INSTITUTO DE SISTEMAS E ROBÓTICA
UNIVERSIDADE DE COIMBRA

Dynamic Background Segmentation

Calibration

Horopter

Face Detection

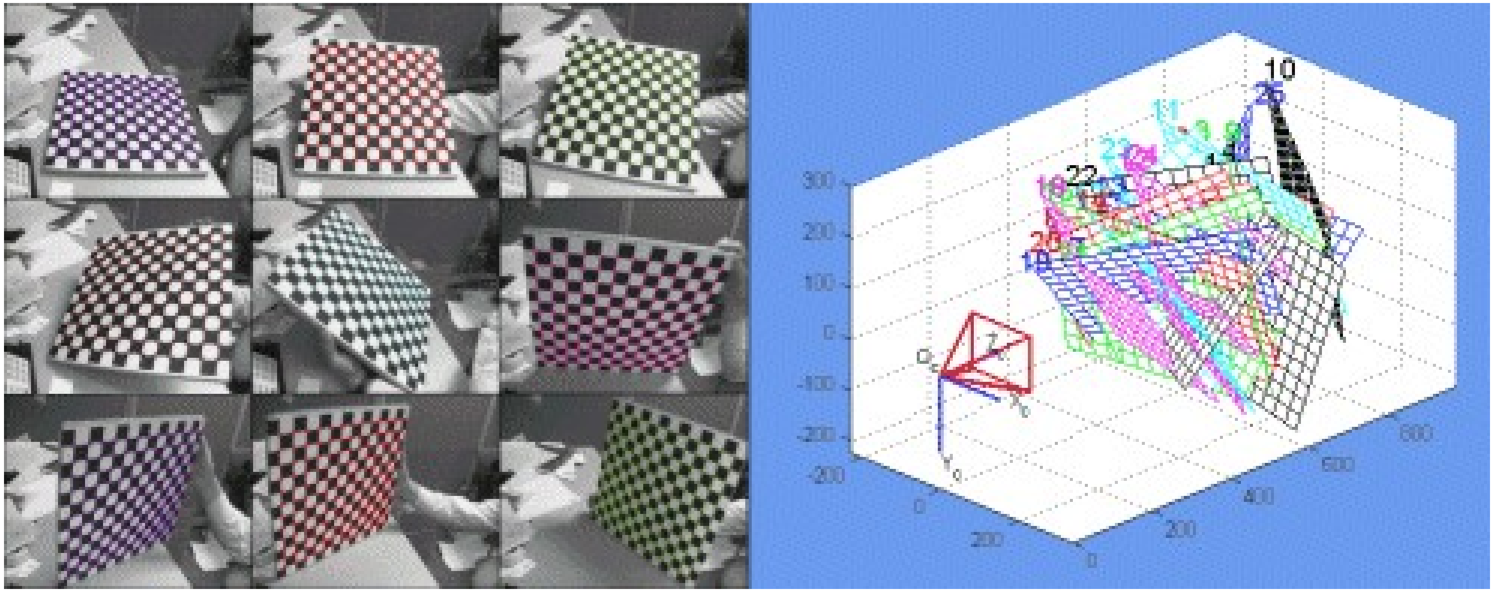
Tracking

Mobile Robotics Laboratory
FCT-UC
ISR – Coimbra

Abstract

In the context of *human machine interaction*, the target is to have a robot capable to detect faces of people that are inside the zone-of-interaction of the robot, and further, to track these faces. As the zone-of-interaction will be sensed by vision and limited by the horopter curve, it becames necessary to first find a good way to have depthmap, consequentlly, to find the horopter. It is also known that for calculating properlly depth map calibration is needed first. After having the zone-of-interaction segmentation on the image, a haar-like features face detection is used and a basic control for tracking was implemented on our robotic head.

