NOISIV
Un Nécessaire Outil d'Investigation pour un Système Informatique de Vision

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ABSTRACT

This paper describes :
- a mechanical and hardware system built for experimenting passive vision algorithms.
- a software toolbox including in its actual state :
  - a) the controlling of "eyes" movements.
  - b) the off-line and on-line calibration
  - c) the edge points finding
  - d) the oriented edge segments forming.
- a first experiment of synthesis : a stereovision matching algorithm dedicated to polyhedral objects.

The testing bench, called NOISIV, has been conceived taking into account :
- a) D. Marr's vision model
- b) Neurophysiology : Hubel and Wiesel,...
- c) Psychophysics data : PANUM, H.R. WILSON,...

and so some parallels are drawned between biological and artificial vision.

I. INTRODUCTION

"The eye has often been compared to a camera... Those who work in the field of artificial intelligence (AI) cannot design a machine that begins to rival the brain at carrying such special tasks as processing the written word, driving a car along a road, or distinguishing faces" says D.H. HUBEL [HUBEL88][1].

Of course, you are right Mr Hubel. Consequently an attractive idea for artificial vision research is to pay attention to the results of the research in neuroanatomy, neurophysiology, psychophysics,... (this research will be called "anaphypsy..." in this paper).
Following such a convincing idea, although one conclusion of "anaphypsy..." is : "We are for from understanding the perception of objects, even such comparatively simple ones as a circle, a triangle or the letter A-indeed, we are for from even being able to come up with plausible hypotheses" [HUBEL 88] [1], a testing bench dedicated to passive computer vision experiments has been conceived.

Of course, whenever the "anaphypsy..." is as vague as "working the exact mechanism for building up simple cells will not be easy..." [HUBEL] [1], ad hoc engineering models and computational algorithms must be chosen.

The "anaphypsy..." landmarks on which this work is based are :
- oculomotor function [YARBUS][2] [GUYTON][3]
- contrast sensitive dectectors [KUFLER][4] [ENROTH-CUGGEL][5]
- multiple spatial-frequency-tuned channels [CAMPBELL][6] [WILSON 83][7] ,[WILSON 84][8]
- oriented edge segments detectors [HUBEL 77][9] [HUBEL 82][10] [MARR 82][11] [HUBEL 88][1]

This testing bench called NOISIV is described in this paper, conforming to the following principal features :
1) the mechanical-hardware aspect of NOISIV
2) the software tool-box of NOISIV that includes :
- the controlling of "eyes" movement
- the off-line and on-line calibration
- the edge-points finding
- the oriented edge segments forming

3) An example of a synthesis experiment : a stereovision matching algorithm.

II. NOISIV MECHANISM AND HARDWARE

A. The mechanical system

KERAVEL et al [12] indicate that as for back as 1083 IBN-AL-HAYTHAM had understood that "The pathways and centres of oculomotor function allowing someone to direct one's eyes towards a precise target are as important as the perceptive apparatus for achieving the visual function". [GUYTON][3].
In a more concrete manner and supported by some experiments, YARBUS[2] argues the fact that the eye movements occur :
- during the saccades that change the direction of the subject's gaze
- when stationary objects are fixed
- during the change of fixation point
- when percepting moving objects.
- when percepting complex objects.

PANUM's[13] works directly infer that the brain cannot perform the binocular fusion without the help of the convergence movement of the eyes.
RASHBASS[14] indicates that these convergence movements are extremely accurate : about 2'
The impact of such arguments has led to the conception of a mechanical system including 2 mobile cameras" like the human eyes" (called the "head") set on a gantry robot (called the "body") (cf. figure 1).

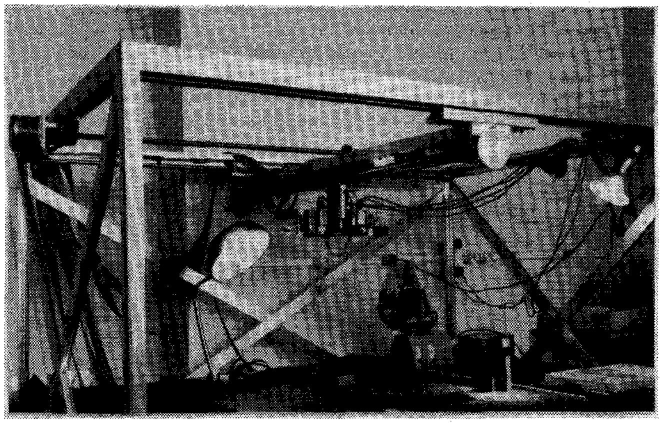


Figure 1.

