRODUCTION

One of the concepts more difficult to handle is the one related with Visual Perception. Visual Perception, as defined b several authors, is the process of acquiring knowledge about environmental objects and events by extracting information from the light they emit or reflect. In that sense, Visual Perception concerns the acquisition of knowledge and is distinct from purely optical processes such as photographic ones. These processes lack of perceptual capabilities and they do not know anything about the scenes they record. In this way, the knowledge achieved by visual perception concerns objects and events in the environment. An object, as seen by a living body, is not just a simple object It is an object in a certain place and with some particular conditions. If place or conditions change, the perception of such an object may change. At least, to the active subject.

Many artificial systems have been proposed in the last years concerning several different tasks in pattern analysis and pattern recognition. Most of them are related with functions as recognizing a certain shape or to differentiate a particula image among a large number of similar ones. Almost every one of the above -mentioned systems works in a similar manne as the living bodies visual system works. But here is a very important difference between these two approaches. The living bodies "see" a certain subject but they "see" it in close relation with circumstances and previous experiences. The main objective of this paper will be to present a possible way to introduce in artificial vision systems some tasks performed b animals.

In living bodies, the correct perceptual representation of size constancy requires that an object's size appear the same when it changes its location with respect to the observer. At the same time, it is necessary that objects at different locations appear to be the same size if they are. In order to do that, the perceptual system must recover from the stimuli impinging on the individual, from the light falling on the retina, a representation of the relative sizes of objects in the environment. Moreover, at the same time, image perception is related to another type of phenomena. It corresponds to the well known perceptual illusions. In some occasions, there errors in perception: you see results from an interaction between the external world and the present state of your visual nervous system.

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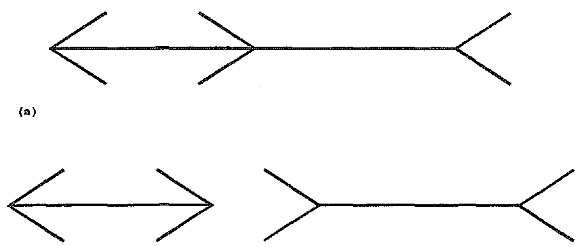
2. VISUAL ILLUSIONS

There are many cases of systematically non veridical perceptions, usually called "illusions". One particularly striking is the moon illusion. Moon looks much larger when it is close to the horizon than it does when it is high in the night sky. By taking a series of photographs as the moon rises, the size of its photographic image does not change in the slightest. It is ou perception of the moon's size that changes.

One of the more familiar situations is the Mülle - Lyer illusion illustrated in Fig. 1. It is obvious in (a) that the horizontal part on the right appears considerably longer than that part in the left half of the diagram. The influence of angles in this illusion can be easily tested b varying the direction of the lines at the ends of the two portions. Fig. 1.b is made up of the parts of the same illusion and it is the normal figure in textbooks. Man other illusions may be seen in several places.



(a)

(b)

Fig. 1. - Müller-Lyer Illusion.

There are many theories trying to explain the above facts. Some of them are related with the T. Lipps explanation. He proposed the principle of mechanical-aesthetic unity, according to which we unconsciously give to every space-form a living personality and unconsciously consider certain mechanical forces acting. Our judgements are therefore modified by this anthropomorphic attitude. The second theory is the one proposed by Wundt. He does not attribute the illusion to a deception or error of judgement but to direct perception. According to his explanation, the laws of retinal image (fixation) and eye -movement are responsible. For example, vertical distances appear greater than horizontal ones because the effort is greater in raising the eyes than in turning them through an equal angle in horizontal plane. The first one, the Lipps theory is of the "judgement" or "higher-process" class and the second one, the Wundt theory, is of the "perceptive" class.

The approach we are going to adopt in this paper concerns another type of relation between the external and the internal world. We are going to extract some information about the real characteristics of the objects, from an objective point of view, and we are going to transfer them to the internal configuration of the visual part of the human visual cortex. The model we are going to propose is just a first approach but some general ideas will be reported in order to perform a higher order model. The simulation we present is a mixture of hardware architecture and software processing although the hardware part give a first treatment of the image in the same way the human visual system does.

