Autocollimator visual Interface proposal

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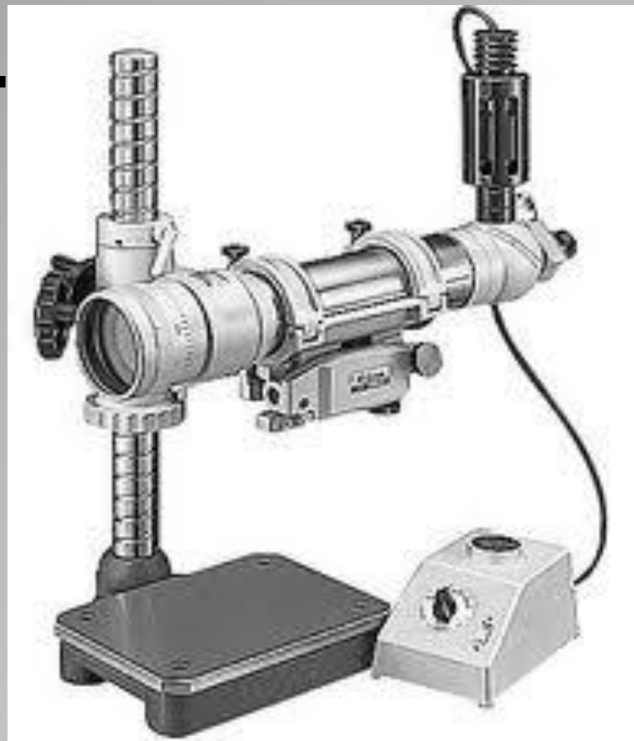
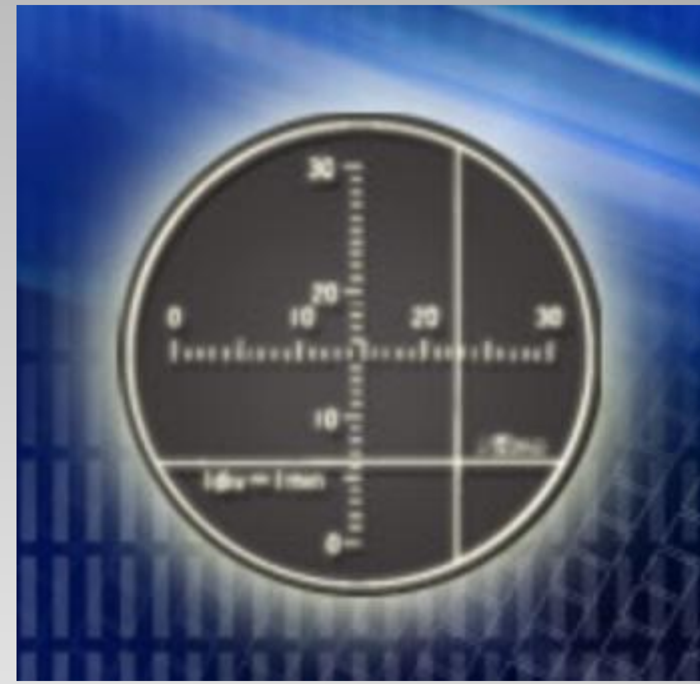
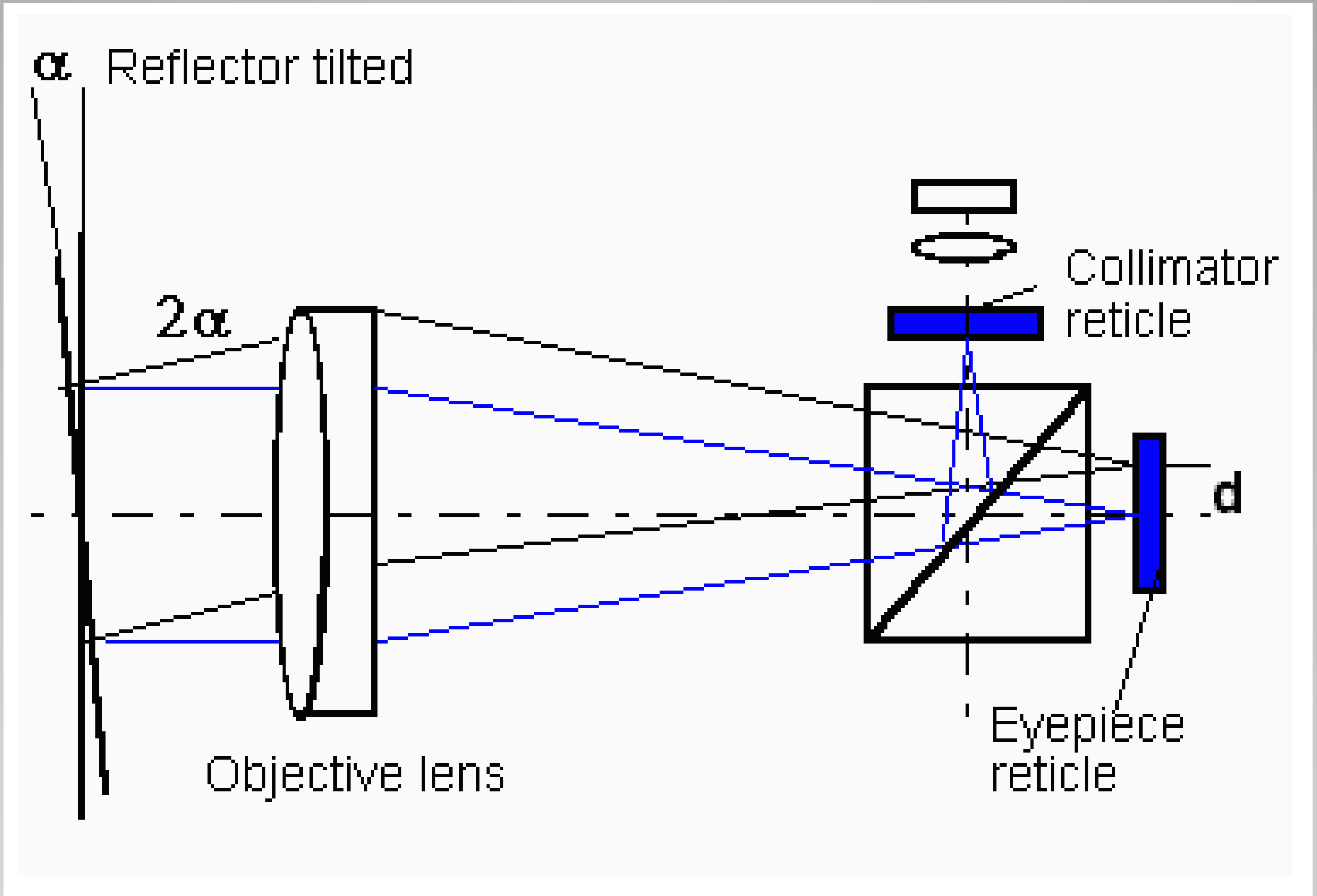