Calibration

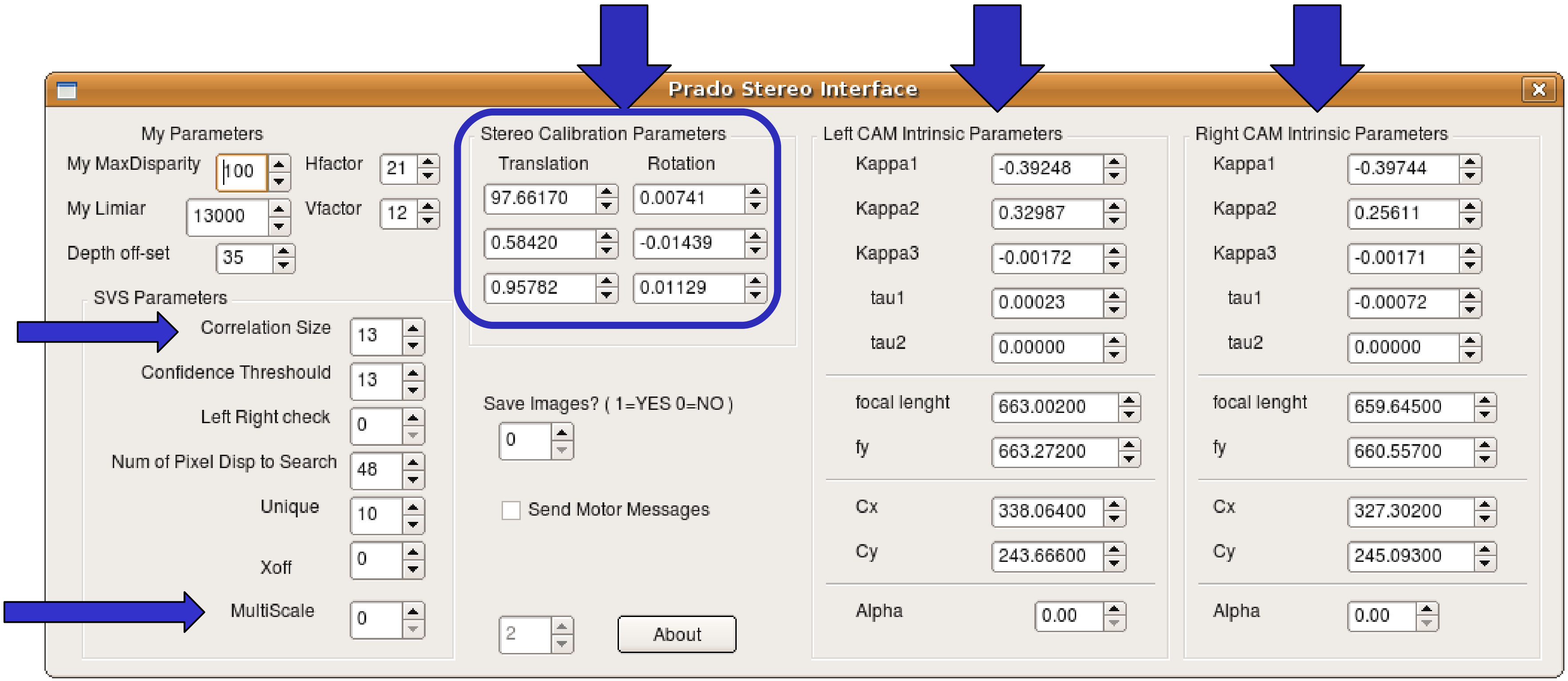


We used a matlab toolkit to calculate the intrinsic and extrinsic parameters of the cameras. Rotation and Translation matrixes between the cameras are also obtained.

Calibration and Parameters

Homografic Matrix

Intrinsic Parameters



- Correlation window
- SIFT
- DoG

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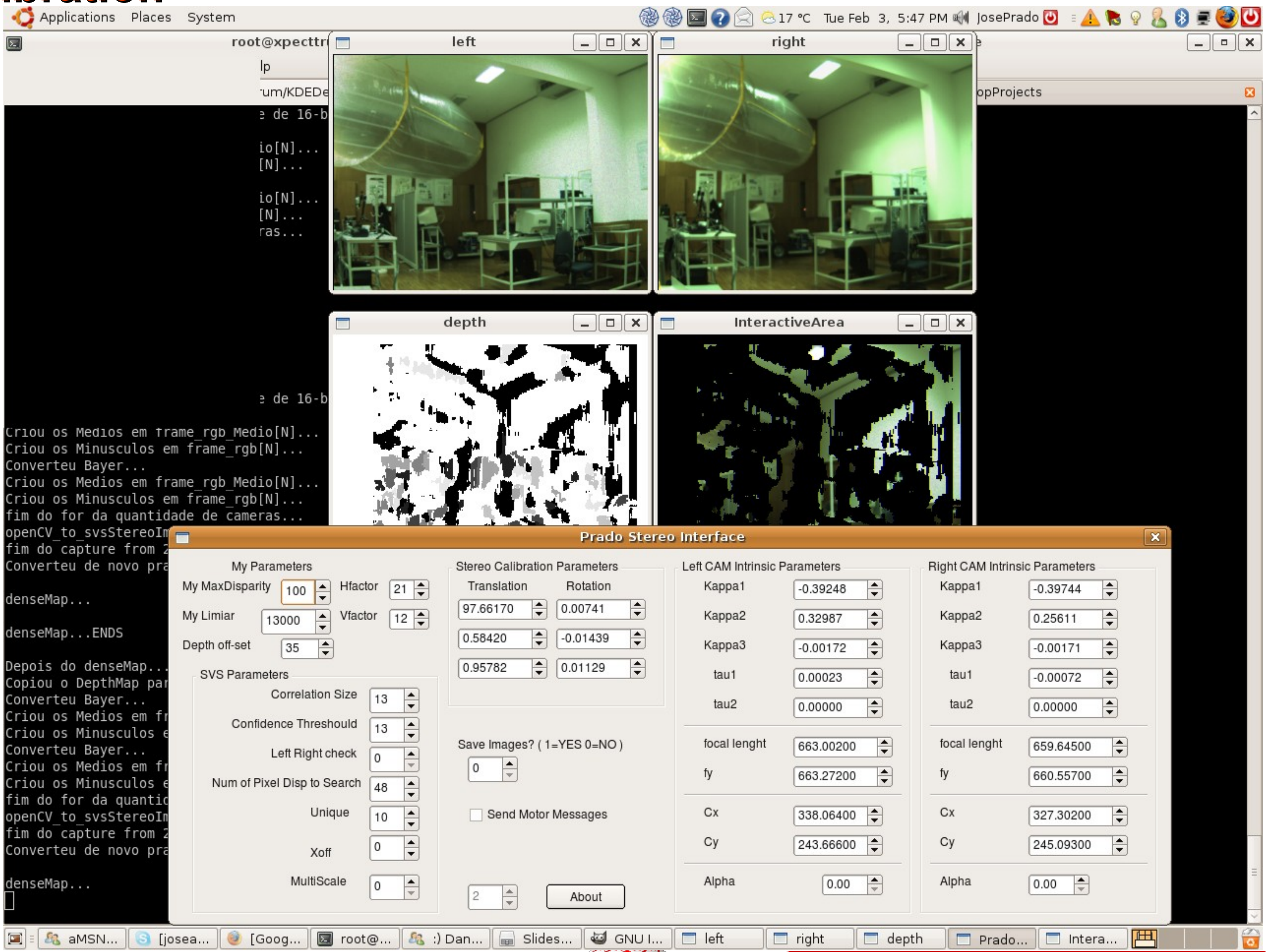
Calibration