In order to achieve this goal, some ideas are first needed concerning the influence of certain details of the objects to be considered. A very important part is related with the influence of angles. We shall concentrate next paragraph in those elements.

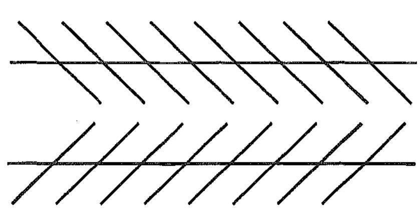


Fig. 2.- Zöllner Illusion.

2.1 The influence of angles

As previously stated with the Mülle -Lyer illusion there is a clear relation between the position of the angles with respect to the horizontal line and the sensation of length. This point, because is fundamental for our model, needs a longer explanation. Apparently Zöllner was the first to describe the illusion, appearing in Fig. 2. Zöllner noticed the illusion that the long parallel lines appear to diverge in the direction that the crossing lines converge. He found that the illusion is greatest wh en the long parallel lines are inclined about 45ª to the horizontal. This may be accomplished for Fig. 2 by turning the page through an angle of 45ª from normal. The illusion vanishes when held too far from the eye to distinguish the short crossing lines, and its strength varies with the inclination of the oblique lines to the main parallels. The most effective angle between the short crossing lines and the main parallels appears to be approximately 30°.

There are several variations of this effect. As an example, Fig. 3 shows the Hering's illusion of direction. The two parallel lines, no longer look parallel offering a certain curvature near the center as they were to joint, at a certain distance, from both sides.

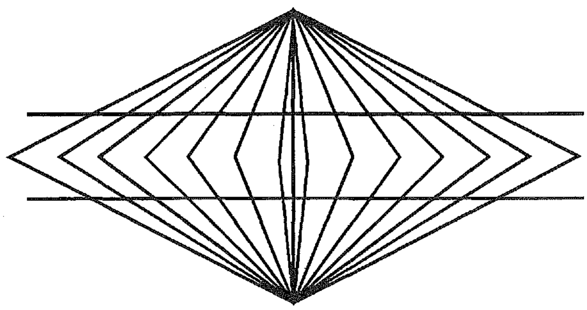


Fig. 3.- Hering's Illusion.

In order to get a deeper feeling about the effect of angles, a new effect appears in Fig. 4. It shows how the angles affect the apparent length of lines. The three horizontal lines are of equal length but they appear unequal. This is due primarily to the size of the angles made by the lines at the ends. With certain limits, the greater the angle the greater is the apparent elongation of the horizontal portion. This generalization appears to apply even when the angle is less than a right angle, although there appears to be less strength to the illusions with these smaller angles than with the larger angles. Other factors which contribute to the extend of the illusion are the positions of the figures, the distance between them, and the juxtaposition of certain lines. The illusion still exists if the horizontal lines are removed and also if the figures are cut out the paper after joining the lower ends of the shorter lines in each case.

From above facts there is a possible conclusion to be obtained: there is a strong influence of the positions of the 1 ines that are around a particular object with a particular shape. The incidence is not the same if lines at certain angles are close to a line that the are at a certain distance. Moreover, the angles interact with the sensation obtained.

It should be interesting to relate these facts with the internal structure of the visual cortex where the images are processed. Some ideas about that will be reminded in the next paragraph.

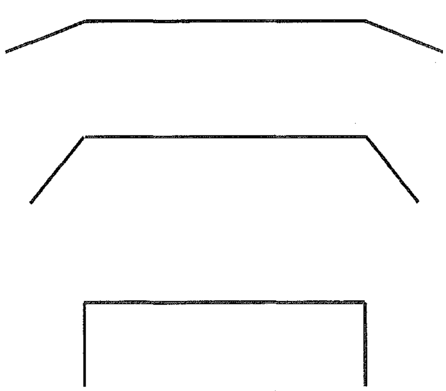


Fig. 4.- Effect of angles on the length sensation.

3. SOME IDEAS ABOUT THE HUMAN VISUAL CORTEX AND ITS MODELING

Although it is not the aim of this paper to present a model of the human visual cortex, some ideas are needed to point out in order to clarify the structure we have adopted. These ideas will be giver at the first part of this paragraph.

