Corso di Robotica (ROB)

C. Modulo di Robotica Bioispirata

Visione artificiale retinica

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Sommario della lezione

- Principi di base della visione retinica
- Alcune proprietà delle immagini retiniche
- Le relazioni matematiche tra immagini retiniche e cartesiane
- La foveazione
- Una testa robotica antropomorfa
- Esempi di applicazione in robotica

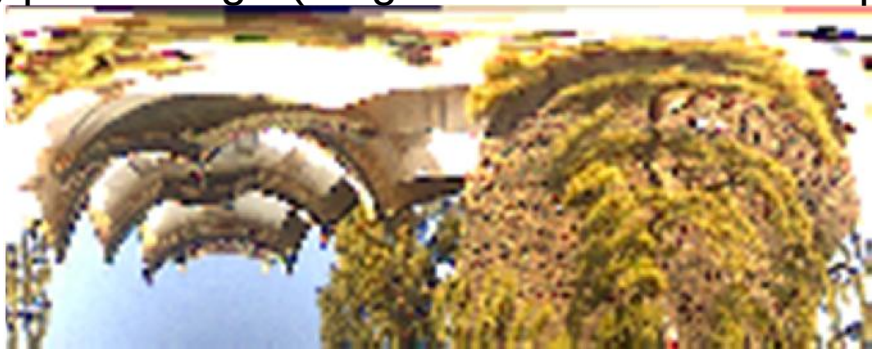
Riferimenti bibliografici:
G. Sandini, G. Metta, “Retina- like sensors: motivations, technology and applications”. in Sensors and Sensing in Biology and Engineering. T.W. Secomb, F. Barth, and P. Humphrey, Editors. Springer-Verlag. 2002.

Principi di base della visione retinica

Standard image

Retina-like image

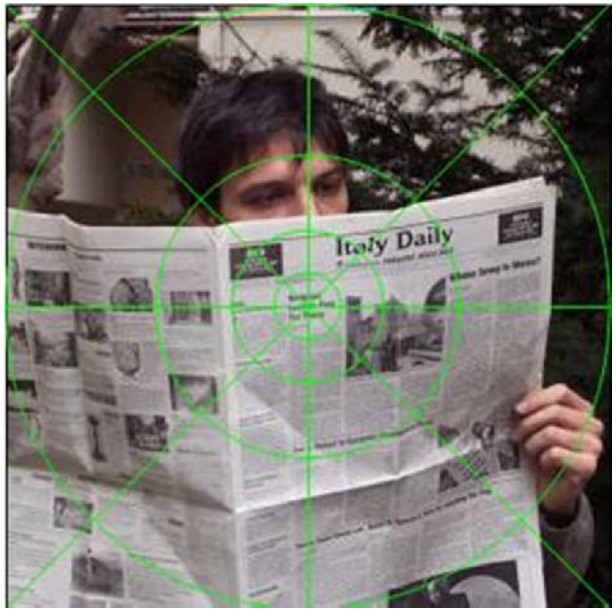
Log-polar image (magnified to 200% for display)