1. The "body"

The "body" of the bench can move along two orthogonal axes, which enables to change the viewpoint. It bears the "head".
The mechanism, a threaded rod combined to a step by step motor, allows movements of 25 microns of amplitude with a precision estimated to 100 micons.

2. The "head"

The head of the bench is constituted of 3 motor elements operating 2 microcameras MICAM conceived in this laboratory [CONTER][15]. Table 1 presents a comparative statement of the characteristics of NOISIV eyes and human eyes. The informations are issued from [BAHILL][16], [CORNSWEET][17],[GALIFRET][18], [GUYTON][3], [HUBEL 88][1] [YARBUS][2]

B. The computational power

a) An architecture including a 680*0 MOTOROLA MICROPROCESSOR that communicates with specialized processors by means of the VME bus.

b) An array processor, SKY WARRIOR, reaching a processing rate of 15 MFLOPS. This one, even less than the "future" connectionists models [FOGELMAN][19] [DURAND][20] does not pretend to simulate the extremely parallel-processing capabilities that one is entitled to imagine in the human brain : more than 10^{10} neurons*10^4 synapses [GALIFRET][18], is one of the obstacles.

	Characteristic	NOISIV Eyes	HUMAN Eyes
OCULOMOTOR FUNCTION	allowed movements	in one of two orthogonal planes	in one of three orthogonal planes
	movements range	[-32°,+32°]	[-50°,+50°] and better
	movements precision	36"	2'
	movements speed	1.2°/s	≤ 500°/s during saccades ≤ 100°/s during convergence
OPTICAL SYSTEM	distance between optical centres	≃ 135 mm	[60,70mm]
	focal length	9 mm	17 mm
	focusing	no	automatic changing of the rubbery jelly-like lens
	iris diaphragm	no	automatic distortion of the pupil
RETINA	resolution	288*208 pixels	$160*10^6$ rods $6*10^6$ cones
	photoreceptor size	10.7'*5.75'	[20",35"] for the foveal cones
	visual angle	18°*13.5°	≥ 104° for the retina ≥ 1.4° for the fovea
	spectrum wavelength	[$500*10^{-9}$m, $1000*10^{-9}$m]	[$400*10^{-9}$m, $750*10^{-9}$m]

Table 1.

c) The processor of image digitization - memorization
It has been built in this laboratory by G. BIGUET to take the electronic characteristics
- particularly the pixel clock of the CCD chip-of the MICAMs into account. It provides natural stereograms, that is to say both a left and right retinal image of any observed scene, at the video rate : figure 2 gives an example.

Figure 2.

d) A unit for synthesizing video images : TRIDYN
e) A unit driving the five step by step motors conceived round an ALU Z80 and communicating with the host computer by serial port.

III. NOISIV SOFTWARE

A. The controlling of the eye movements

The bench is considered a mechanical articulated system with 5 degrees of freedom whose geometric modelling (figure 3) is :

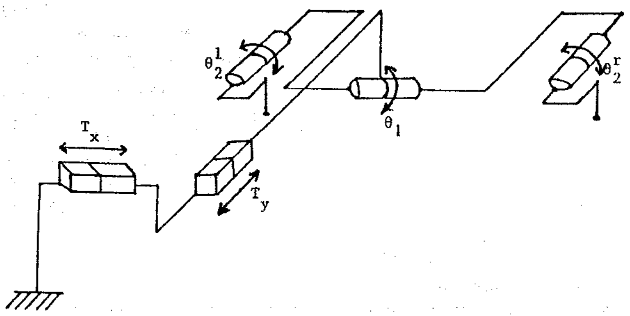


Figure 3.

Such a system is driven by a control kernel allowing the "head" to be moved and the "eyes" oriented. 2 levels of control can be considered :

1. Simple movements
- resetting to a reference position
- absolute displacements with regard to the origin issued from the preceding operation.
- relative displacements with regard to the current position.
- change of the starting point of the work session.
- etc...