3.1 The mapping of visual functions in the visual cortex: Functional architecture of area V1

The most detailed map of the retina is found in area V1 of the mammalian visual cortex. This detail goes close with a rich functional architecture, uncovered by Hubel and Wiesel in thei physiological studies. They proposed that V1 was made up of a set of orientation columns and a set of ocular dominance columns. A way to clarify these ideas is to see how cells encountered in a penetration made perpendicular to the cortical surface of V1 respond.

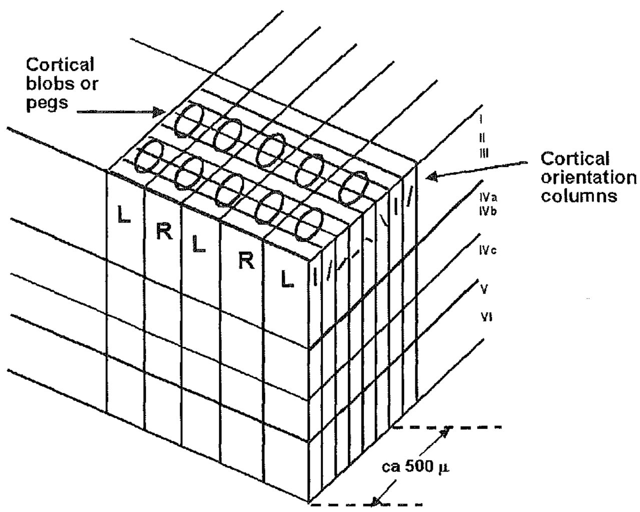


Fig. 5.- Structure of a part of the mammalian visual cortex.

Some cortical visual neurons have receptive fields with "on" or "off" zones arranged in parallel. Diffuse illumination of the entire receptive field causes little change in the spontaneous activity of them. But if a "bar" of light in the "correct" orientation and position is projected into the receptive field, there is strong activation. These fields are called "simple" receptive fields, because it is easy to establish their functional organization by projecting small spots of light onto different parts of the recep tive field. Other type of neurons with "complex" receptive fields covers higher orde functions. The whole structure and function of the neuron primary visual cortex architecture is somehow much more complex. Their nerve cells are arranged in six distinct cytoarchitectonic layers parallel to the cortical surface. These nerve cells are organized not only within layers parallel to the surface but also in "columns" perpendicular to it. When the neurons laying at these columns are tested with contours oriented in various directions one finds a progressive change in optimal orientation across adjacent columns. In other words, the cells in a particular column share the same preferred orientation. This orientation changes in a systematic way as one moves across the cortical surface, such that after half a millimetre or so we are back to the first orientation. Thus the visual cortex is traversed by a series of bands, within each of which every possible orientation is represented. This fact may be demonstrated anatomi cally. A highly stylized representation of a slab of visual cortex, showing its organization into columns, is shown in Fig. 5. It is necessary to add that vision corresponding to right and left eyes are at alternate columns. It is necessary to travel a minimum distance of about 0.8 mm for the cells to respond to the right eye plus the left eye and then start the sequence again, a distance comprising the orientation hypercolumn. Equally, it is necessary to travel about 1 mm for all 18 orientations to be covered, a distance comprising the orientation hypercolumn. Each small part of the field of vie is screened for one eye and then for the other eye, and each small part is simultaneously screened for different orientations, the entire process being repeated again in the adjacent millimetre for an adjacent small part of the field of view. Colours are detected, in a similar way, at specific places, named cortical blobs o pegs.

The extraordinary regularity and precision of the retinal map in V1 may have misled to some people into thinking that it must be the retina that is mapped in all visual areas. But the results from studies of the prestriate cortex suggest that it may need a new concept of what a map in the cortex means. Some people are inclined to think of these maps as static maps of the retina. But may be useful to think of them as dynamic maps and even constructional maps. The relation between the external image and image the living bod "sees" may have some to do with this aspects of the visual cortex.