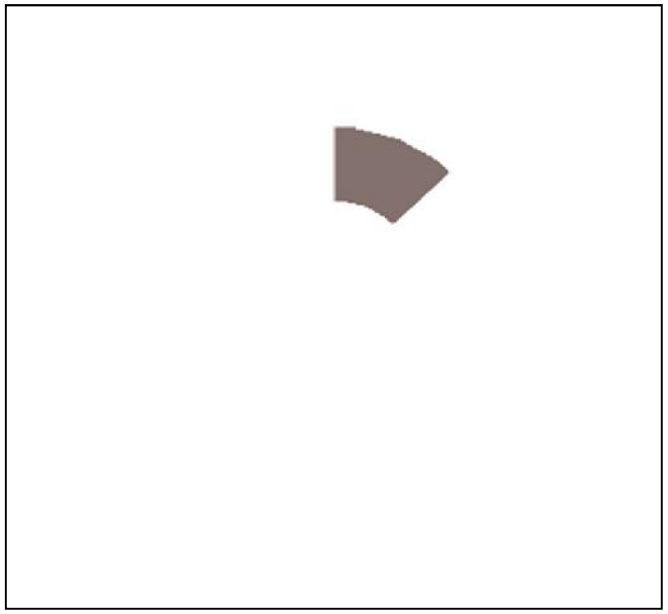
Log-polar projection

Costruzione di un’immagine retinica

Immagine cartesiana tradizionale



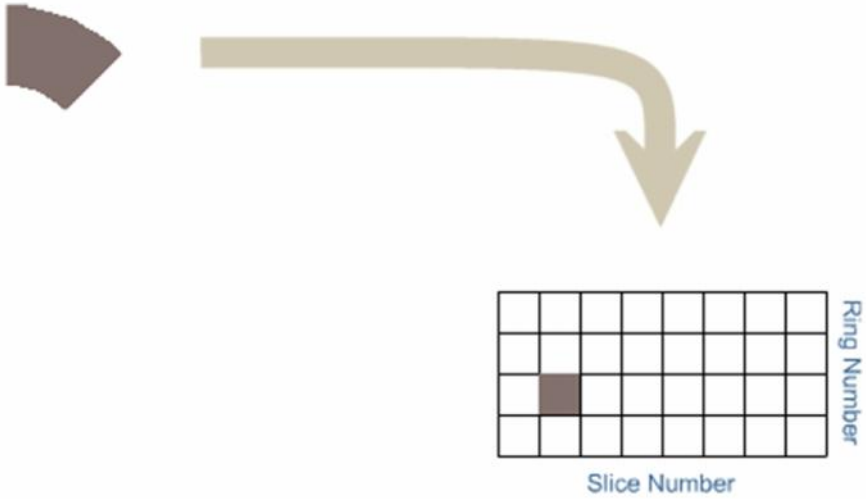
Divisione in circonferenze e spicchi



Calcolo del valore medio di un settore

http://www.retinica.com/

Costruzione di un’immagine retinica

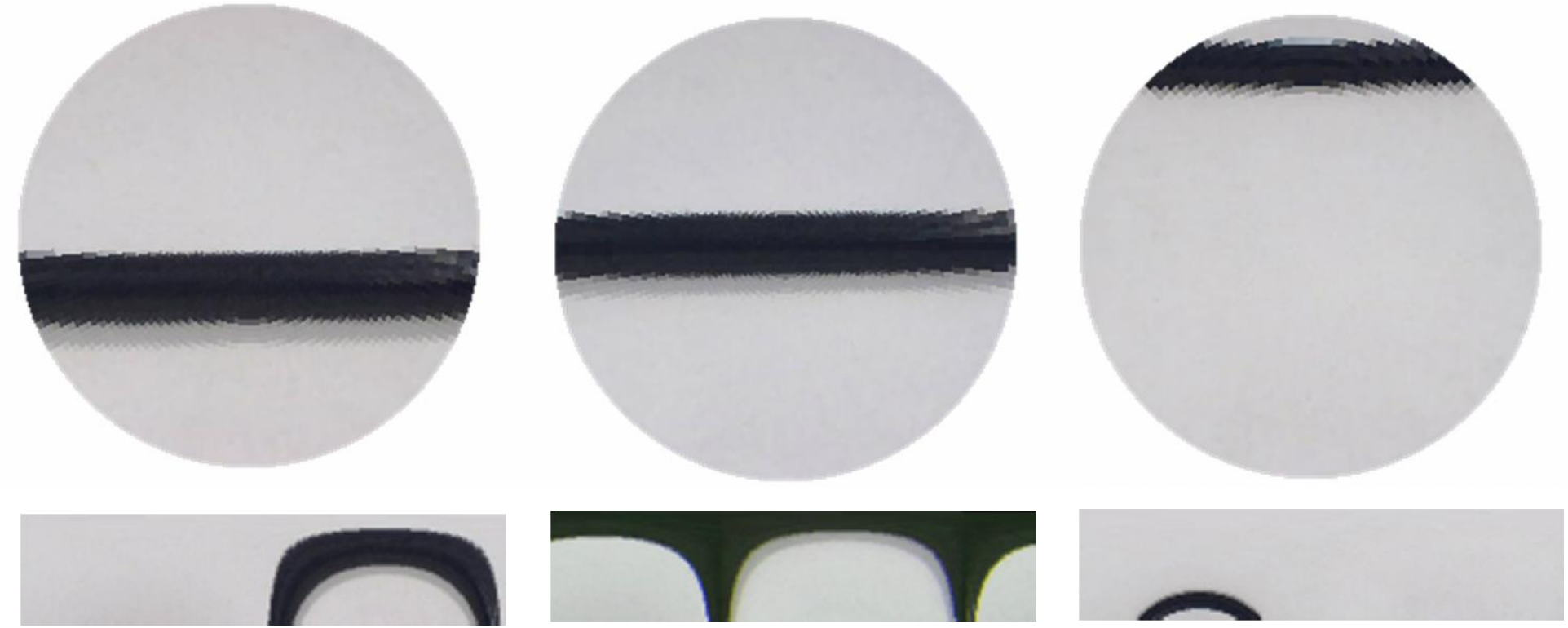


Copia del valore medio di un settore in un pixel di un’immagine polare

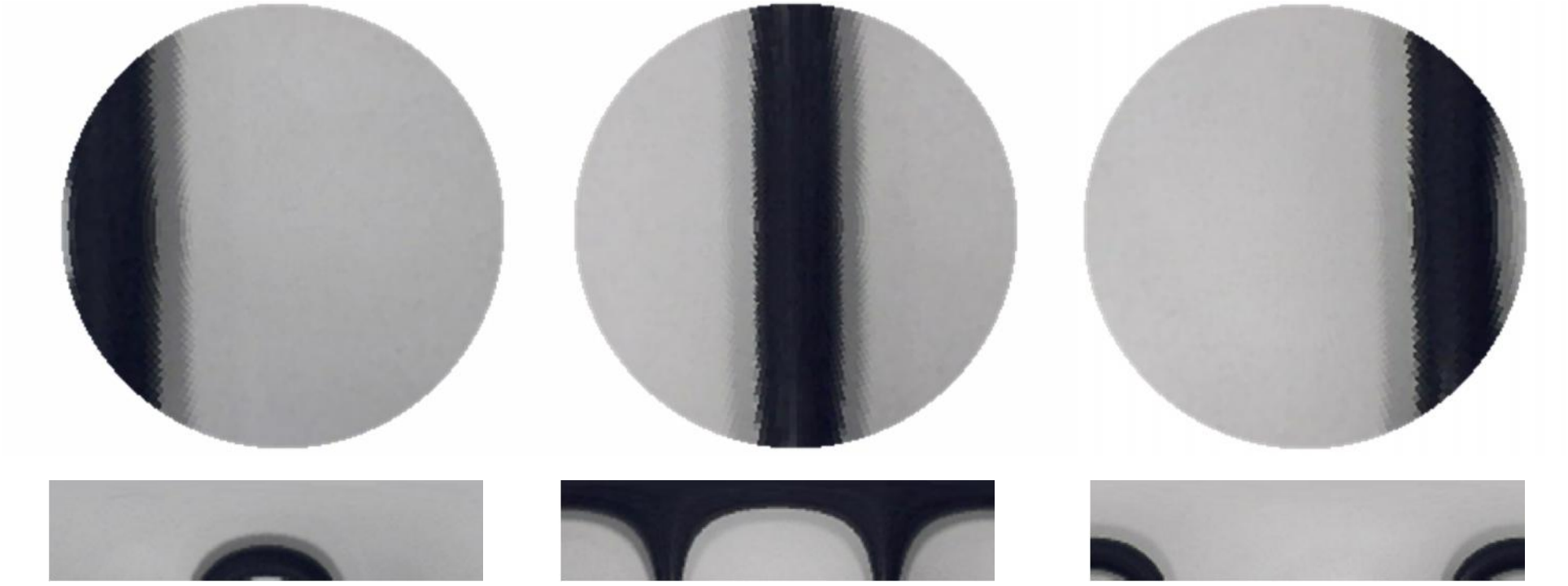
Immagine polare risultante

Immagine cartesiana ricostruita dalla polare

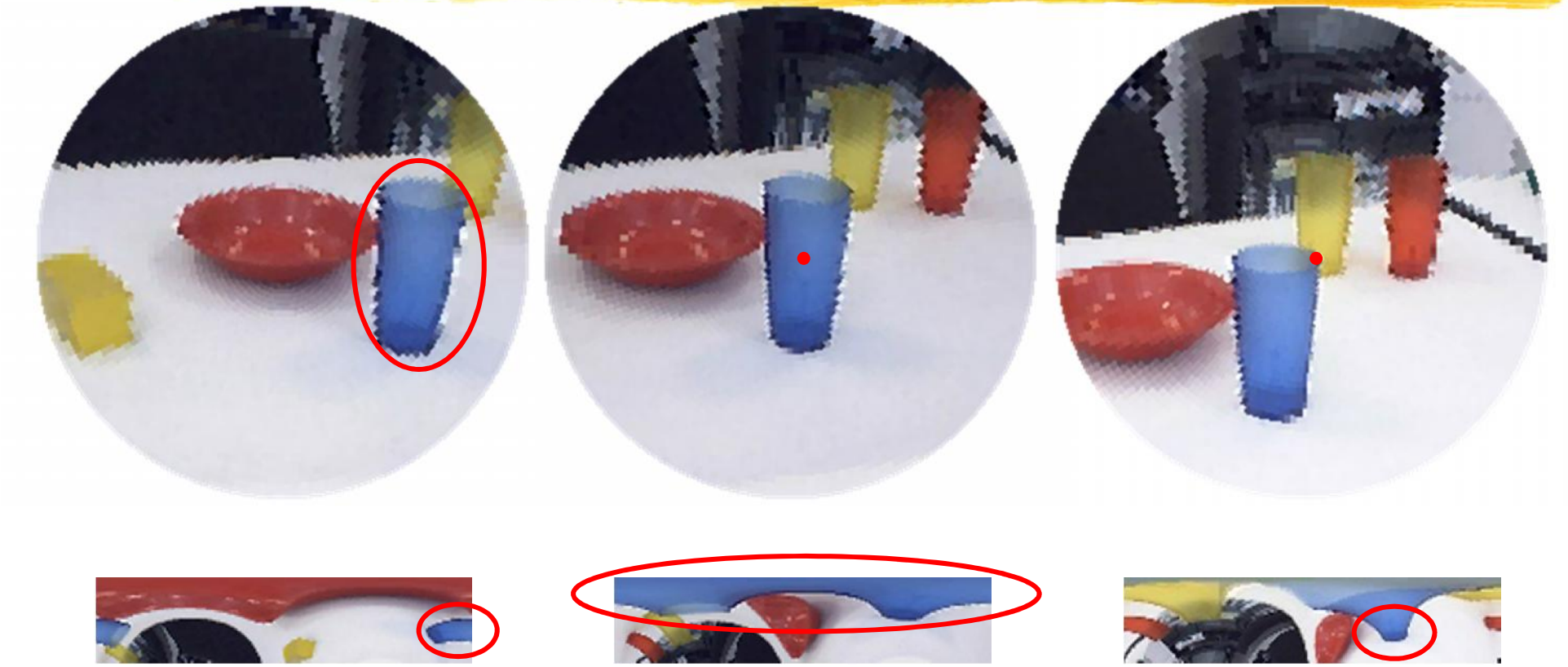
An example of pattern translation



An example of pattern translation



An example of simulated foveation



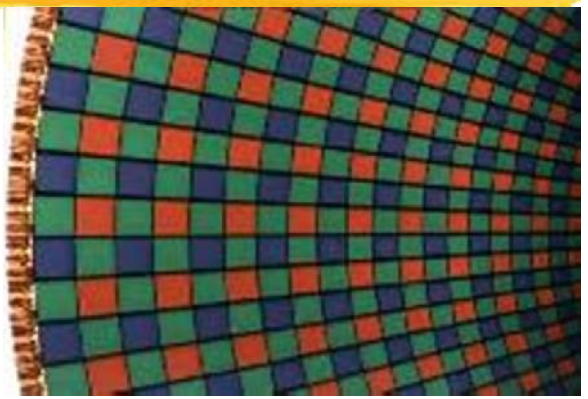
Object detection in the periphery

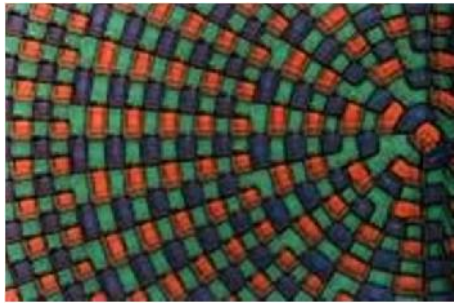
Object foveation

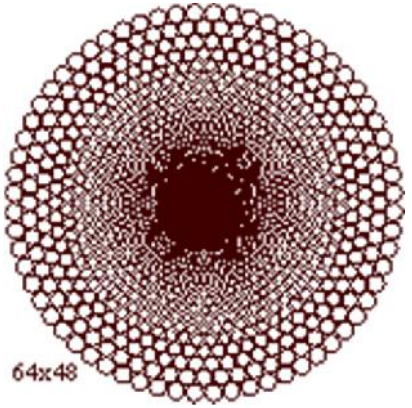
Foveation of a point of interest (edge)

The Retina-like Giotto cameras

- Technology: 0.35 micrometer CMOS
- Total Pixels: 33193
- Geometry:
  - 110 rings with 252 pixels
  - 42 rings with a number of pixels decreasing toward the center with a "sunflower" arrangement
- Tessellation: pseudo-triangular
- Pixels: direct read-out with logarithmic response
- Size of photosensitive area: 7.1mm diameter
- Constant resolution equivalent: 1090x1090
- On-chip processing: addressing, A/D, output amplifier







Le relazioni matematiche

From standard image to log-polar image

$$\circ(x,y)=\begin{cases}(F-1)+\log_{a}\left[\left(F-\tfrac{1}{2}-\sqrt{x^2+y^2}\right)(1-a)+a\right] & \text{if } \sqrt{x^2+y^2}>(F-\tfrac{1}{2})\\ \left(\sqrt{x^2+y^2}+\tfrac{1}{2}\right) & \text{if } \sqrt{x^2+y^2}<(F-\tfrac{1}{2})\end{cases}$$

$$r(\circ)=\left[(F-\tfrac{1}{2})+a\,\frac{1-a^{\circ-F}}{1-a}\right] \text{ if } \circ>F$$

$$-(x,y)=\frac{\Theta}{2\circledR}\cdot\arctan\left(\frac{y}{x}\right)+\frac{\Theta}{2}+\text{Shift Factor}$$

F=42
P=152
Q *=252*
X=545
Y=545
λ=1.02314422608633

F = size of the fovea in rings.