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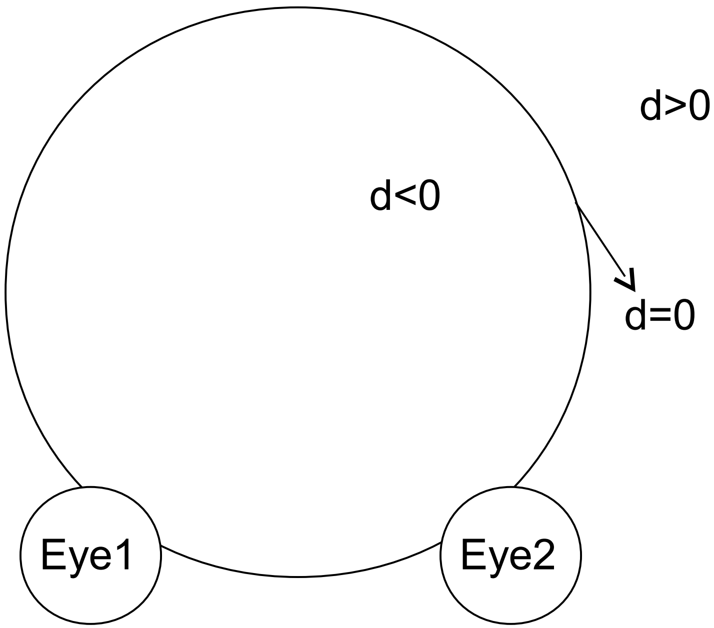
Horopter

Horopter is the zone where the disparity is zero.
So, after calculating the disparity, we can know if the region is inside or out-side the horopter just by looking to the sign of it.



The theoretical horopter is the Vieth-Muller Circle.
It is a circle that pass at the 2 pupil center and also at the focal point.

Horopter

In 3D, the horopter is generally consider to be a cylinder.
Vieth-Muller circle projection in different planes.

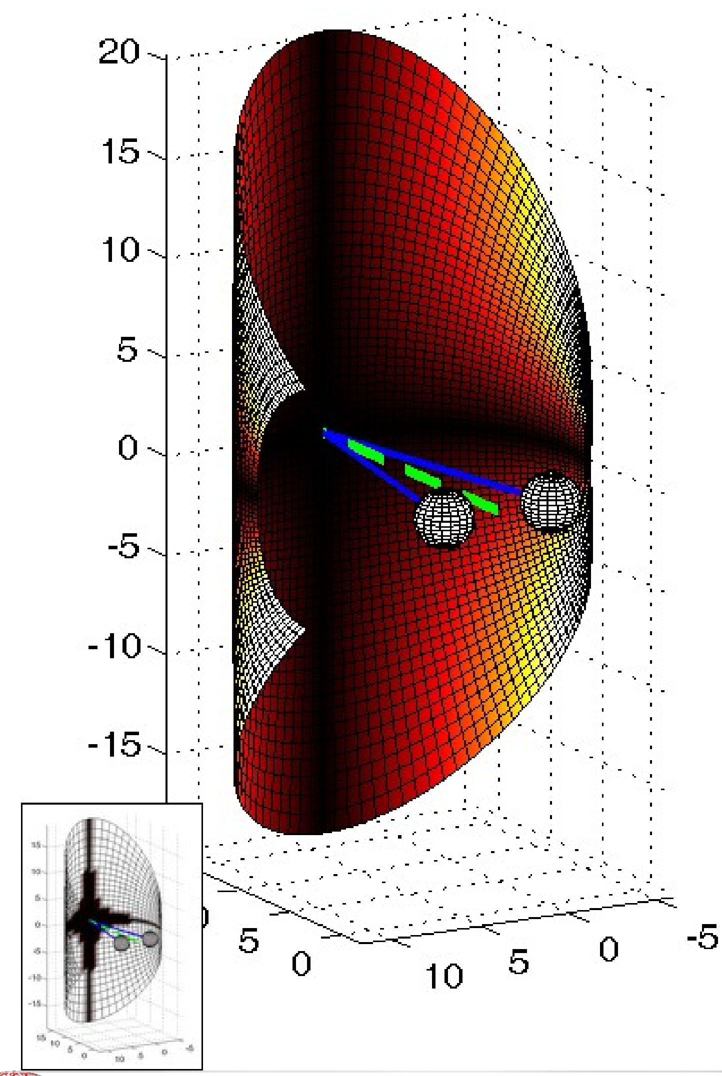


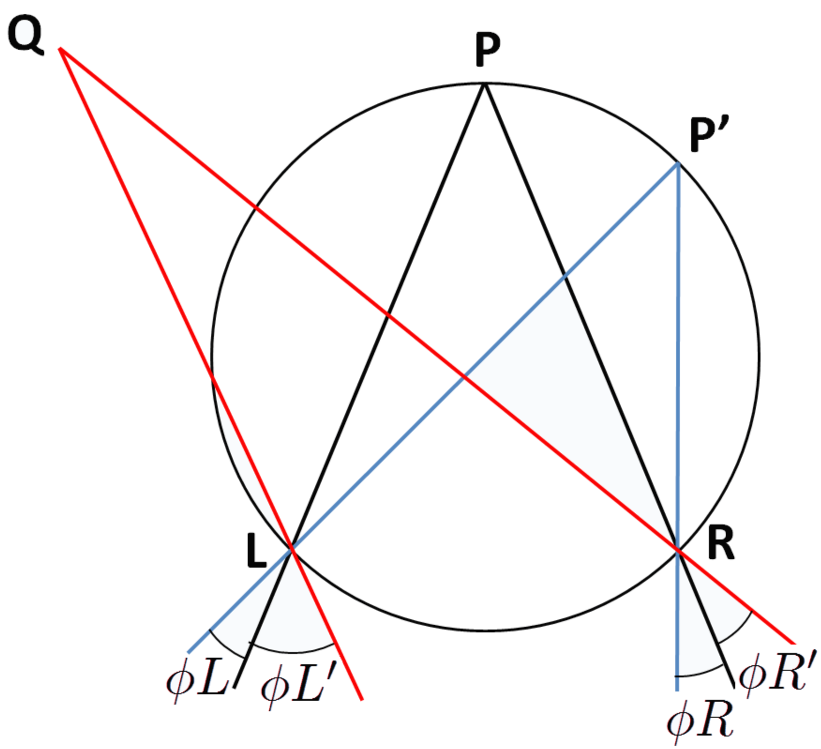
Figure by: "Kai M. Schreiber, Douglas B. Tweed, Clifton M. Schor – The extended horopter: Quantifying retinal correspondence across changes of 3D eye position – Journal of Vision 2006"

Stereo Disparity

Properties of Vieth-Muller Circle

We can define the following properties for given Vieth-Muller Circle

1 - If the eye movement is a pure version eye movement, the fixation point stays on the same Vieth-Muller Circle. As in Figure bellow: the fixation point P moves to P‘ .