Autocolimador.

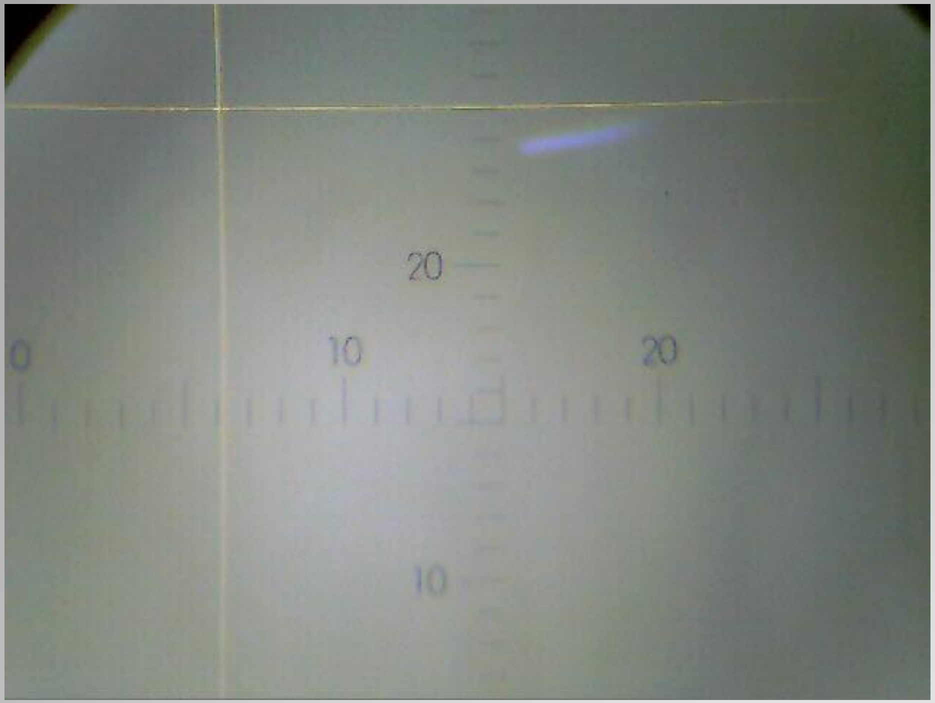


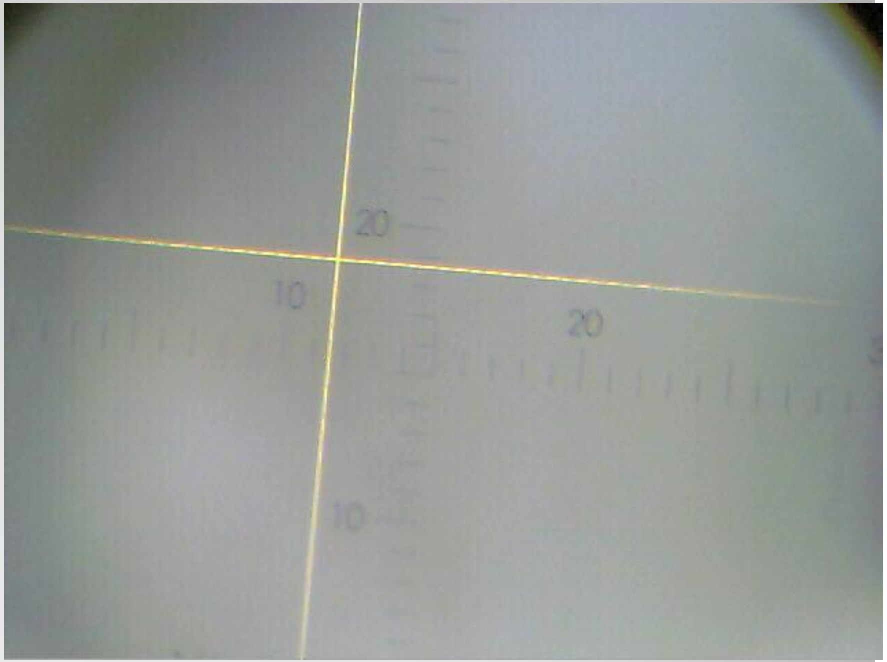
Retícula de Medición.