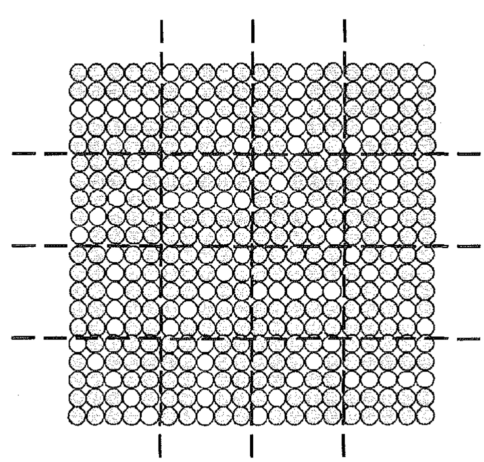


Fig. 6.- Proposed structure for the sensing system.

3.2 Modeling of the V1 region of the visual cortex

Two structures need to be developed in order to implement the above-considered behaviours. The first one concerns the way to extract the visual information from the scene. The second one concerns the system to p erform the logical operations needed to analyze such information. Several approaches may be adopted to carry out these functions. We have reported previously several ways to perform the first task[7-9]. In this case, and because our present aim is just to pesent general ideas to clarify the above concepts, the model to be presented is a very simple one.

The first step is to offer a possible way to detect simple orientations in a similar way as the single cells does it. The structure we have developed is jus t a bidimensional configuration as the one shown in Fig. 6. It is composed by a two dimensional distribution of squared arrays with optical fiber arranged in the way shown there. White circles correspond to optical fibers whereas dark circles correspond ei ther to dummy fibers or to empty spaces. Linear light signals are detected by the squares with a fiber distribution similar to the linear geometry of the incident light. Different portions of the total mosaic detect different parts of image. This structure resembles, in some way, to the one shown in Fig. 5. Optical fibers coming from each particular square are added together and the resulting optical signal is detected at the end. According to its intensity, information is obtained concerning the number of fibers with light. Just when the light distribution corresponds to the orientation of fibers, intensity maximum is obtained. The accuracy of the system is given by the fiber diameter and the optical image projection system employed. The pattern shown in Fi g. 3 is given just as an example. Different configurations give different patterns to process information. This structure gives a further possibility. If our present dumm fibers are optical fibers, and their particular connections may be modified, possibi lities to alter the obtained information are possible. This aspect needs a more careful analysis and cannot be presented her.

4. ANALYSIS OF SOME SIMPLE CONFIGURATIONS WITH THE REPORTED MODEL

4.1 Basis of the method to analyze illusions about length

According to the previous paragraphs, region V1 of mammalian visual cortex is divided into an array of columns detecting different angles corresponding to the impinging image. Although the difference in rotation between two consecutive columns is just some few degrees, the first model we are going to present offers a rotation of 45° from a column to the adjacent ones. Hence, a certain direction get the same position just after four columns because there is no determination of sense in the directions to be recognized. In the same way, objects to be "sensed" have only four possible line directions.

The first object to be analyzed is the Mülle -Lyer illusion. Fig. 7 shows how the two lines are analyzed. At the first row are the two lines. Second row indicates how many vision" units cover. The third one shows the bidimensional configuration employed to detect different directions. It is assumed that just a set of basic detection units is needed to recognize the objects.

The data obtained from the sense array are two. The number of sense units excited per column is obtained first. Secondly, the number of columns where there has been some detection is recorded. In this way, the data extracted from above configuration appear in Table I.

Table 1

Figure	A			B				
Column	1	2	3	1	2	3	4	5
Bits	3	1	3	2	1	1	1	2
Total Bits	7			7				
Excited Columns	3			5				
Object Length	3			3				
Λ	*13/7*			*23/9*				