2 - Now keeping the fixation point, we study disparity for various points. Disparity is defined as ΦL - ΦR .

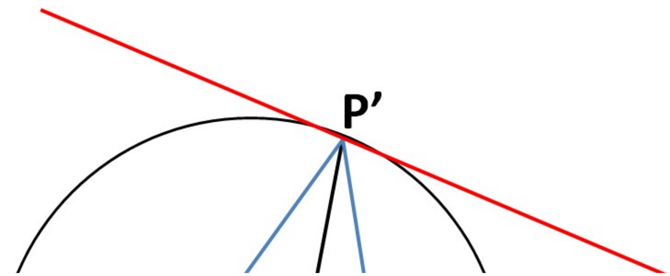
Stereo Disparity – Horizontal Disparity

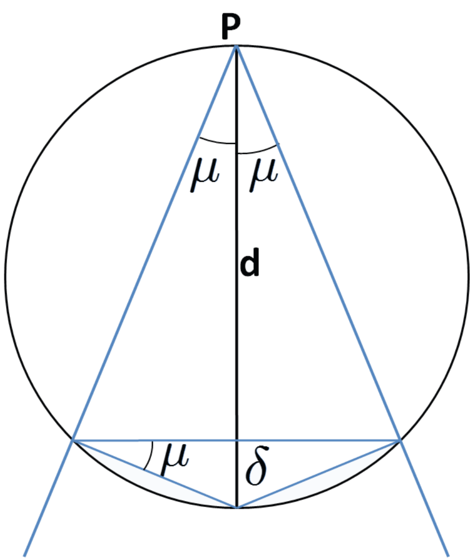
In this figure, ΦR and ΦL are made by line of sight with the straight ahead direction.

Gaze angle:

Vergence angle:

Horizontal disparity

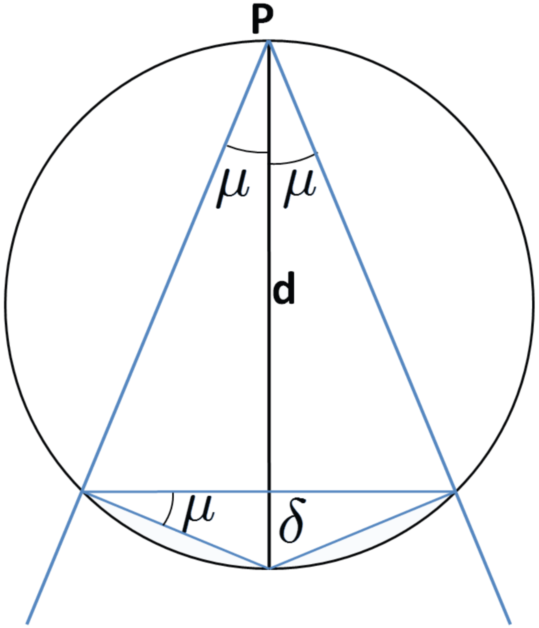




Stereo Disparity – Vertical Disparity

Where (x,y) are cyclopean image coordinates, $x = X/Z$, $y = Y/Z$, $Z = d + \boldsymbol{\delta}$,
I is the interocular distance. So the coordinate system changes with the cyclopean eye.

Theorem 1: $d = I \cos\gamma / \sin 2\mu$

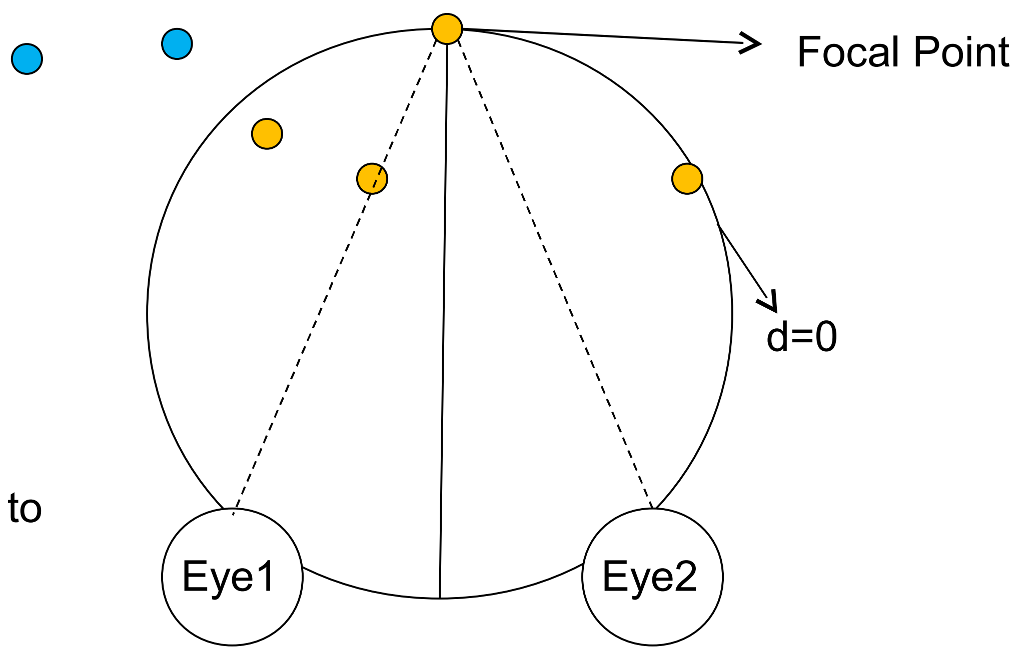


A simple justification for $\gamma = 0$

$$I/2 = d \times \sin\mu \times \cos\mu \rightarrow d = I \cos\gamma / \sin 2\mu$$