R = total number of rings.

Q = maximum # of pixels in each ring.

$2X$ = horizontal size of the cartesian image.

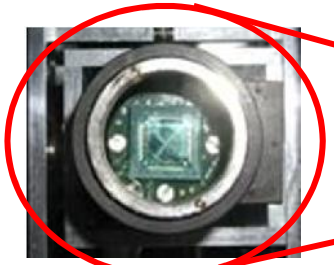
$2Y$ = vertical size of the cartesian image.

r = ring number in the log polar image.

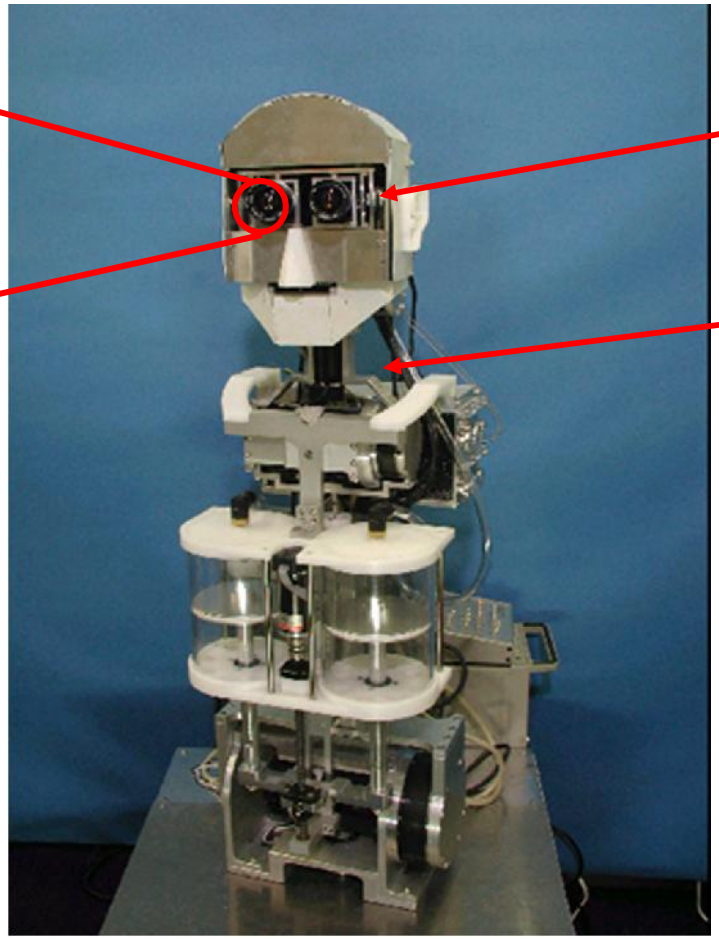
q = angular polar coordinate.

Retina-like vision for visuo-motor co-ordination of a robot head

WE-4 robotic head with Giotto cameras



Retina-like Giotto cameras by the University of Genova, Italy



3 dof for eye movements

4 dof for neck movements

WE-4 robotic head by Takanishi Lab, Waseda University, Tokyo, Japan

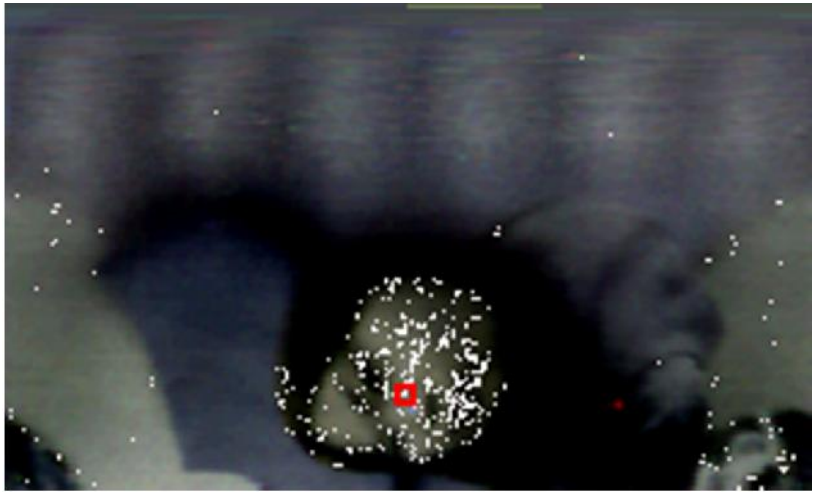
Face detection by hue

Hue = information on the color

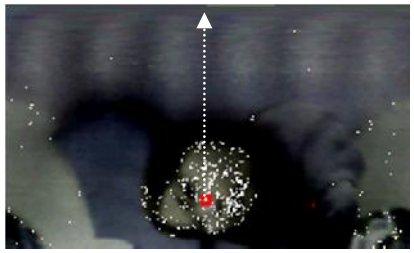
$$\text{Hue} = \cos^{-1}\left(\frac{(R-G)+(R-B)}{2\sqrt{(R-G)^2+(R-B)(G-B)}}\right)$$