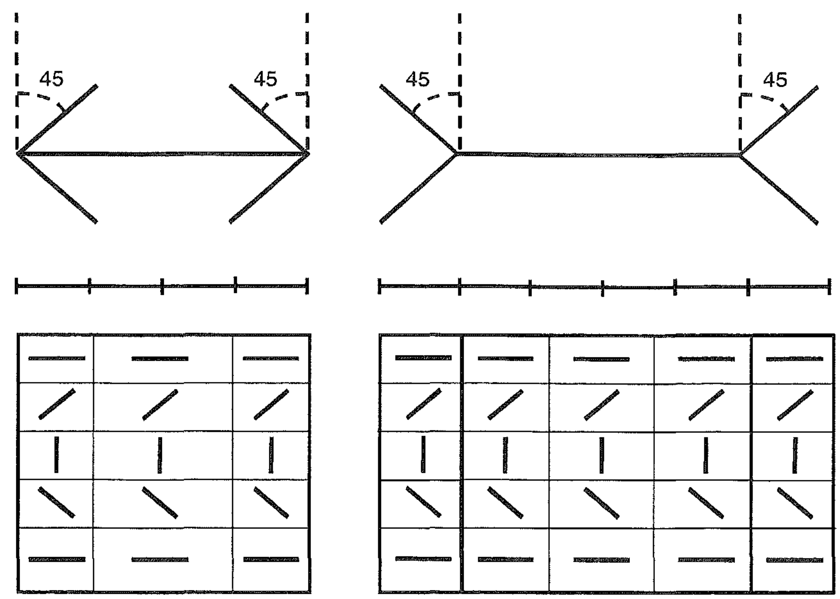


Fig. 7.- Analysis of the Müller-Lyer Illusion.

Any excitation obtained from every sense unit has the same weight, namely a bit "1". We have considered two length units. The first one, indicated as "Excited columns" gives the total number of columns where has been obtained signal. "Object length" corresponds to the "real" length of the observed object. In every case, the adopted unit has been the corresponding to the length of a detection column.

The last row gives the number we propose as an indication of the subjective characteristics of the object. It corresponds to the following expression

$$\Lambda = \frac{\sum_1^n \sigma_{B_n} \lambda_n^2}{\sum_1^n \sigma_{B_n} \lambda_n}$$

Being Λ the subjective length, n the total number of excited columns, σ_{B_n} the total number of bits obtained from the nth column and λ_n the distance of column n to the center of image in column units.

In the present case, the Figure A, gives a value of 13/7 fo Λ and 23/9 for object B. If the absolute value is an indication of the length sensation, we see that object B gives a number larger than A. The sensation for object B is that its length is larger than that object A. Hence, the numerical result agrees with the subjective length.

4.2 Influence of angles

As we have pointed out before, there is a strong influence of the angle value with the length sensation. In previous case w have considered that just 45° was the possible angle to be detected at the sensor arrangement. This is not the real situation in the visual cortex. It is necessary 1 mm to cover 18 orientations. That means the difference between two consecutive orientations is, as much, 10°.

In order to analyze this situation we took the situations indicated in Fig. 8.

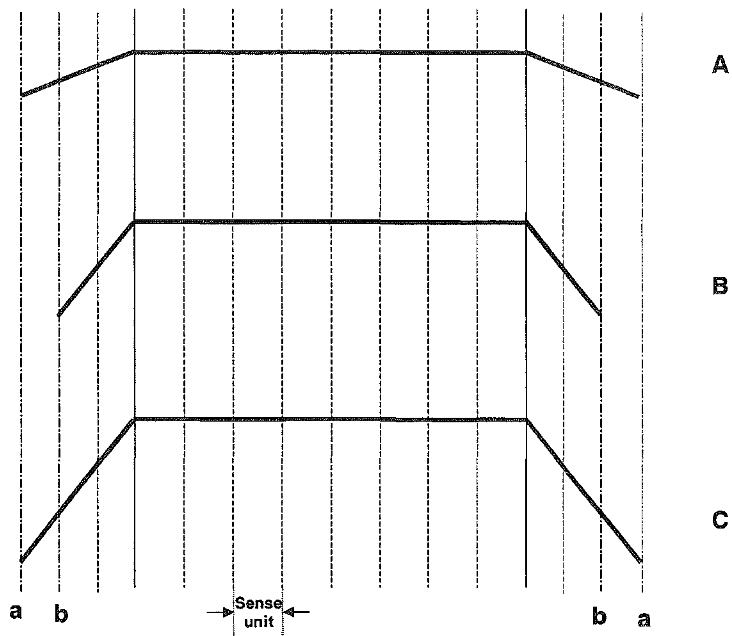


Fig. 8.- Analysis of the angles influence on the line length.