Zone of Interaction

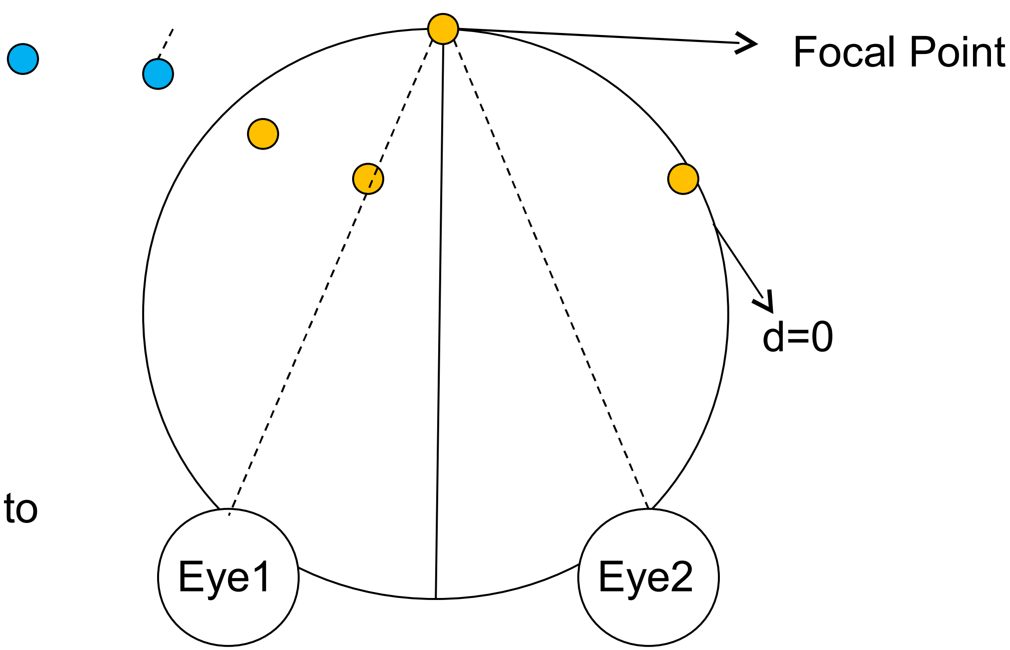
We define as our interactive zone, the zone inside horopter (disparity <= 0).
•i.e. everything out-side interactive zone will be erased from the image, and will be invisible, having thought none interaction effect with the robot.



Only the orange objects are visible to the robot

Zone of Interaction

Once one object moves and enter in Interactive Zone, it will turn-out visible



Only the orange objects are visible to the robot

Zone of Interaction

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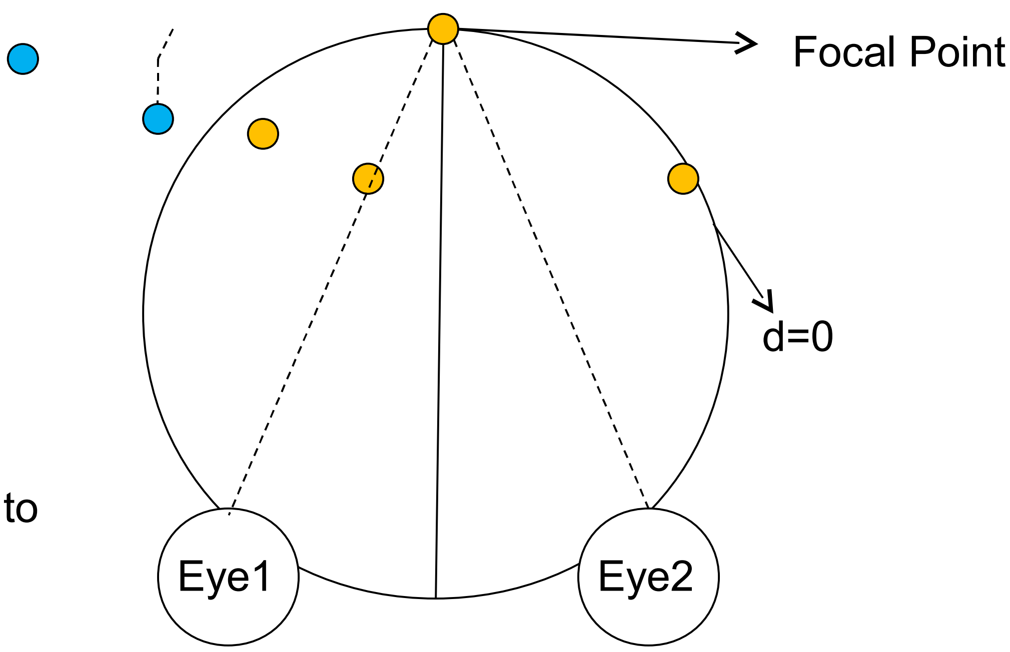