2. Complex movements
- Fixing a target of the 3D space with the 2 cameras : convergence movements or change of direction of the "eyes".
- A rotating motion of the 2 cameras round the observed scene while fixing a target point.
- etc...

B. Calibration of the stereoscopic sensor

How does the human brain, this expert geometer,[NINIO][21] manage to juggle so skilfully with the notion of distance inter and intra-objects in the surrounding world ? To ask it to "keep up 30 meters apart behind a car" is indeed to much for it, since it is apparently conceived to deal with relative dimensions. This handicap, however, does not exclude precision : man is exceptionally able to distinguish 2 points respectively located at 1000 and 1000.15 mm in front of him[BOURDY][22]. Another question is how can the human visual system still function after any movement of the eyes ? Any hasty answer is not recommended ; the present solution in NOISIV follows 2 stages :

a) Off line calibration of the cameras

It is the calculation of the equations of the punctual transformation that makes a point $P^l(y^l,z^l)$ and P^r (y^r,z^r) on the respectively left and right retinas - each retina determining a coordinate system - correspond to any point $P(x_0,y_0,z_0)$ of the 3D space relative to an absolute coordinate system.

A robust calibration code, that could be built in conformity with the graph in figure 4 represents more than 30 000 FORTRAN lines.

No details concerning :
- the opto-electronic geometric model
- the numerical algorithm of the resolution of the problem of parameter estimation

are given here ; the interested reader can find a more complete exposition in [ABI-AYAD][23] , [TSAI][24]

Supposing they are chosen, consider :

1. Locating $(x_0,y_0,z_0)_i$ and $(y,z)_i$

The quality of the solution of the calibration problem depends upon :

a) nbmes = number of reference points

The forming of images on the retina is a physical phenomenon involving 2 spaces (respectively R^3 and R^2) with an infinite number of points. This phenomenon is investigated by means of measures in finite number. Consequently, while ignoring the difficulties encountered in numerical algorithms, the quality of the solution increases with nbmes. NOISIV usually works with nbmes = 256 and exceptionnaly with 512.

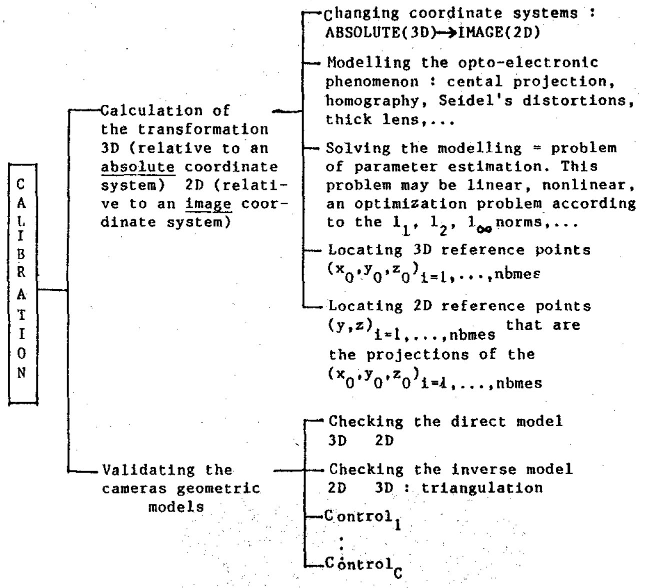


Figure 4

b) Accuracy in locating $(x_0,y_C,z_C)_{i=1...nbmes}$

In NOISIV $(x_0,y_0,z_0)_i$ is the centre of a matt surfaced disk where : $-(x_0,y_0)_i$ depends directly on the "head" position.

$-(z_0)_i$ depends directly of the height of the disk holder (called "candle").