CEMETRO



Autocollimator



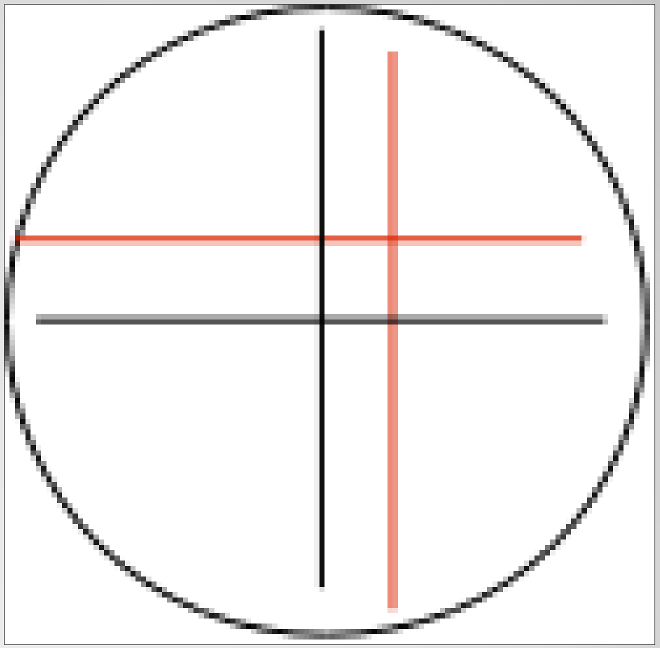


Operator replacement

- These pictures were obtained with a very simple webcam.
- They show that the camera's aperture angle is too small to capture the whole reticule, but we were able to measure its aperture, identifying the type of metrological camera to buy.
- We should see a set of marks that forms the ruler, and a very fine cross representing the reflexion of the object.
- We should notice too the optical deformation in the bordeline of the image

Problems

- If the camera is properly set to capture the whole autocollimetor cuadricule, we should observe a figure like the simplified one
- We would like to segment these lines



Simulation

- A recurring problem in computer picture processing is the detection of straight lines in digitized images.
- In the simplest case, the picture contains a number of discrete, black figure points lying on a white background.
- The problem is to detect the presence of groups of colinear or almost colinear figure points

Problem

- It is clear that the problem can be solved to any desired degree of accuracy by testing the lines formed by all pairs of points.
- However, the computation required for n points is approximately proportional to n^2 , and may be prohibitive for large n.

Naive solution

- Rosenfeld [1] has described an ingenious method due to Hough [2] for replacing the original problem of finding collinear points by a mathematically equivalent problem of finding concurrent lines.
- This method involves transforming each of the figure points into a straight line into parameter space.
- The parameter space is defined by the parametric representation used to describe lines in the picture plane.

Hough solution I

- Hough chose to use the familiar slope-intercept parameters, and thus his parameter space was the two-dimensional slope-intercept plane.
- Unfortunately, both the slope and the intercept are unbounded , which complicates the application of the technique.