We present in this case two equal length segments with lines at their ends forming a certain angle. The difference with previous case is that the response of the sensing units has not the same weight. According to neuron theory, the response of a neu on is affected by the response of adjacent neurons. Hence, their influence will be different if they are at columns nearby that if they lay at columns some neuronal units away. In the present situation, and in order to keep the model as simple as possible, we consider just two possible angles between 0° and 90°. So, to return to the original orientation is needed now seven positions instead the three we had before. The influence on the final measure depends on the following rule

Line angle (°)	Weight
0	3
30	2
60	1
90	0

Moreover, there is another point to consider. It affects the length of the lines located at the end of the central segment. Two are the considered possibilities. First one is that the length of the ending lines is the same independentl of the angle value. Second one is that they project on the same lengths over the horizontal line. These two possibilities are the cases B and C and correspond to lines a and b in Fig. 8.

The expression to be applied now is

$$\Lambda = \frac{\sum_{1}^{n} \varpi_n \sigma_{B_n} \lambda_n^2}{\sum_{1}^{n} \sigma_{B_n} \lambda_n}$$

being ϖ_n the corresponding weight according to previously indicated rules. This expression is, as it can be seen, equivalent to the inverse of the previous one. The reason in that the first equation was indented to compare two objects with different shape. The intention now is to determine the incidence of angles on the length sensation. This distinction needs a more careful explanation.

As an example, the value for Λ obtained from object A is

$$\Lambda = \frac{\left[(7^2+6^2+5^2)2+(4^2+3^2+2^2+1^1)3\right]2}{\left[(7+6+5)2+(4+3+2+1)3\right]2} = \frac{310}{66} = 4{,}69$$

With these considerations the results for this case are shown in Table 2.

The sensation is, in this case, that object A has an horizontal line longer than B and C. This corresponds with values for Λ larger for A than for B and C.

Table 2

Object	A	B	C
Total Bits	36	28	30
Excited Columns	14	12	14
Object Length	8	8	8
Λ	*310/66*	*200/48*	*151/41*

4.3 Analysis of parallelism: illusions about parallel lines

We propose, as a final model, another analysis concerning parallelism. In this case is the difference in perception between two lines that are parallel and the same lines when other lines forming an angle with them cross them. This corresponds with illusions indicated in Fig. 2 - 3 and in a more extended form in Fig. 9. The appearance of parallelism is strongly dependent

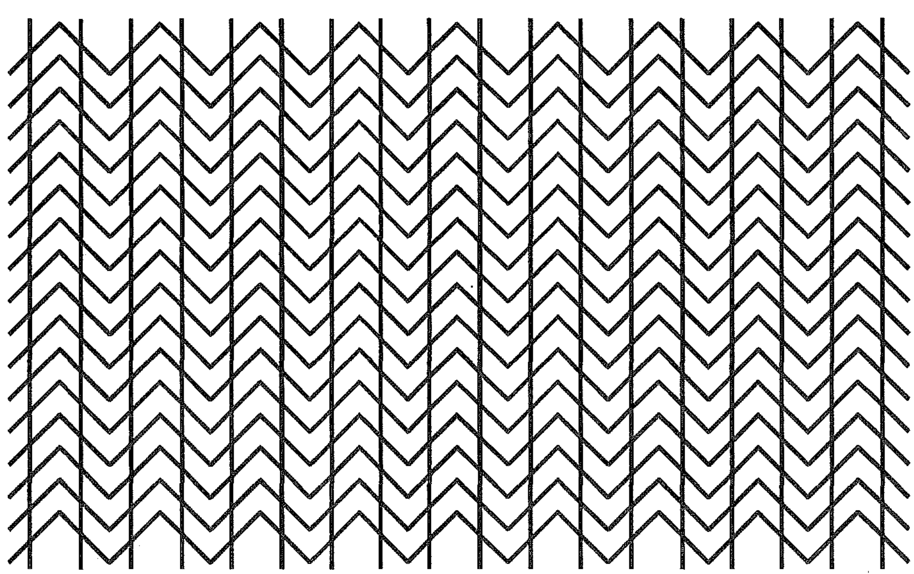


Fig. 9.- Extended Parallelism Illusion from the Zöll ner effect.