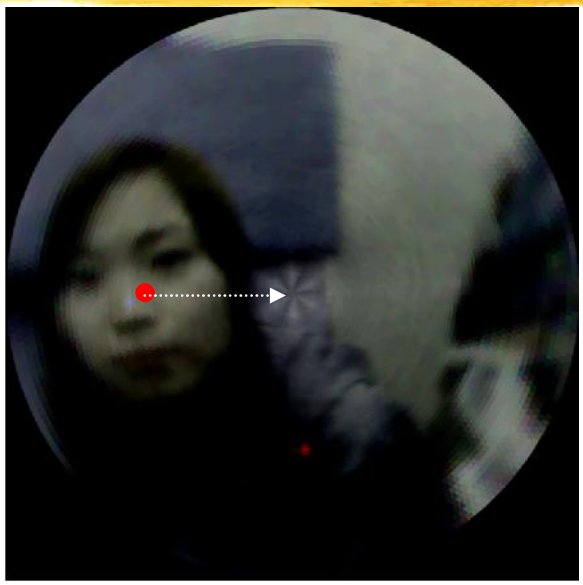
if B>G then Hue = 2π - Hue

R, G, B = RED, GREEN, BLUE components, respectively

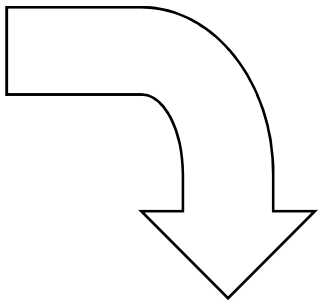


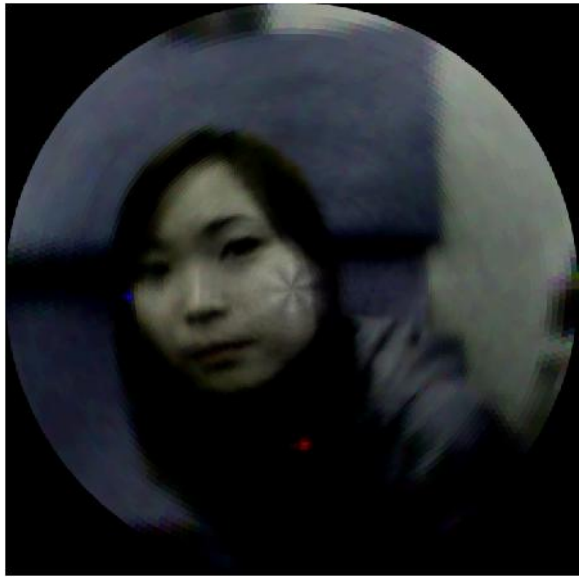
An example of foveation





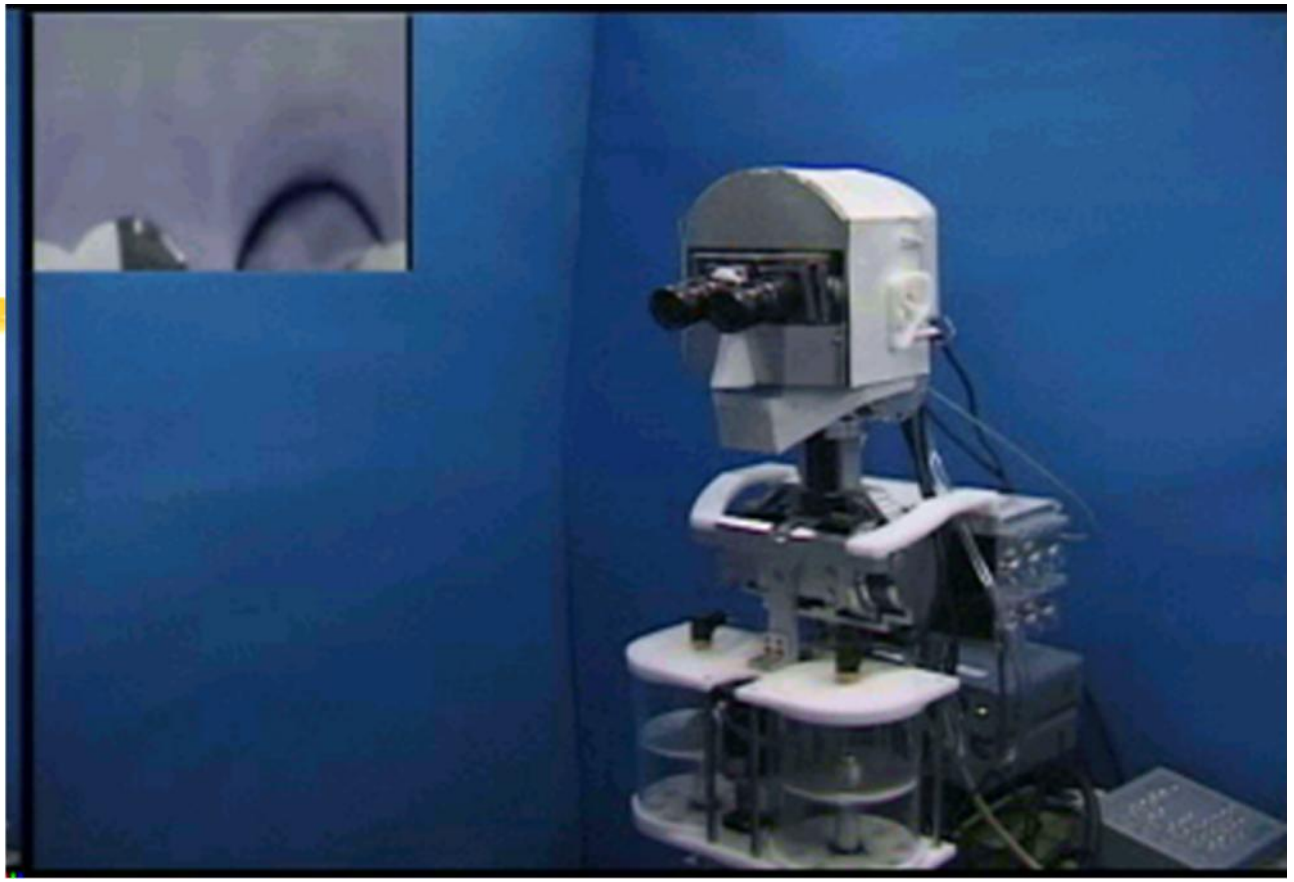
Eye/neck movements

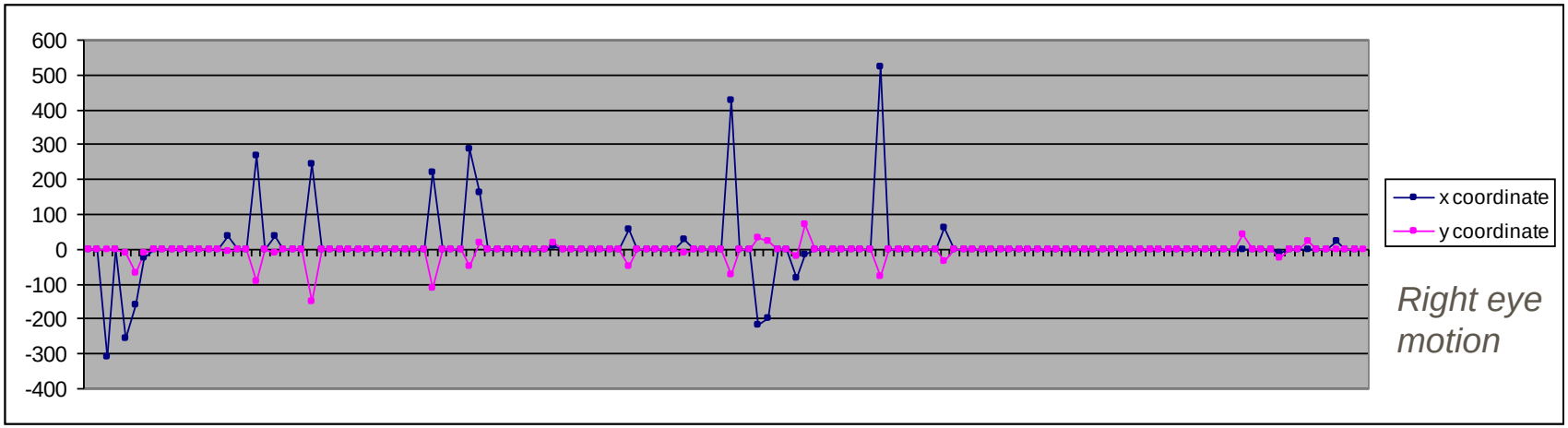




Proportions are rescaled for display purposes

Experimental trials





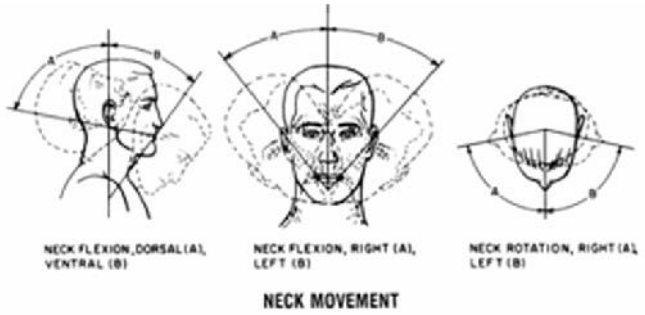
[Cecilia Laschi, Hiroyasu Miwa, Atsuo Takanishi, Eugenio Guglielmelli, Paolo Dario, 2002]

Example of design and development of a human-like robotic head

The ARTS humanoid robot head

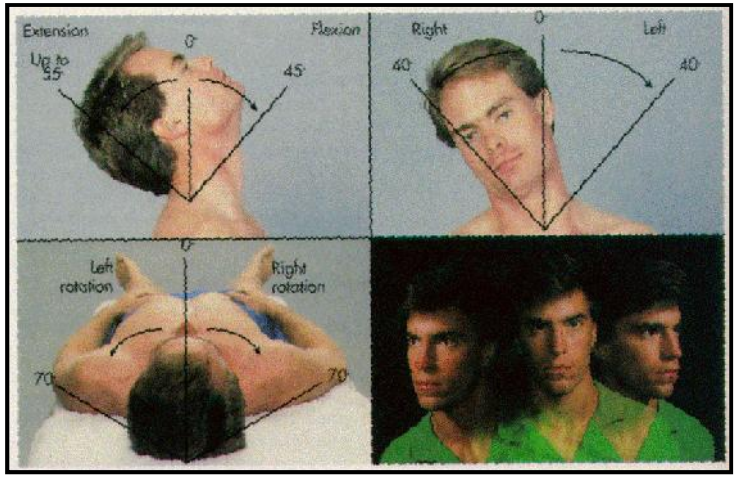
Synthesis of characteristics of the human oculo-motor system

- Eye movements:
  - Saccades
  - Vergence
  - Pursuit
- Ranges of motion:
  - 120° for the tilt eye movements
  - 60° for the pan eye movements
- Eye speed:
  - Up to 900°/sec (in saccades)
- Inter-ocular distance: between 60 and 80 mm