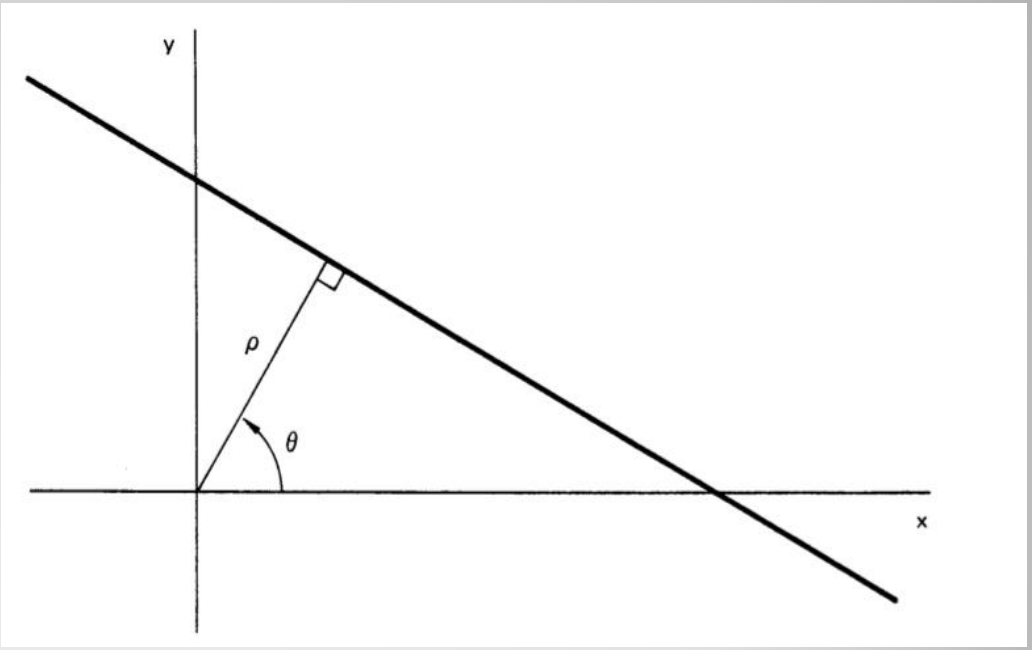
Hough solution II

- The set of all straight lines in the picture plane constitutes a two-parameter family.
- If we fix a parametrization for the family, then an arbitrary straight line can be represented by a single point in the parameter space.
- Duda and Hart chose the normal parametrization instead of the classical slope-intecept one.

Duda and Hart solution

- This parametrization specifies a straight line by the angle θ of its normal and its algebraic distance ρ from the origin.
- The equation of a line corresponding to this geometry is

$$x.\cos(\theta) + y.\sin(\theta) = \rho$$



Duda and Hart solution

- If we restrict the angle θ to the interval $[0,\pi)$ then the normal parameters for a
- line are unique.
- With this restriction, every line in the x-y plane corresponds to a unique point in the $\theta-\rho$ plane.

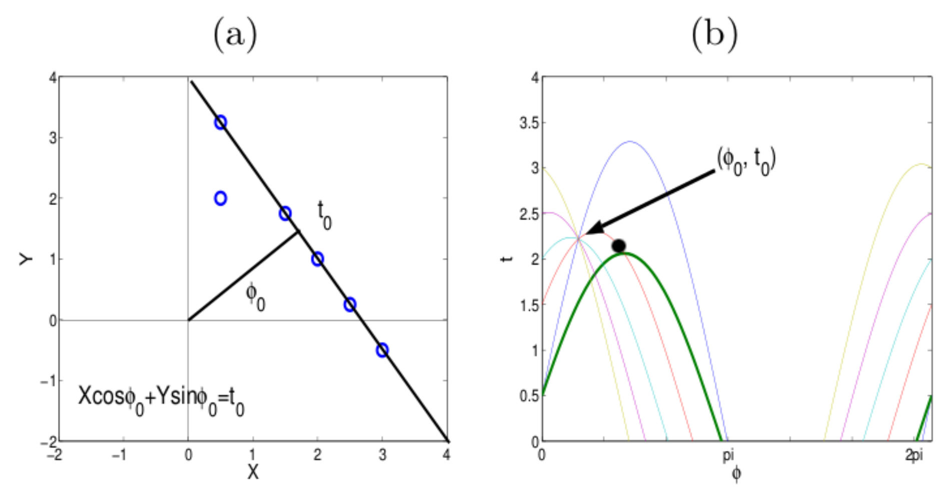
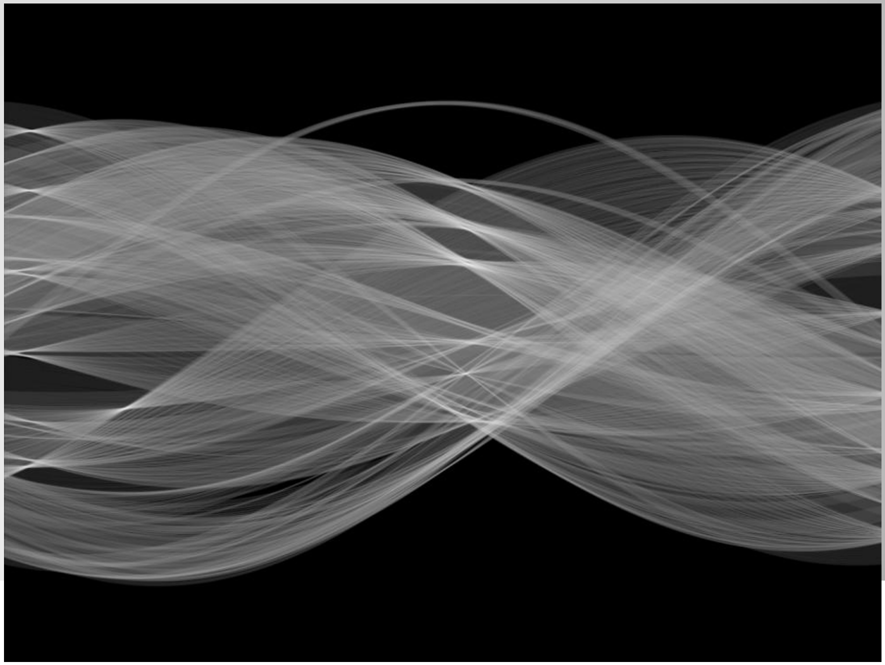