on the presence of lines crossing, at a certain angle, with the parallel lines. It is clear that the long parallel lines appear to diverge in the direction that the crossing lines converge. Zöllner found that the illusion is greatest when the long parallel lines are inclined about 45° to the horizontal. The most effective angle between the short crossing lines and the main parallel lines appears to be approximately 40°-45°. It in interesting to note that steady fixation diminishes and even destroys the illusion.To analyze this new situation a different approach must be adopted. There is now a different concept to introduce. It is the related with the presence of parallel lines and short lines crossing them at a certain angle. The study will be based on the representation that appears in Fig. 10. Two different situations appear in this figure. There are two sets of parallel lines and small lines crossing them with equal angles. The difference between both sets is the position of the small lines at each one of the parallel lines. In Fig. 10 (a) the lines have a C_2 symmetry around an axis in the middle of the long lines. In Fig. 10 (b) the only symmetry operation is a translation along a line perpendicular to the parallel lines. There is illusion in the first case but there a e not in the second one.

The method to measure the illusion is now somehow more complex. It is necessary to rotate along the C_2 axis and apply some mathematical expression to the resulting figure. In the first case, because the two long lines with the smal l ones superpose, the results is to double the effect of just one. The expression to be applied should be

$$\Lambda = \frac{\sum_1^n \varpi_n \sigma_{B_n} \lambda_n^2}{\sum_1^n \sigma_{B_n} \lambda_n}$$

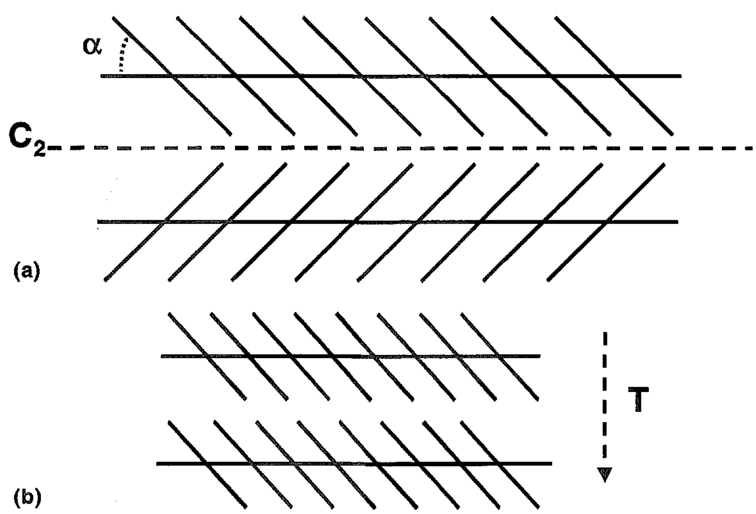


Fig. 10.- Symmetry operations in two sets of parallel lines with small crossing lines.

In this case we propose for ϖ

$$\varpi = \varpi_0 \sin 2\alpha$$

being ϖ_0 the maximum wei ght for 45° and α the corresponding angle between lines.

If we apply this expression to Fig. 10 (b) the result is 0 because the influence of both sets of lines compensates. On the contrary, in Fig. 10 (a) the value should be positive indicating the presen ce of a illusion.

5. CONCLUSIONS

The above reported concepts are just some of the many that can be applied to extract some objective information about particula illusions. It is sure that every different illusion will need a different type of modeling. We have tried to initiate a possible way to make objective, in some way, concepts that are merely subjective. There are many different types of illusions, every one concerning a different type of feeling. This feeling is, in some cases, related with the relation between the object and the boundaries. This has been the case of the examples we have presented in this paper. But there are many others where the illusion, or the wrong feeling, is related with previous experiences of the subject. A person coming from the desert does not feel the sense of altitude in the same way a newyorker does. The sense of perspective is not the same for a man always living in the forests than for native from a city. These facts should be introduced, in some way, in a possible model.

Moreover, an important task should be tried to obtain the corresponding data from each particular case with an automatic method. This should be implemented with the fibre configuration indicated previously. Each grouping of fibers, with a particular orientation, will allow to extract the quantity of light corresponding to such a direction. Lines of fibers detecting some other direction will allow to obtain an amount of radiation proportional to the number of fibers intersecting the impinging direction. P rocession of this light will give the numbe Λ for every situation. This system would have to connect with a memory of past events in order to introduce the facts pointed out in the previous paragraph. At the same time, some other qualities of the scenes s hould need to be introduced. We have proposed some of them, as the symmetry, previously[8]. But some more work is necessary to complete the model.

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