$-\forall i$, $(\Delta x_0)_i \simeq (\Delta y_0)_i \simeq (\Delta z_0)_i \simeq 10^{-1}$mm.

c) Accuracy in locating $(y,z)_{i=1...nbmes}$

$(y,z)_i$ is the centre of gravity (theoretically when the retina and the disk are parallel and approximately in usual experiments with NOISIV) of a patch made homogeneous by a thresholding segmentation ; this patch presents an elliptic boundary [HARALICK]^{25} since it is the image of the disk used in 1.b . Accuracy depends on :

- the value of the small ellipse axis.
- the average grey level on the patch before the thresholding.

and is estimated to : $\forall i$, $(\Delta y)_i \simeq (\Delta z)_i \simeq 0,07$ pixel

d) Distributing $(x_0,y_0,z_0)_i$ and $(y,z)_i$

A delicate choice has to be made :

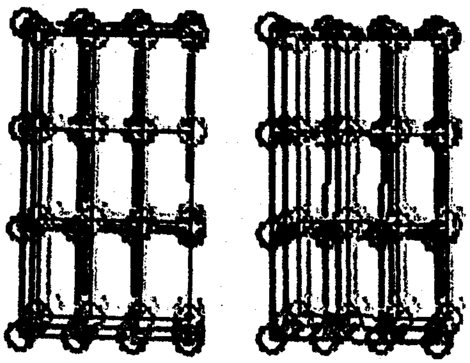
- if the best direct "perspective" model (3D→2D) is desired, the intuitive idea says to choose the $(x_0,y_0,z_0)_i$ equidistributed in the volume at the intersection (for example the largest parallelepiped, as shown on the stereogram of figure 5) of the visual fields of the two cameras.
- on the contrary if the best inverse "perspective" model (2D→3D) is desired, the $(y,z)_i$ have to be equidistributed on the retina. Unfortunately it is difficult to meet this requirement : to know the direct model would be necessary and also to be able to choose automatically the height $(z_0)_i$ of the "candle", in order to take the same $(x_0,y_0,z_0)_i$ for the 2 cameras, would be useful.

NOISIV allows to juggle between the two antagonistic possibilities but choosing $(x_0,y_0,z_0)_i^l \neq (x_0,y_0,z_0)_i^r$, $\forall i$.

The algorithm of the simultaneous location of the $(x_0,y_0,z_0)_i$ and (y^l,z^l),(y^r,z^r) which implements 2 parallel tasks is :

```
For all the selected "candels" ($z_0$) do
    For all the selected ($x_0$,$y_0$) do
        Move the head to : ($x_0$,$y_0$) + translation
        Start shooting = digitize the two images
        Calculate ($y^l$,$z^l$),($y^r$,$z^r$)
    End For
End For
```

Figure 5.



e) Smoothing $(y,z)_i$ data

The accuracy in locating $(y,z)_i$ can be improved thanks to NOISIV mechanism : according to 1.d a reference point (x_0,y_0,z_0) is at the intersection of 3 straight lines :

$$Dz_0 \begin{cases} X_0 = x_0 \\ Y_0 = y_0 \end{cases} \quad Dy_0 \begin{cases} X_0 = x_0 \\ Z_0 = z_0 \end{cases} \quad Dx_0 \begin{cases} Y_0 = y_0 \\ Z_0 = z_0 \end{cases}$$

Consequently, according to the selected opto-electronic model, (y,z) has to be at the "intersection" of :

- either 3 straight lines D_z,D_y,D_x, images respectively of Dz_0,Dy_0,Dx_0 in the case of a central projection or homography.
- or 3 polynomial curves C_z,C_y,C_x of a degree 2, images respectively of Dz_0,Dy_0,Dx_0 in the other cases.

D_z,D_y,D_x are calculated as least square staight lines ; there is one simple analytical solution available.

Cz,Cy,Cx are calculated by solving an unconstrained nonlinear least squares optimization problem called "orthogonal distance regression" ; Bogg's[BOGGS]^{26} algorithm is used.

f) Smoothing $(x_0,y_0,z_0)_i$ data.

A manner to smooth the $(x_0,y_0,z_0)_i$ is to develop a formal statement of the problem of parameter estimation, mentioned in the graph of B-a, as a "nonlinear orthogonal distance regression" problem [BOGGS]^{26} rather than an ordinary least squares problem because errors in the $(x_0,y_0,z_0)_i$ measurements are not small with respect to those in the $(y,z)_i$ measuremnts.