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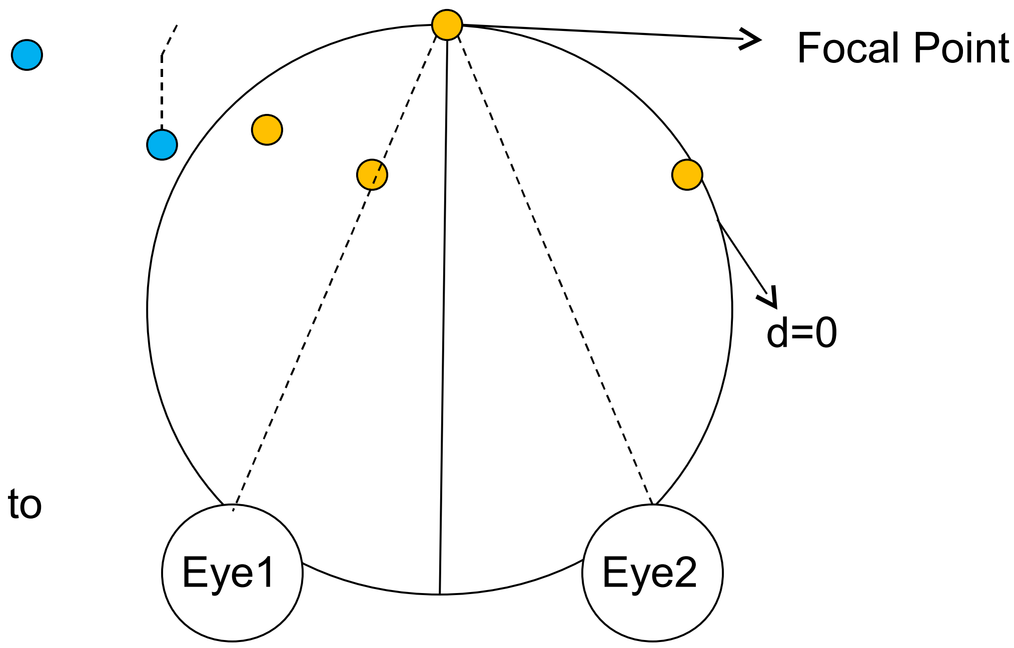

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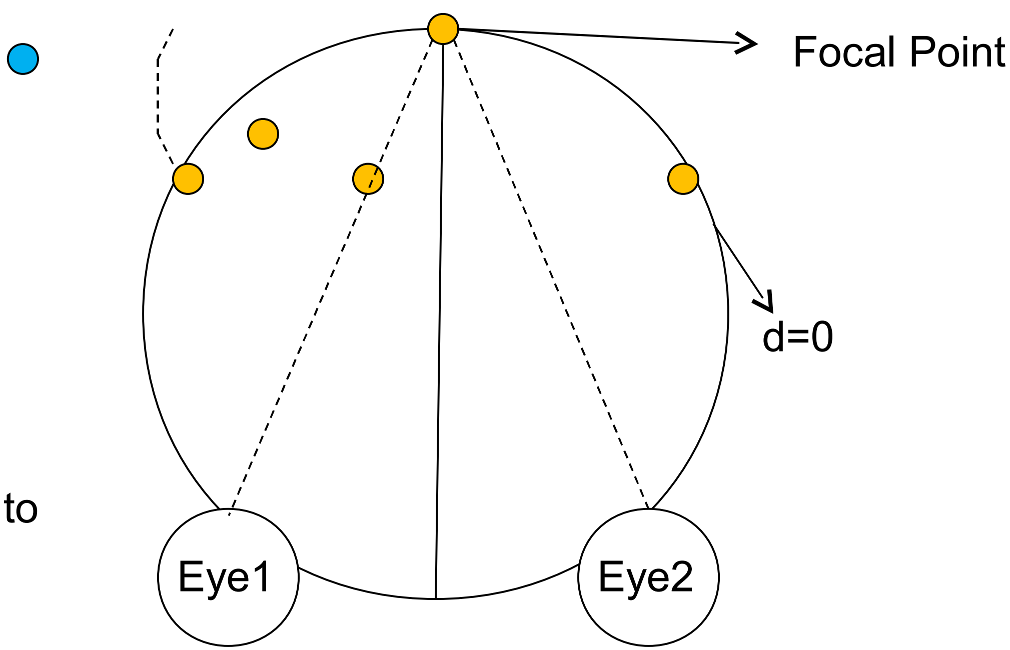