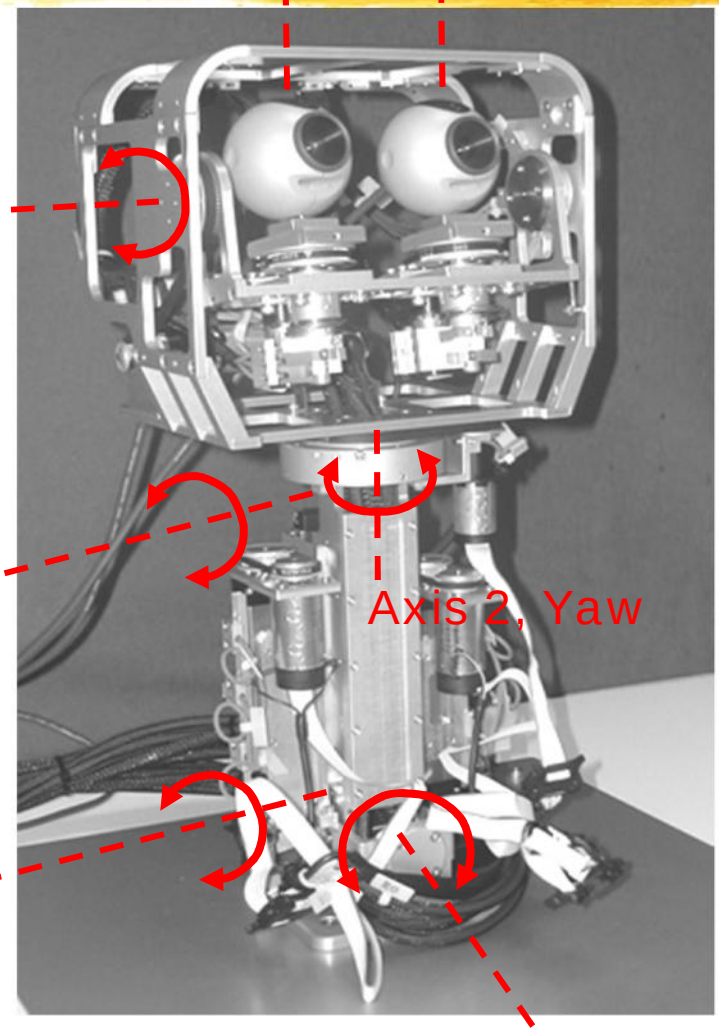
	Average	
Ventral flexion	60°	
Dorsal flexion	61°	
Right-left flexion	41°	
Right-left rotation	79°	

RANGE OF MOVEMENT AT THE NECK JOINT*
*Male civilians.



[Thibodeau & Patton, 1996]

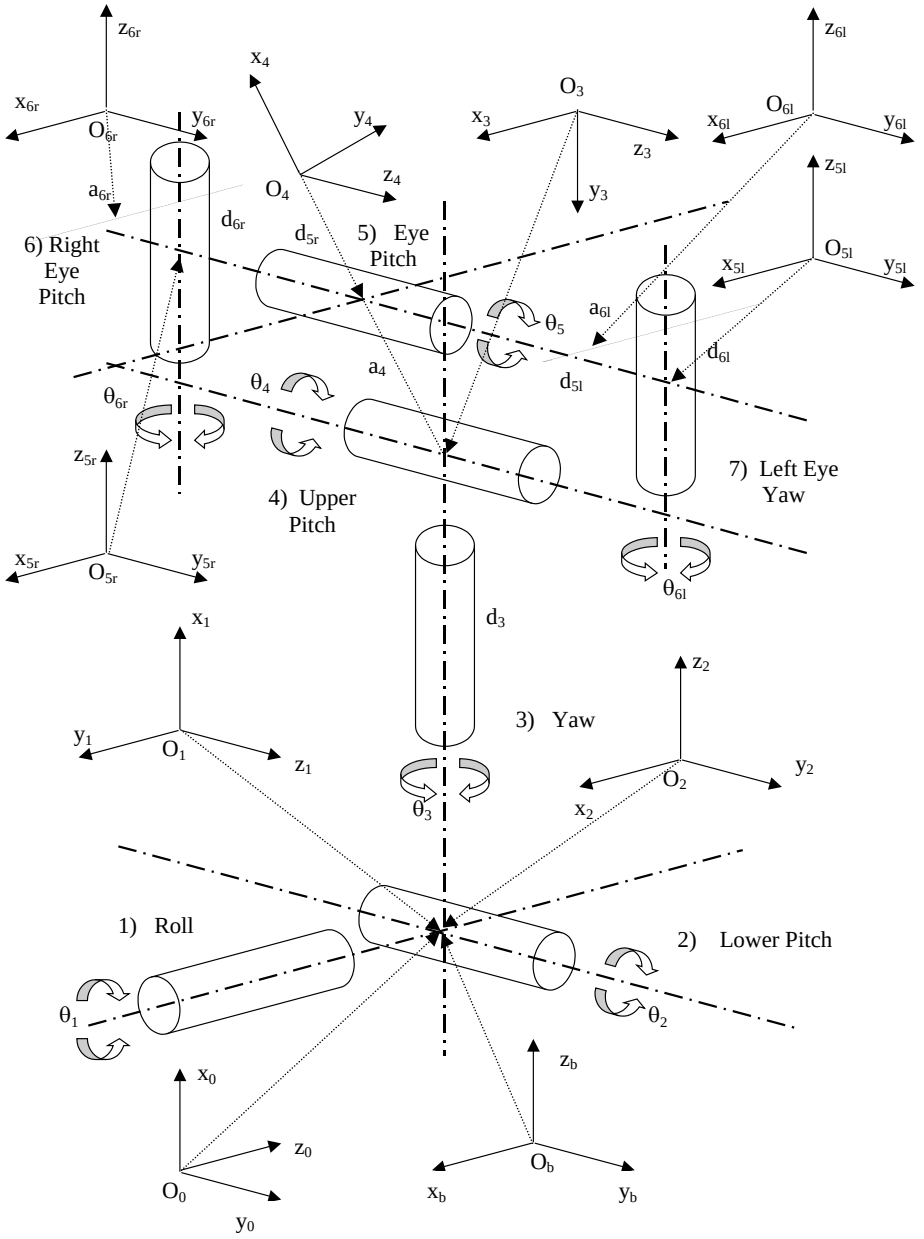
Kinematic structure of the SSSA Robot Head



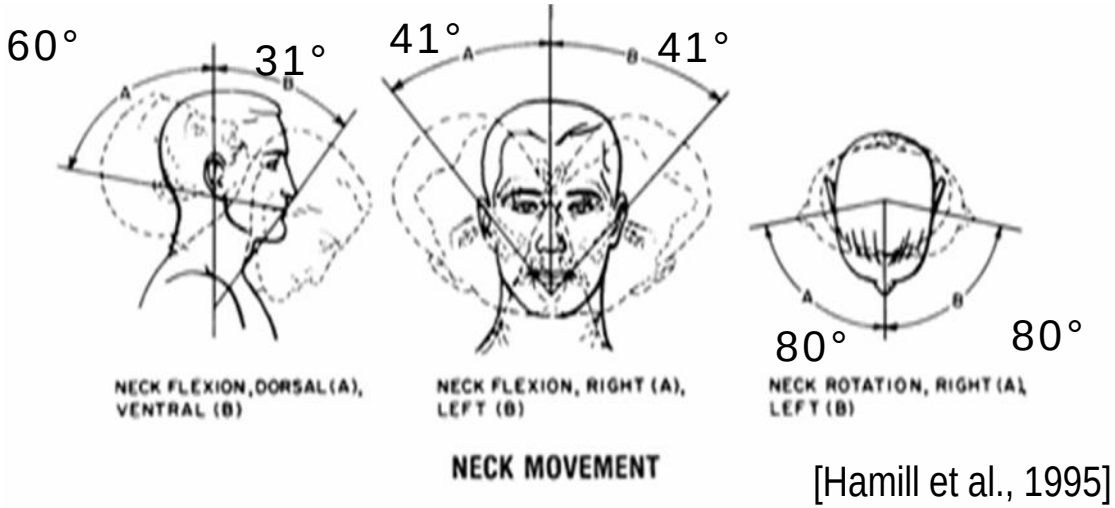
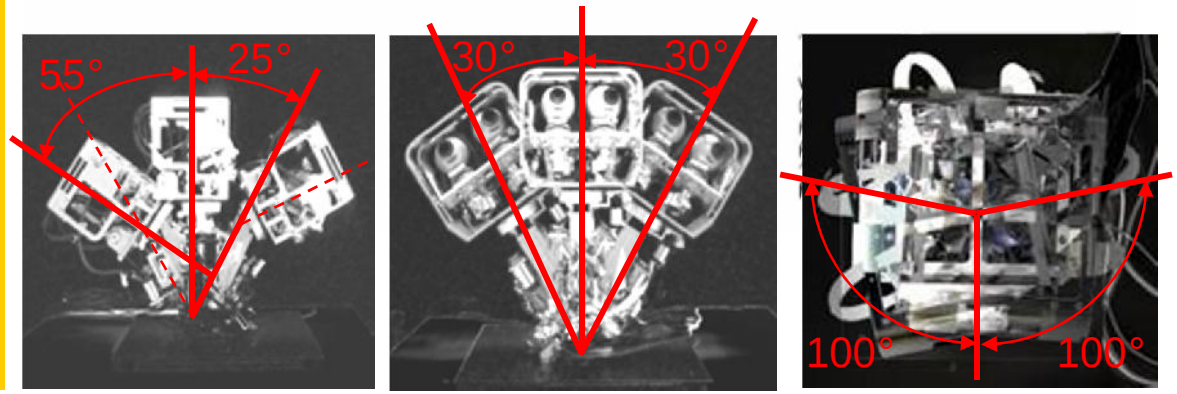
- Eye Pitch Axis: ±47°, 600°/s
- Eye R/L Yaw Axis: ±45°, 1000°/s
- Yaw: ±100°, 170°/s
- Roll: ±30°, 25°/s
- Upper Pitch: ±30°, 120°/s
- Lower Pitch: ±25°, 20°/s