2. Validating the cameras geometric models

a) Checking the direct models : 3D→2D

NOISIV allows the automatic checking on as many points as wanted ! ($\geq 10^7$). The algorithm is the one described in 1.d to which "Evaluate the error of the direct model of the left camera (respectively right)" is added in the final action of the most internal loop ; this error, $\|\overrightarrow{P_C^l \; P_l^l}\|$ (respectively $\|\overrightarrow{P_C^r \; P_l^r}\|$), where the subscript C (respectively l) means calculated (respectively located) is evaluated.

- An interesting visual tool is a retinal map of errors
- The calibration is said robust when the average error of the direct model and the one made when the reference points $(y,z)_i$ are located, are more or less of the same order. It is true for NOISIV.

b) Checking inverse models

- The equations of the inverse models (2D→3D) are established from the direct models. In the case of a central projection or homography there is no difficulty [BALLARD]^{27} ; in the other cases such as Seidel's distortions for instance, the inverse distortion must be applied beforehand, which can be delicate.
- Measuring the precision of the inverse models is based on the triangulation operation defined as follows : given $P^l(y^l,z^l)$ and $P^r(y^r,z^r)$ image of P, P_C

is calculated as the "intersection" of the projecting rays that have generated them. The triangulation error, then is $\|\overrightarrow{P\,P_C}\|$. For NOISIV an average error of about 2×10^{-1} mm is obtained when the distance between the object and the camera is approximately 500 mm, which is, therefore about the same for human eyes [BOURDY][22] ; this fact is confirmed by the theoretical formula that evaluates the maximum triangulation error, in the case of a central projection [MAC VEY][28], such as :

error = k*(error when locating P^l and P^r)*
(distance between object and optical centers)^2*pixel size/
(focal length*distance between optical centers)

b) Real-time updating the cameras models after a rigid motion (=translation+rotation) of the cameras

Accuracy, then depends on the quality of the geometric modelling of the stereoscopic sensor (figure 3 is only a sketch) : 18 physical parameters are used. For more details see [ABI-AYAD] [23].

C. The processing of "RETINAL" images

1) Définition of contrast sensitive detectors

Litterature is full of algorithms detecting intensity changes in digitized images . Blicher [BLICHER][29] has counted 28 of them in his thesis. This can be explained by the fact that the problem to be solved is not well specified. When the "physician" provides his personal interpretation of the problem, the mathematician finds out a solution : for example [CANNY][30].

On the contrary, in NOISIV, the choice is only based upon the results given by "anaphypsy..." and mathematics which indicate :

i) the X ganglion cells (and others of the lateral geniculate body,...) are contrast-sensitive. [KUFFLER] [4].

ii) These cells have symmetric circular receptive fields ; they are centre-surround type with a variable size [ENROTH-CUGGEL] [5]

iii) There are several channels processing these contrast effects, which are tuned on spatial frequencies [CAMPBELL] [6] [WILSON] [7].

4i) The implulse response issued from the linear shift invariant stage of these filters can be modelled by linear combination of gaussians :

DOG (Difference of Gaussian), TRIGAU (TRIPLE Gaussian).

5i) DOG_s have mathematical properties [MARR 82] [11] [MARTHON 85] [31] and can be considered approximately second order differential operators.

Consequently NOISIV contrast sensitive detectors are copied from WILSON's data [WILSON 84] [8] : the impulse response has been standardized as follow :

$$\mathrm{Filter}(x,y) = \alpha_1\, g_1(x)g_1(y) + \alpha_2\, g_2(x)g_2(y) + \alpha_3\, g_3(x)g_3(y)$$

$$\text{with } g_i(u) = \frac{1}{\sqrt{2\pi}\,\sigma_i}\, e^{-(u^2/2\sigma i^2)} \qquad i = 1,2,3 \; ; \; u=x,y$$

Table 2 gives all the characteristics of the implantation that uses FFT (Fast Fourier Transform) algorithm.

Filter		Pf (1)	Bp (2)	α_1	α_2	α_3	σ_1	σ_2	σ_3	Tc (3)
.	Fa	0.8	2.64	1	-1	0	.101	.519		345
D	Fb	1.7	2.15	1	-1	0	.069	.208		163
O	Fc	2.8	1.75	1	-1	0	.078	.082		99
G	Fd	4.0	1.76	1	-1	0	.055	.058		69
T	F'c	2.8	1.49	.149	-.299	.149	.059	.133	.179	99
R	F'd	4.0	1.50	.104	-.209	.104	.042	.093	.125	69
I	Fe	8.0	1.32	.067	-.135	.067	.027	.042	.054	35
G	Ff	16.0	1.32	.034	-.067	.033	.013	.021	.027	19

Table 2.