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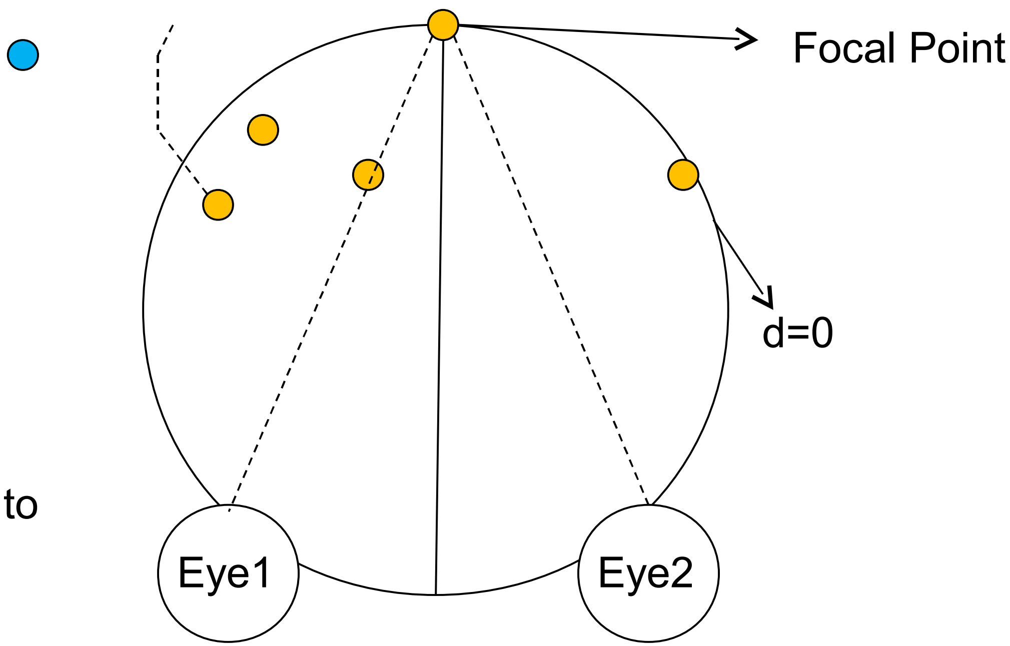
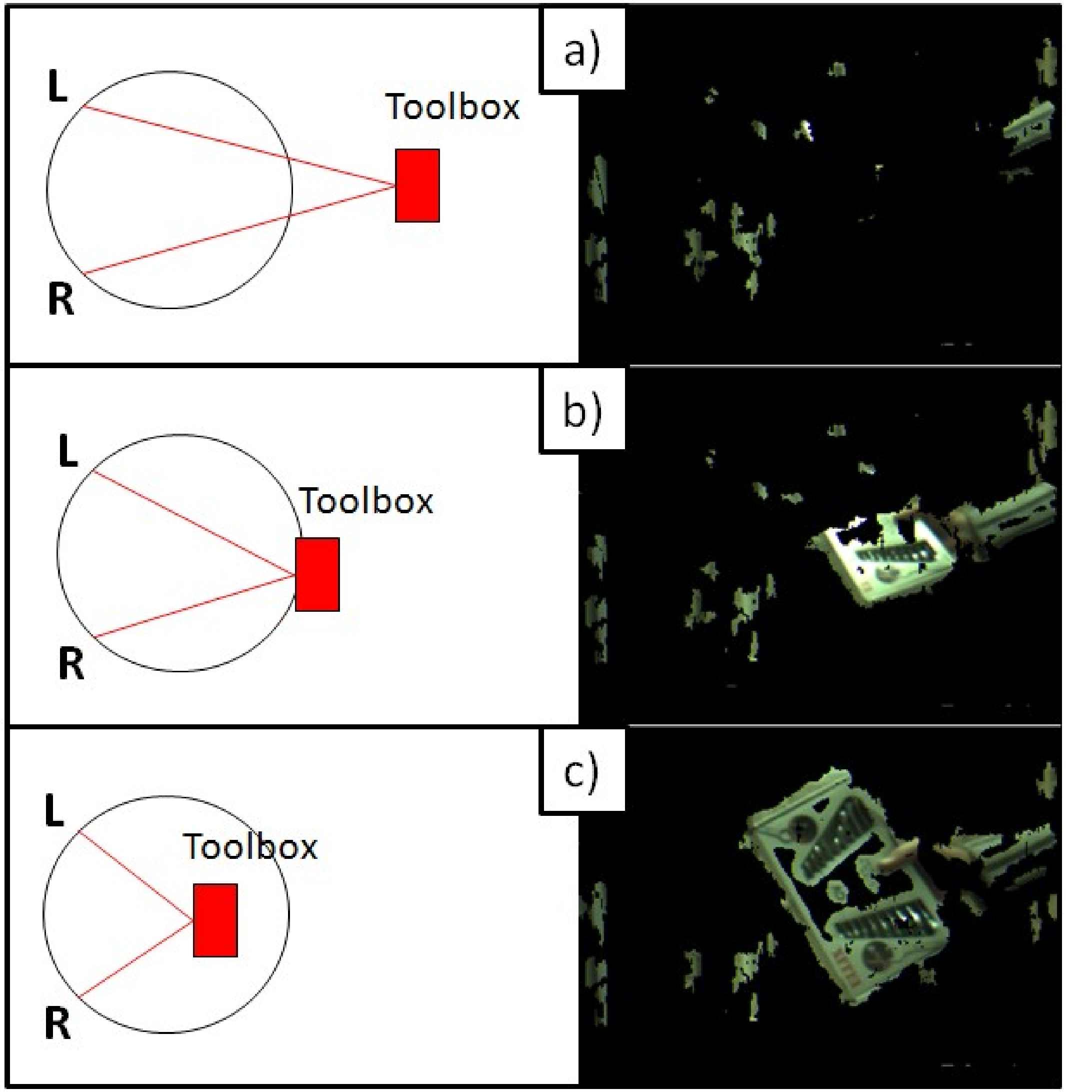
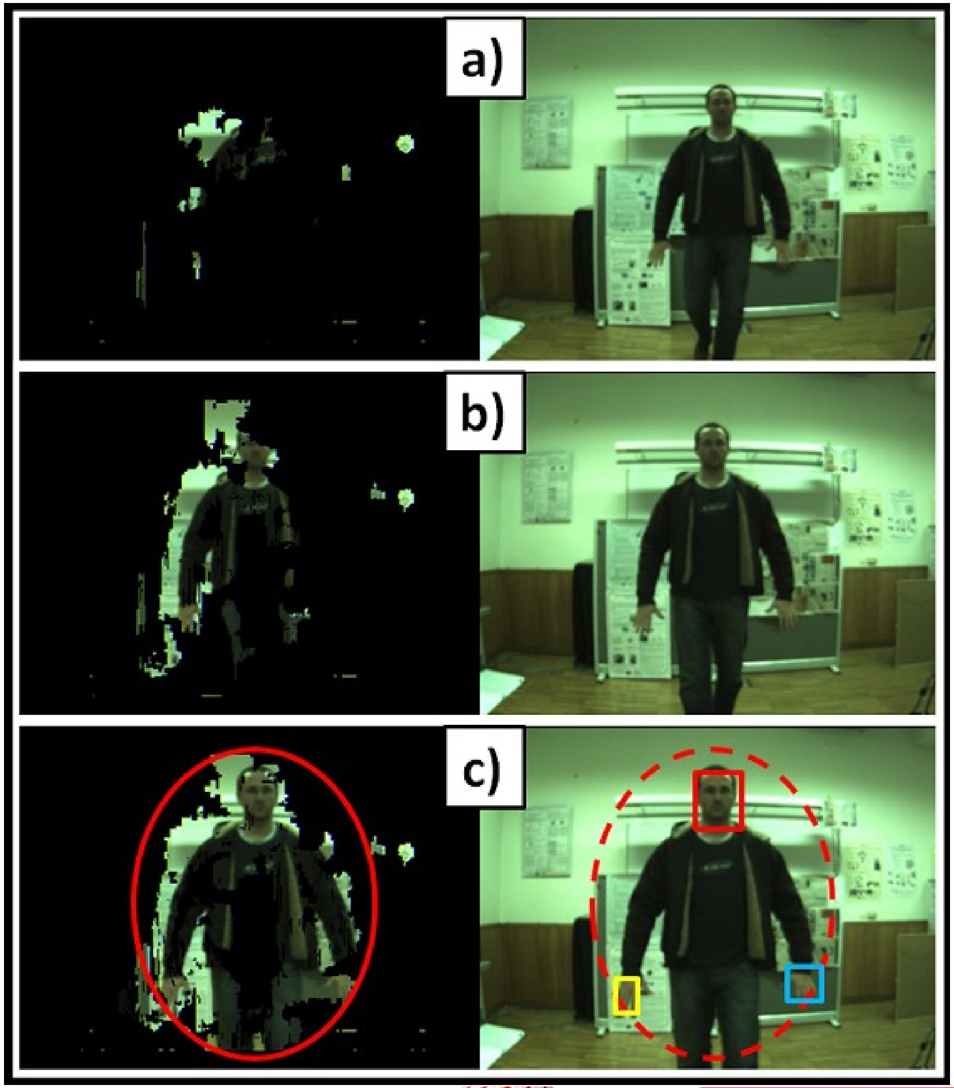