Head kinematic chain and Denavit-Hartenberg parameters

Joint	a_i (mm)	d_i (mm)	α_i (rad)
J1	0	0	$-\pi/2$
J2	0	0	$\pi/2$
J3	0	195	$-\pi/2$
J4	137.5	0	0
$J5_r$	0	$-30 \div -50$	$\pi/2$
$J5_l$	0	$30 \div 50$	$\pi/2$
$J6_l$	a_{6l}	d_{6l}	0
J6r	a_{6r}	d_{6r}	0



Comparison of performances between human and robotic head

	Neck:	Eye:
Human	 [Hamill et al., 1995]	Pitch: ± 60°, 600°/s Yaw: ± 30°, 600°/s
Robot		Pitch: ± 47°, 600°/s Yaw: ± 45°, 1000°/s

The movements of the 7 dofs of the robotic head

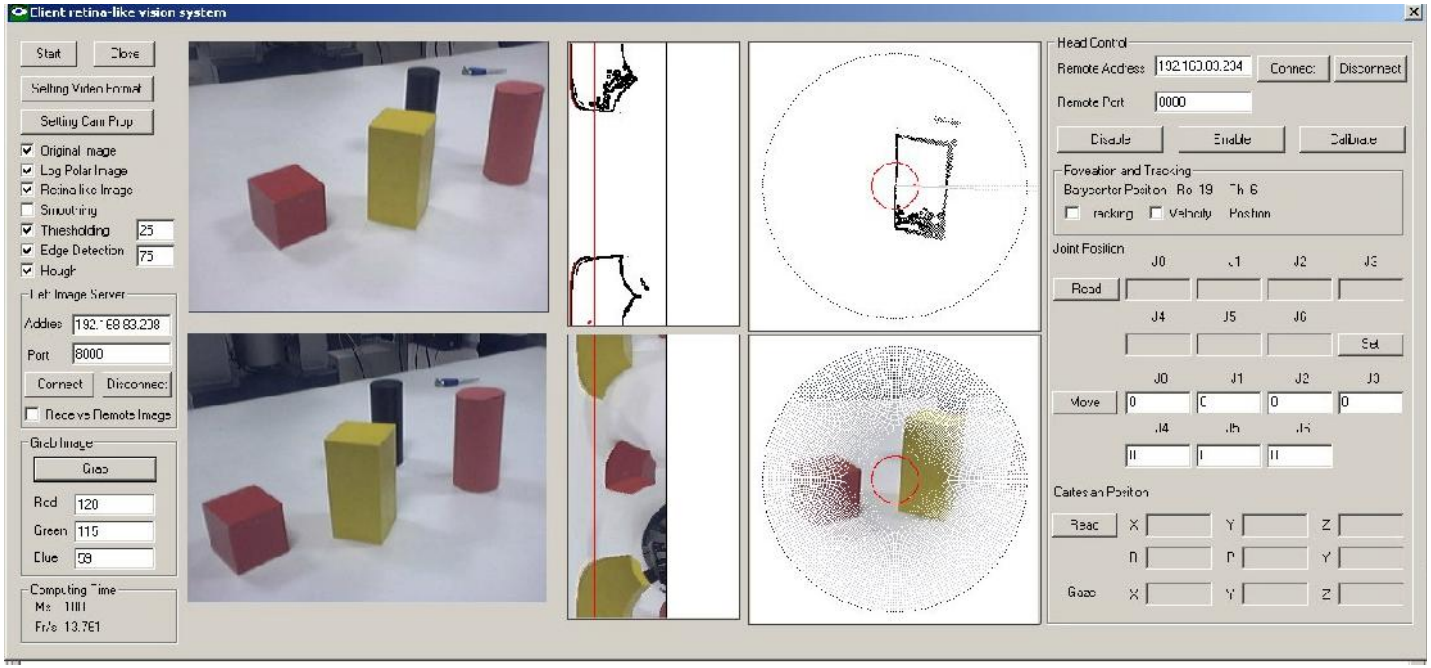
head_performances.avi

Examples of algorithms developed for retina-like image processing

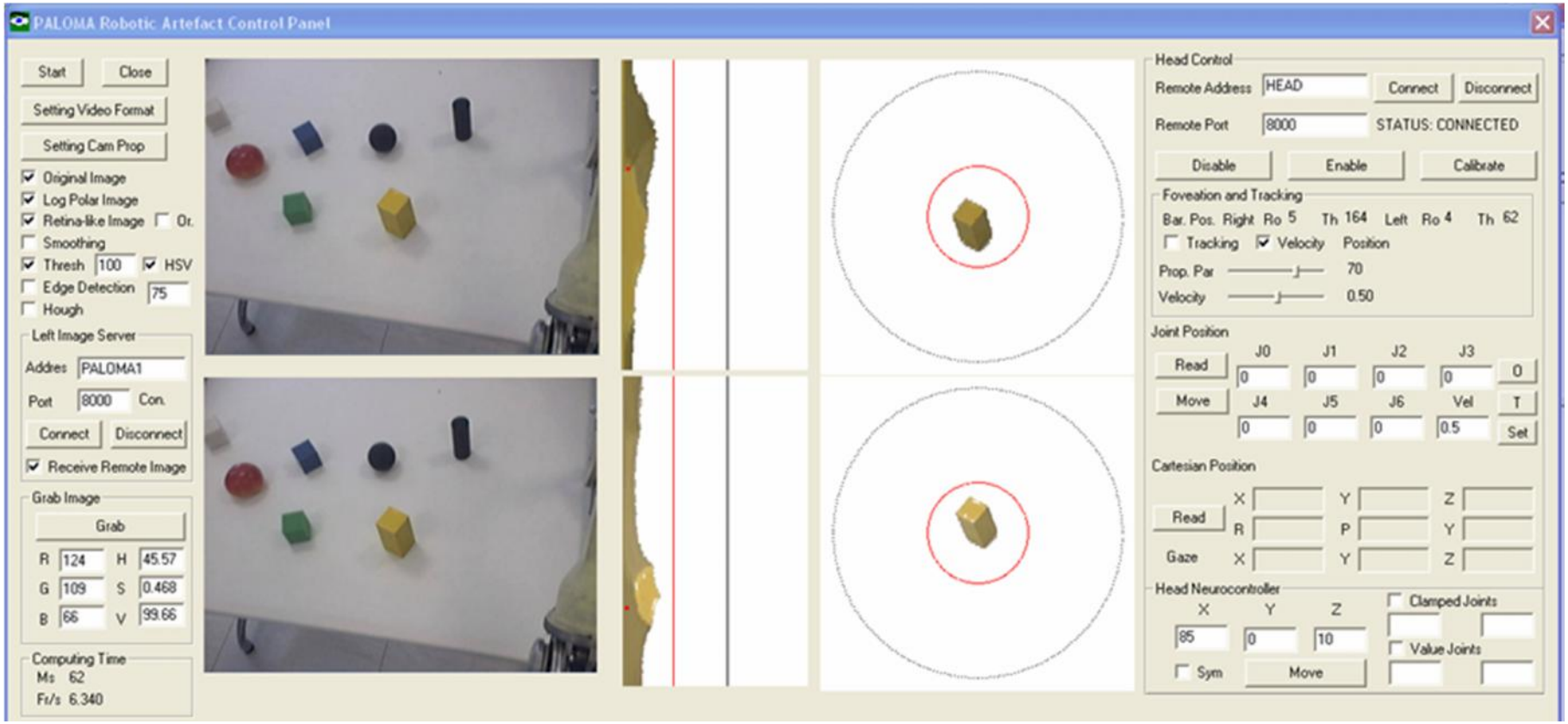
- Acquiring standard image
- Creating log-polar image from standard image
- Creating retina-like image from log-polar image
- Thresholding of image based on RGB and HUE
- Computation of the centroid of a thresholded area
- Edge detection
- Line detection