Figure 1: (a) Original domain. (b) Hough domain.

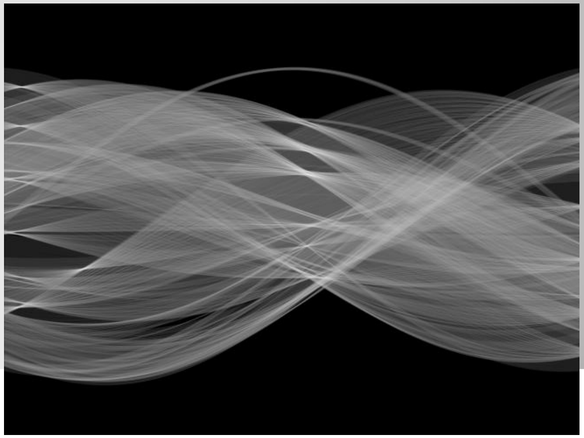
Duda and Hart solution

- Suppose, now, that we have some set $\{(x_1,y_1),\ldots,(x_n,y_n)\}$ of figure points and we want to find a set of straight lines that fit them.
- We transform the points (x_i,y_i) into the sinusoidal curves in the $\theta-\rho$ plane defined by

$$x_i\cos(\theta)+y_i\sin(\theta)=\rho$$



- The curves corresponding to colinear figure points have a common point of intersection.
- This point in the $\theta-\rho$ plane, say (θ_0,ρ_0) defines the line passing through the colinear points.
- Thus, the problem of detecting colinear points can be converted to the problem of finding concurrent curves.



Duda and Hart solution

- A dual property of the point-to-curve transformation can also be established.
- Suppose we have a set $\{(\theta_1,\rho_1),\ldots,(\theta_n,\rho_n)\}$ of points in the $\theta-\rho$ plane, all lying on the curve

$$x_0\cos(\theta)+y_0\sin(\theta)=\rho$$

- Then all these points correspond to lines in the x-y plane passing through the point (x_0,y_0)

Unicidad

- Suppose that we map all of the points in the picture plane into their corresponding curves in the parameter plane.
- In general , these n curves will intersect in n(n-1)/2 points corresponding to the lines between all pairs of figure points.
- Exactly collinear subsets of figure points can be found at least in principle, by finding coincident points of intersection in the parameter plane.
- Unfortunately, this approach is essentially exhaustive, and the computation required grows quadratically with the number of picture points.