Only the orange objects are visible to the robot

Horopter / Zone of Interaction



Horopter / Zone of Interaction Results



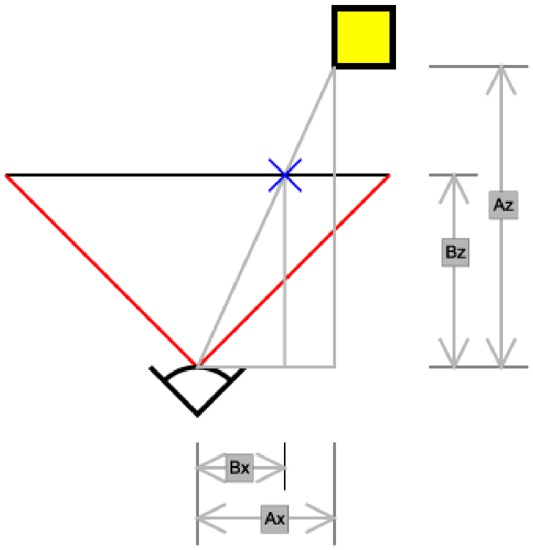
Horopter / Zone of Interaction Results

enteringHoropter.mpg

Tracking

After horopter segmentation, the tracker calculate the center of mass of the remaining pixels.

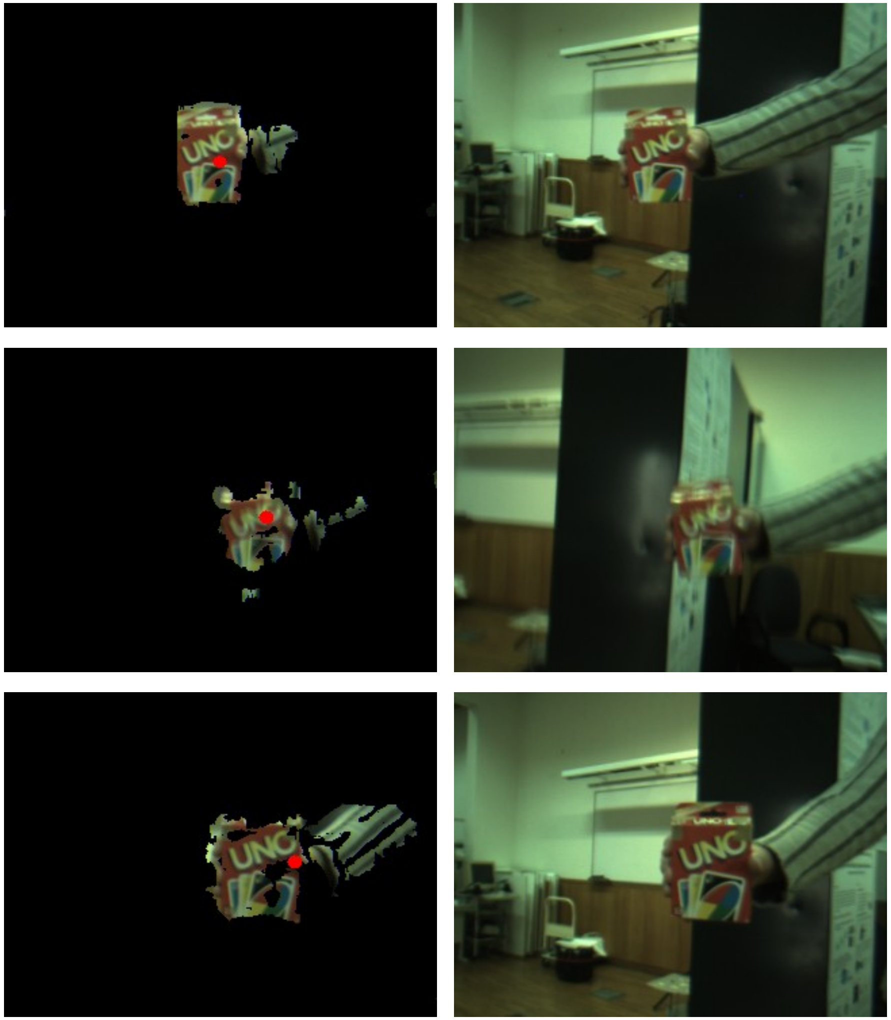
This point is a vector on the camera frame referencial, thus, as the camera and the motors are in the same rigid body, we send motor comands to the corresponding compensation angle.



Bz = distance from camera to projected object
Az = distance from camera to the real object

(The angle is the same)

Tracking Results



Tracking Results

HoropterandTracker.wmv

Face Detection

Haar Like Features

A recognition process can be much more efficient if it is based on the detection of features that encode some information about the class to be detected.

This is the case of Haar-like features that encode the existence of oriented contrasts between regions in the image.

A set of these features can be used to encode the contrasts exhibited by a human face and their spacial relationships.

Haar-like features are so called because they are computed similar to the coefficients in Haar wavelet transforms.

Face Detection Results

faceTracking.avi

FaceTracking.mpg

Future Work

1. Integrate face detection and horopter

1. Tracker will control also the body of the robot, not only the head

1. This *human robot interaction* capabilities will be used for probabilistic learning of gaze and pursuit control

Thanks