Simulation of retina-like cameras and basic image processing

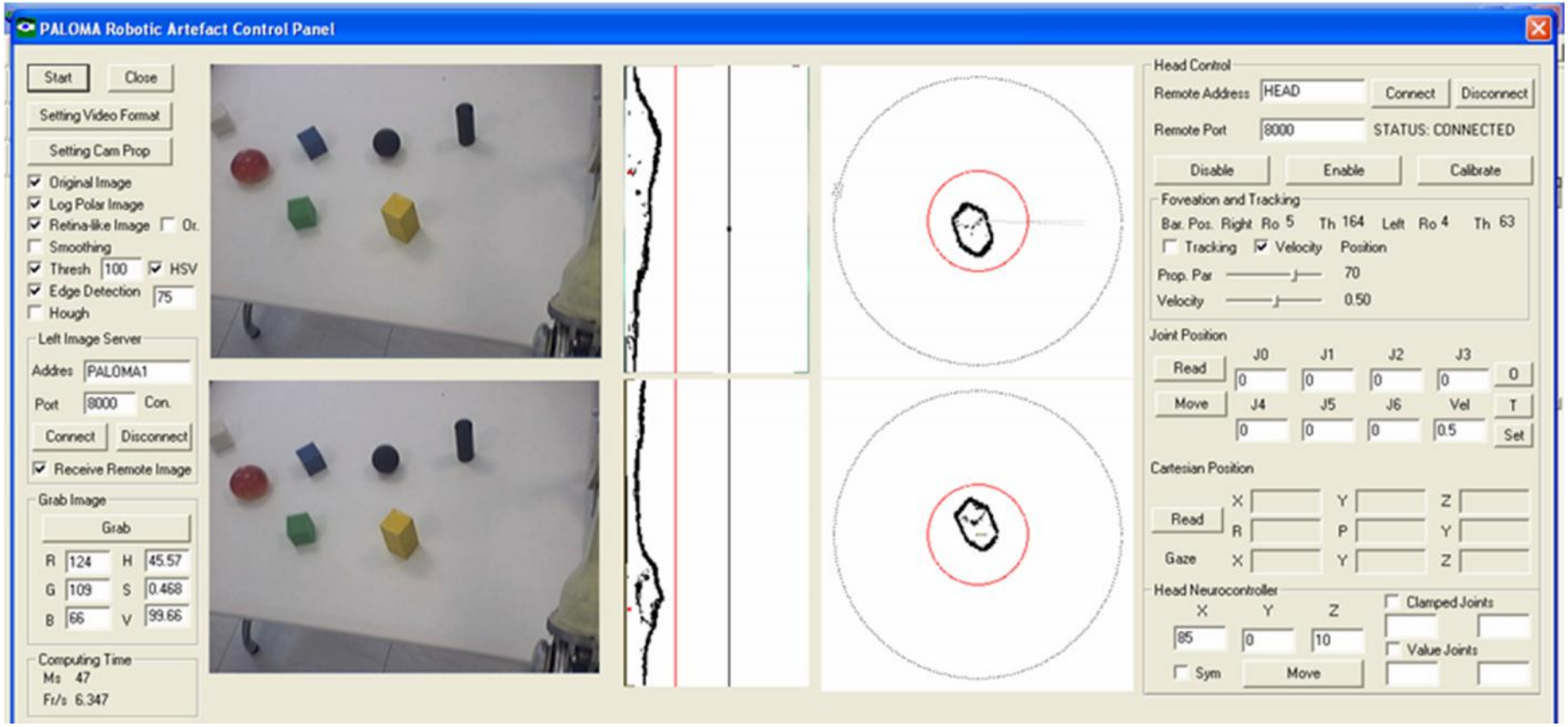
- Acquiring standard image
- Creating log-polar image from standard image
- Creating retina-like image from log-polar image



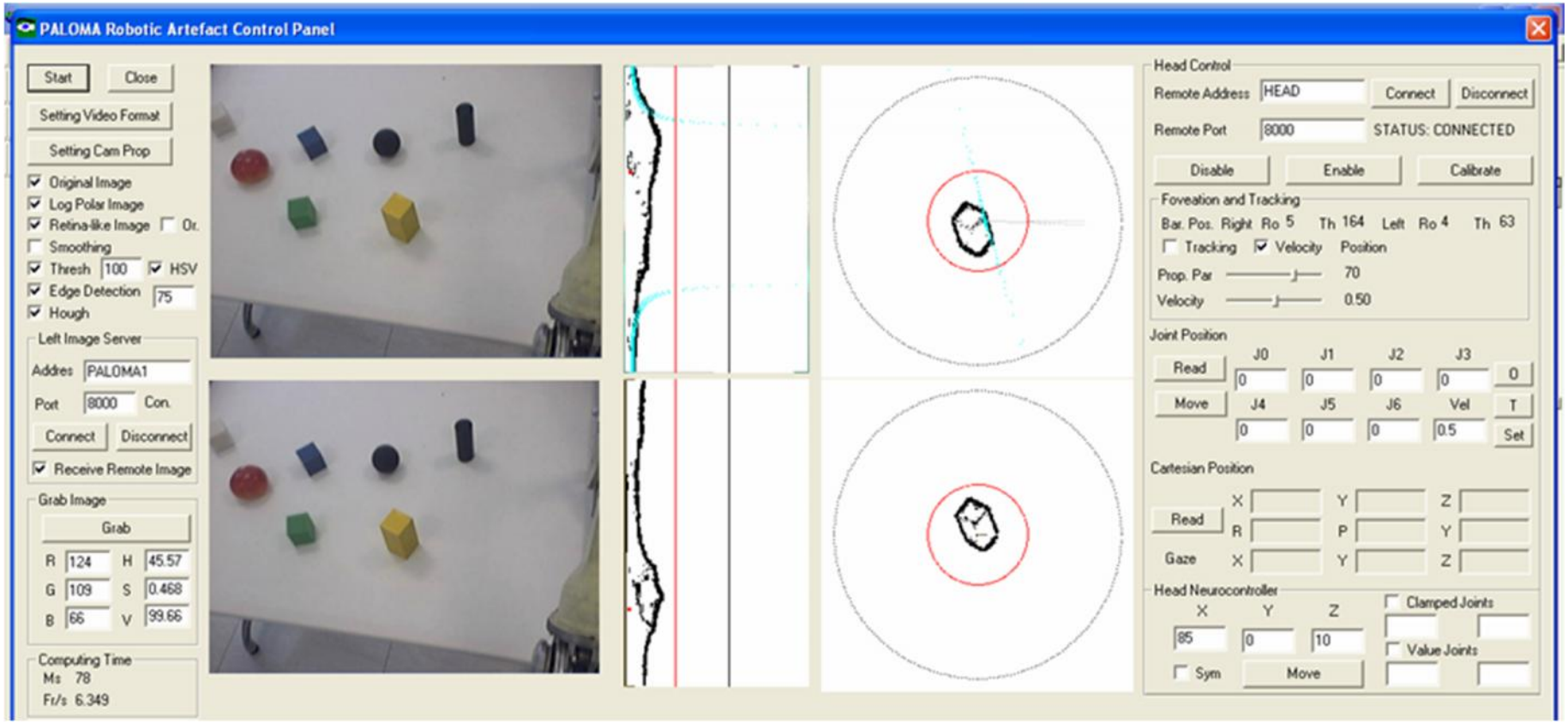
Thresholding of image based on RGB and HUE



Edge Detection (gradient based method)