(1) frequency sensitivy peak (cycles per degrees)
(2) half sensitivy bandpass (octaves) - (3) sizes(cones)

Filters with frequency sensitivy peak equal to 2.8 and 4.0 cycles/degree are in both DOG and TRIGAU, for the second TRIGAU excitatory lobe -a physiological reality according to [DEVALOIS] [32]- introduces a priori unwanted consequences : to be tested !

2. Adapting cone-pixel-focal length-viewing distance

The continuous filters defined in table 2 are sampled with respect to the average size of foveal cone. Of course, an adaptation is necessary for a computational implementation in order to take into account the following facts :

i) a pixel of a viewed image is not necessarily cast on a foveal cone ; it depends on the visual angle covered by this pixel and more precisely the couple (distance of observation do, size of the pixel)

ii) a CCD photoreceptor does certainly not cover the same visual angle as a foveal cone ; its depends on the couple (focal length, size of the pixel).

The adaptation chosen in NOISIV consists in a repacking : the weight attributed to a pixel of the discrete convolution mask is the "sum" of the contributions of the cones, covered by a projected pixel (case i) or representing a visual angle equal to the camera pixel (case ii). The effect of the repacking corresponding to the case (i) on the F_a filter profile is illustrated figure 6. (cast pixel size = 2 * cone size).

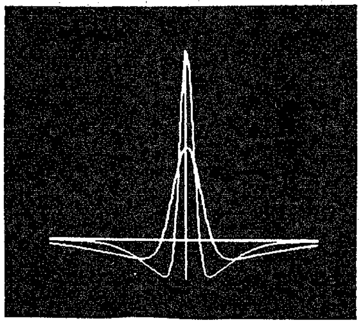


Figure 6.

3. Detecting edge points

Marr [MARR 80][33] has suggested a biological mechanism extracting points in which there is a contrast effect (called edge points) from an (ana) logical "AND" between 2 adjacent cells (of the lateral geniculate body ?) respectively coding the positive and negative response of the result of the convolution.

As it had already been done by Grimson [34], this idea has been transposed to NOISIV. The vector implementation also exploits the spatial relation between "cells whose response is of opposed signs" to code the local edge orientation (see c.4).

a) Eliminating false edges

Some of the zero crossings (ZC) of the convolved image may be parasite [BERZINS][35] [MARTHON 85][31]. Berzins has proposed a test for eliminating them : NOISIV is equipped with it.

The intervention of the contrast magnitude measured as the gradient vector module (of the original or convolved image) offers another opportunity to sort out the ZC_s. The experience proves that a minimum 3 x 3 neighbourhood is required for calculating the gradient (using SOBEL masks for example).

At this stage of the image simplification, what to think of the fact that the human eyes interpret an image of coded edges with their magnitude more easily than an image of binary edges ?! (figure 7).

b) Improving the edge location-Cooperation between filters

The mathematical theory [MARTHON 85] [31] shows that the DOG_s may displace the ZC_s with regard to the true edge position : for example for the corners, rectangles, circles,... Among other things, the displacement amplitude depends on the size of the central excitatory region of the filter.

Assuming that the edges are "topologically" maintained when replacing a coarse filter by a finer one, (according to [BABAUD] [36], in fact only Laplacian of Gaussian owns this remarkable property) NOISIV utilizes finer filters to improve the location of the edges provided by coarser filters. There is the following algorithm (the same idea is developped in [BERGHOLM][37]).