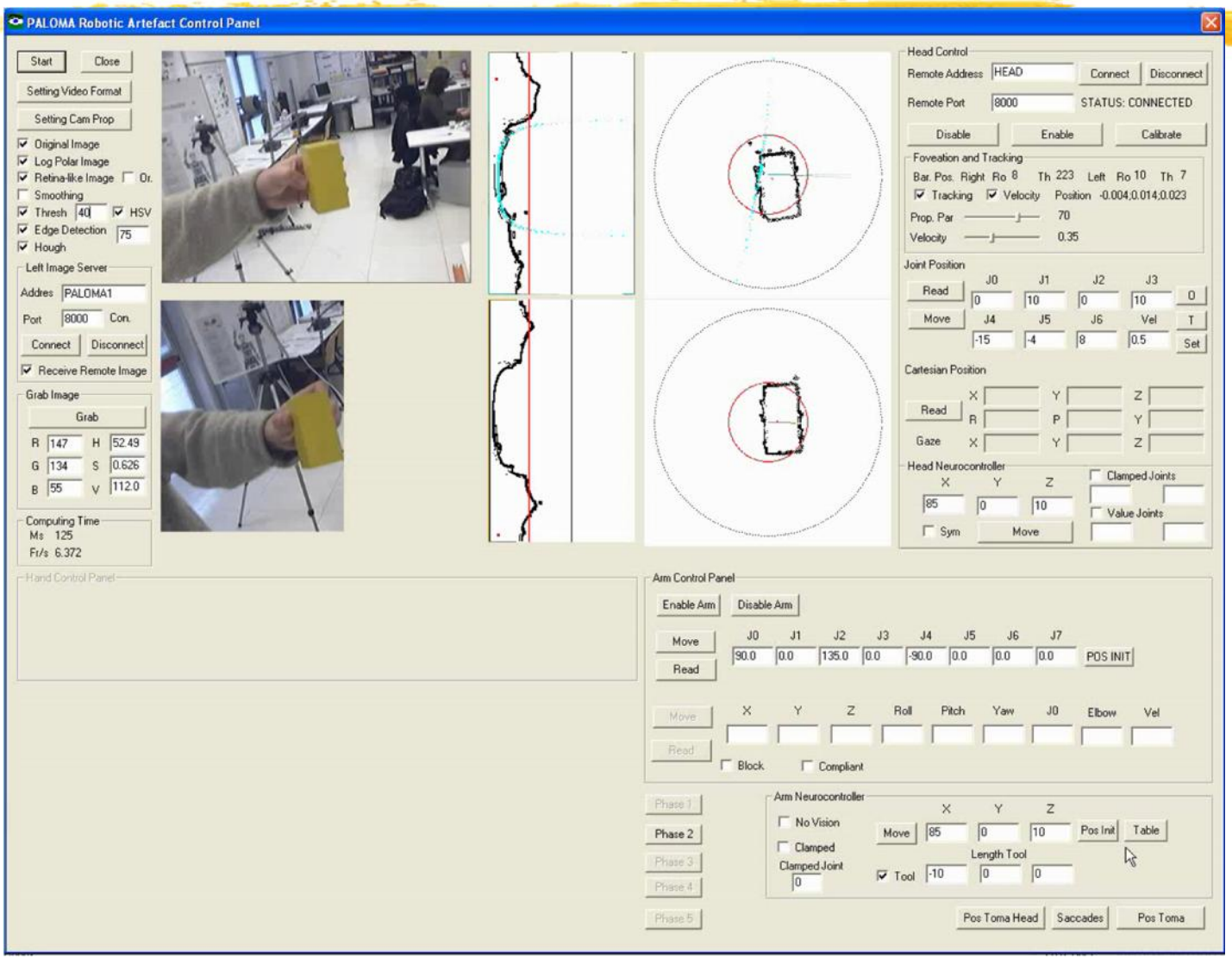


Line detection (Hough method)

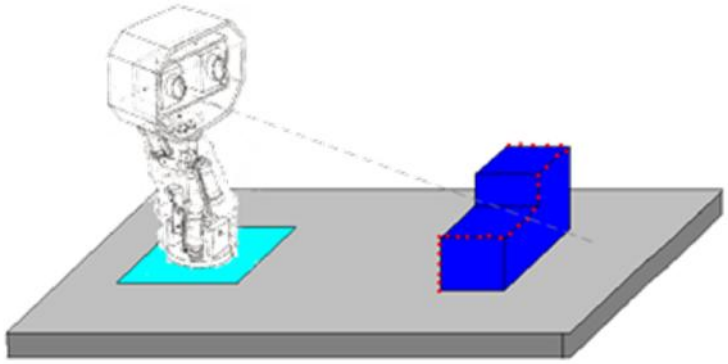


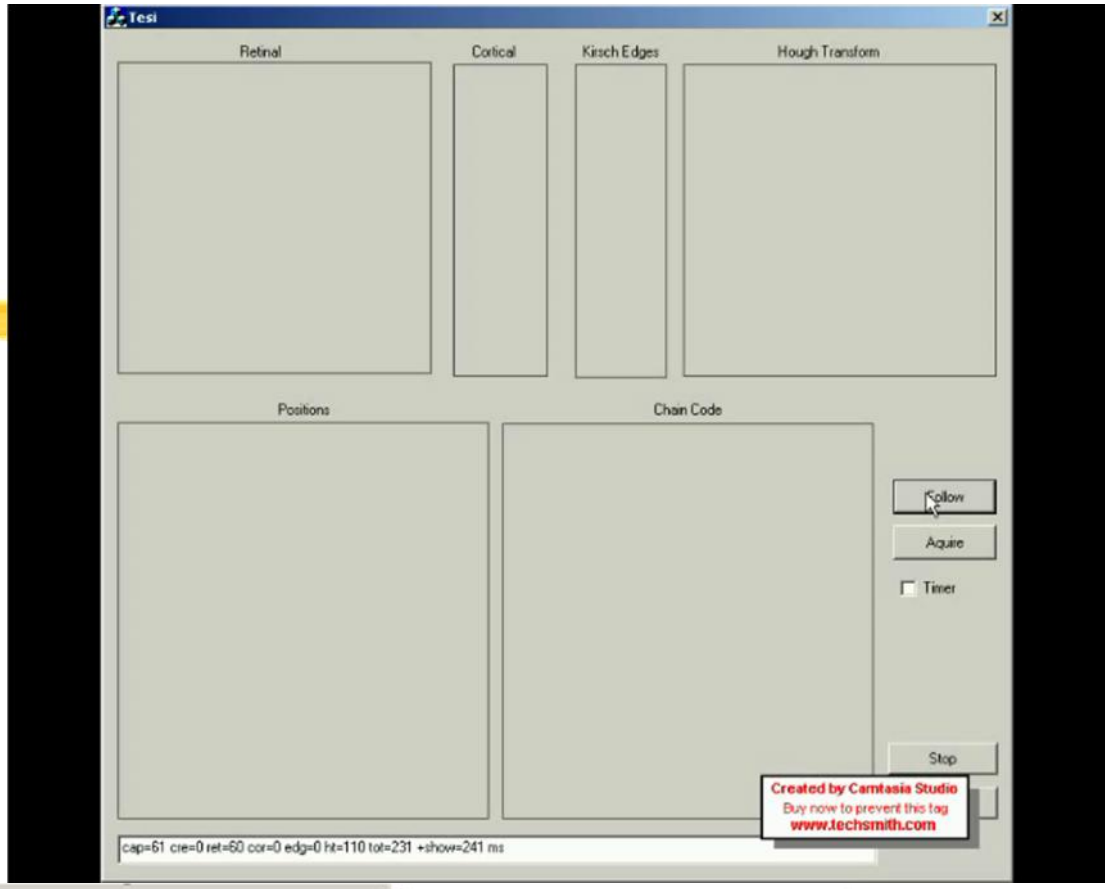
- Applied only to pixels belonging to the fovea

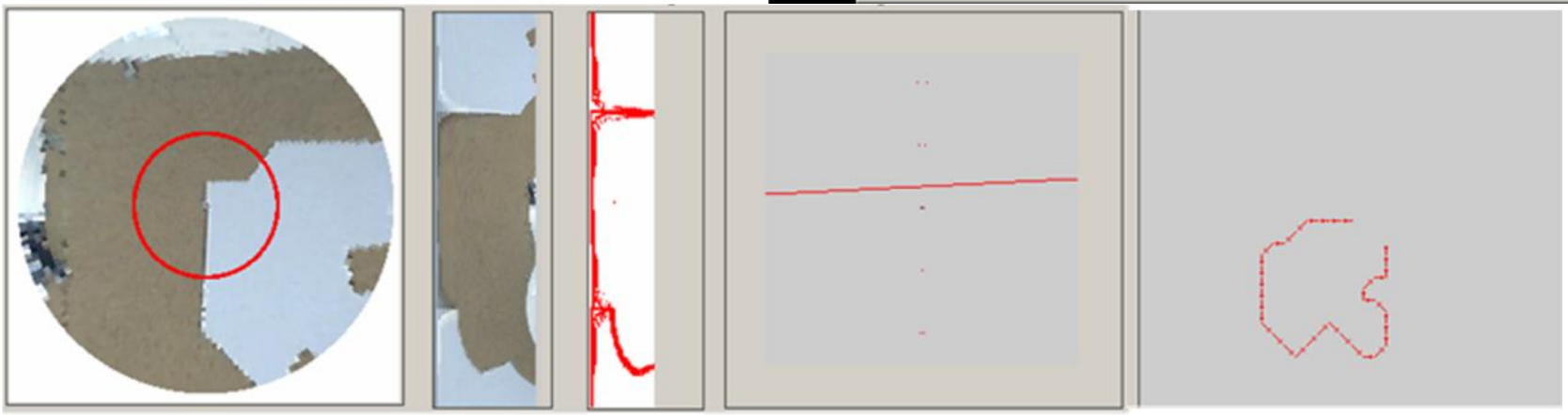
Line detection



Foveation and tracking of borders of object and reconstruction of the geometry of the object







Retina Like image

Log Polar Image

Edge of log polar image

Detected lines (Boundaries)

Boundary reconstruction based on eye positions