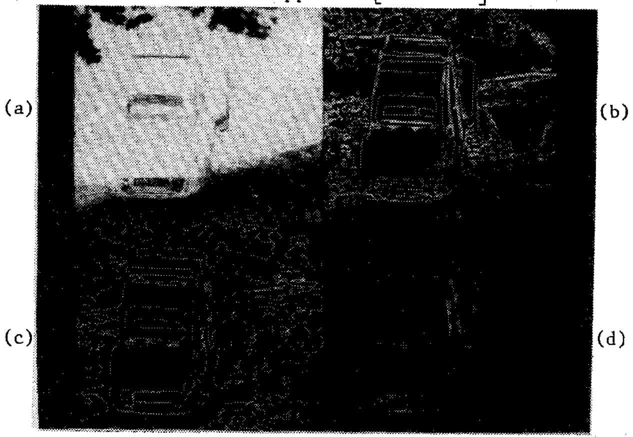


Figure 7.
(a) raw image (256x256) IM ; (b) ZC_s of $IM \circledast F_c$ with repacking factor = 8.19 ; (c) ZC_s of $IM \circledast F_c$ with repacking factor = 2.05 ; (d) (b) with strength of the edge.

Given, IM the image to be processed, F_i the beginning filter F_n the final filter :

```
Extract the edges from $F_i \circledast IM$ --> $IMF_a$
For F := $F_{i+1}$ to $F_n$ dO
    Transcribe the edges onto the area of maximum
    displacement ---> $IMF_a$
    Extract the edges from $F \circledast IM$ ---> $IMF_n$
    $IMF_a$ <--- $IMF_a$ AND $IMF_n$
End For
```

The area of maximum displacement of an edge point (y,z) is the union of some of its neighbourhoods (open discs centred on (y,z) with radius = maximum displacement)

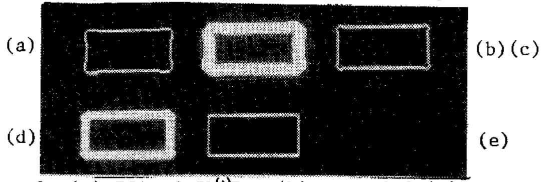


Figure 8. (a) ZC_s of $IM \circledast F_a$. (b) expanded (a)
. (c) ZC_s of $IM \circledast F_b$ AND (b) .(d) expanded (c)
(e) ZC_s of $IM \circledast F_c$ AND (d)

4. Forming oriented edge segments

One of the most important results of Hubel and Wiesel is to have pointed cells-called simple, complex, end-stopped- of the primary visual cortex, which are sensitive both to the orientation and length of slits, light-dark edges. Marr has also proposed a model for a simple cell which can (?) detect oriented edge segments. For Hubel, this model is one among others and furthermore he concludes "Even after twenty years we still do not know how the inputs to cortical cells are wired in order to bring about this behavior [HUBEL] 88 [1].

Here is an example where the "anaphypsy..." lacks quantitative models. So, an ad hoc engineering mechanism must be chosen since the oriented edge segments constitute meaningful features on the visual pathway. Griswold[38], for example, partially solves the problem by convolving $\nabla^2 G \circledast IM$ with a unidimensional rectangle oriented filter. But, $Rect \circledast \nabla^2 G$ defines a 2D oriented filter and so makes useless the stage of circular centre surround type ganglion (and others) cells.

An extraction of the oriented edge segments, in 2 phases, is proposed in NOISIV .

a) Extracting edge orientations

A local orientation attributed to one edge point is one of the 8 following ones :

D0	D45	D90	D135	D180	D225	D270	D315
++ --	+- +-	+- +-	+- +-	-- ++	-+ -+	-+ -+	-+ -+

This orientation could be calculated by scanning the 8-neighbourhood of the edge points ; the vector implementation selected in NOISIV is the following one :

i) Conventionally, as no interpixel is introduced, ZC_s are systematically marked on the pixels that bear a positive convolution result.

ii) Dividing the ZC_s into 4 main classes :
HPLUS (respectively HMOINS) = horizontal ZC_s corresponding to the configuration ++ (respectively --)
-- (++)
VPLUS (respectively VMOINS) = vertical ZC_s corresponding to the configuration +- (respectively -+)
+- (-+)

iii) Obtaining diagonal orientations

AND	VPLUS	VMOINS
HPLUS	D45	D315
HMOINS	D135	D225

4i) Obtaining horizontal-vertical orientations
D0 = HPLUS AND (NOT D45) AND (NOT D315)
D90 = VPLUS AND (NOT D45) AND (NOT D135)
D180= HMOINS AND (NOT D135) AND (NOT 225)
D270= VMOINS AND (NOT D225) AND (NOT 315)

The results are represented in figure 9.

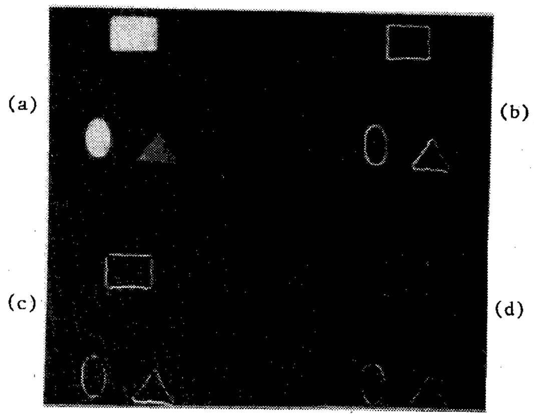


Figure 9. (a) raw image .(b) all the edge points
(c) D0,D90,D180,D270 .(d) D45,D135,D225,D315

b) Grouping the edge points into oriented edge segments

It is executed throughout an algorithm of "edge tracking" guided by the local orientation. The implementation is a 8-state automaton (whose transition table is represented in figure 10) with a system of priorities over the transitions, which makes it very performant : about 1.5 tests per edge point. Of course such an automaton would fail, when processing a real graph with complex nodes. In its most elaborated form, the result is represented by a vertex graph that might be smoothed [MARTHON 87][39] for improving the segment orientations.

St \ Nb	i,j+1	i-1,j+1	i-1,j	i-1,j-1	i,j-1	i+1,j-1	i+1,j	i+1,j+1
D0	D315 7 D0 8	D90 5 D45 6						
D45	D315 2 D0 7	D90 6 D45 8					D270 3	D0 1 D315 4
D90			D45 7 D90 8	D180 5 D135 6				
D135	D0 3	D90 1 D45 4	D45 2 D90 7	D180 6 D135 8				
D180					D135 7 D180 8	D270 5 D225 6		
D225			D90 3	D180 1 D135 4	D135 2 D180 7	D270 6 D225 8		
D270							D225 7 D270 8	D0 5 D315 6
D315					D180 3	D270 1 D225 4	D225 2 D270 7	D0 6 D315 8

Nb= Neighbour ; St = State ; 1 ..8 = increasing priority of tests
Figure 10

IV. AN EXPERIMENT OF SYNTHESIS : MATCHING STEREOSCOPIC IMAGES

The first stereovision algorithm is dedicated to polyhedral objects. For both the features and the matching algorithm, (following a classification in [THIESSE][40]) two levels are distinguished : global and local. This idea is well discussed by Julesz[41].

Also important is the epipolar geometry constraint, that is to say : to combine the inverse model (for the reference camera) and the direct model (for the other one) and also to know the calibration volume set a limit to the search of corresponding points to an epipolar segment (and its neighbourhood).

On the contrary very little trust is put in the orientation constraint, because the analytical (or projective) geometry [SKORDAS][42] shows that "any" left oriented segment may correspond to any right oriented one. Here is an apparent inconsistency between mathematics and "anaphypsy..." which says that all binocular cells in the primary visual cortex have the common characteristic of orientation specificity.

1. Global level

a) features : significant closed edge lines. It is a manner to translate the "figural continuity" constraint of MAYHEW and FRISBY[43]

b) algorithm : 2 features match if and only if there is at least one edge point on the reference one that exactly matches one and only one edge point on the other one, in conformity with the epipolar geometry constraint.

2. Local level

a) features : the vertex graphs (cycles) issued from the edge tracker.

b) algorithm : to summarize, it is the search for subgraph isomorphisms, which induces that the unicity constraint is satisfied.

For more details and results see [MARTHON 87][39].

V. CONCLUSION

This is nearly where NOISIV is, today. It would be nonsense to think that all is well finished while HUBEL concludes his book with "The knowledge we have now is really only the beginning of an effort to understand the physiological basis of perception."

To improve the current NOISIV in its weaknesses (see table 1) is a first goal. To use NOISIV to introduce the oculomotor function in artificial vision and particularly in stereovision is also an attractive plan.

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