Computational Burden

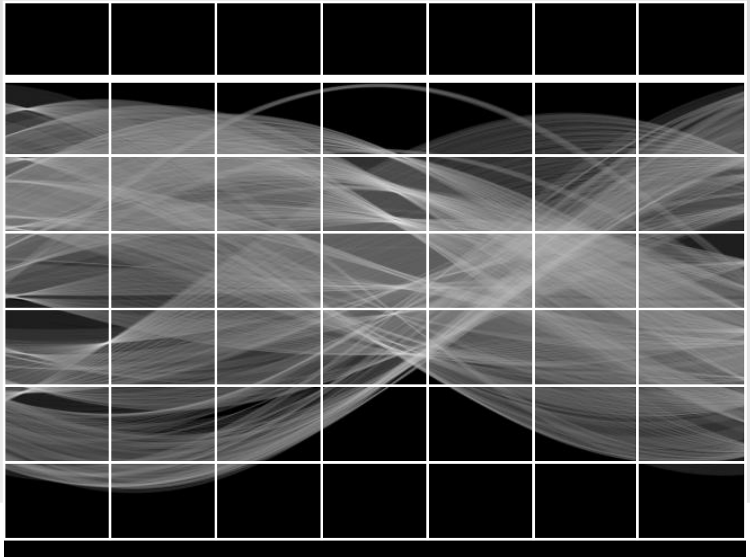
- Following Hough' s basic proposal , we specify the acceptable error in e and p and quantize the e plane into a quad ruled grid.
- This quantization can be confined to the region $0 \leq \theta < \pi$, - R $\leq \rho \leq$ R , where R is the size of the retina, since points outside this rectangle correspond to lines in the picture plane that do not cross the retina.
- The quantized region is treated as a two-dimensional array of accumulators.

Discretization

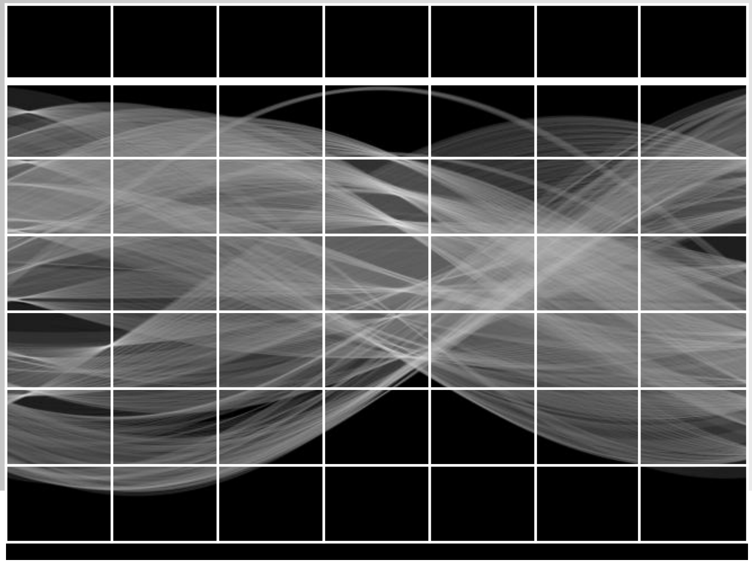
- The quantized region is treated as a two-dimensional array of accumulators.
- For each point (x_i, y_i) in the picture plane , the corresponding curve given by

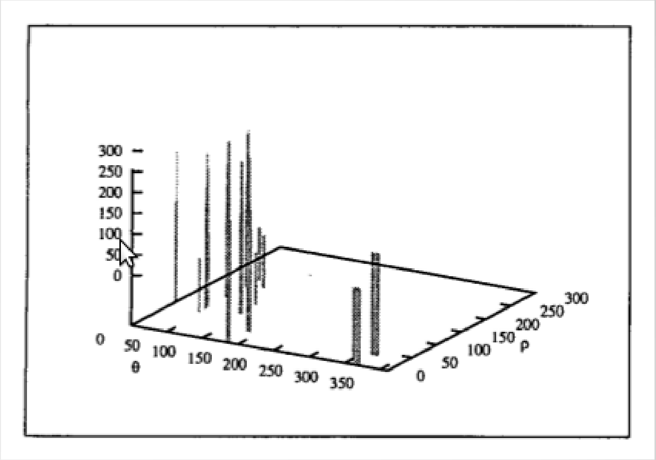
$$x_i \cos(\theta) + y_i \sin(\theta) = \rho$$

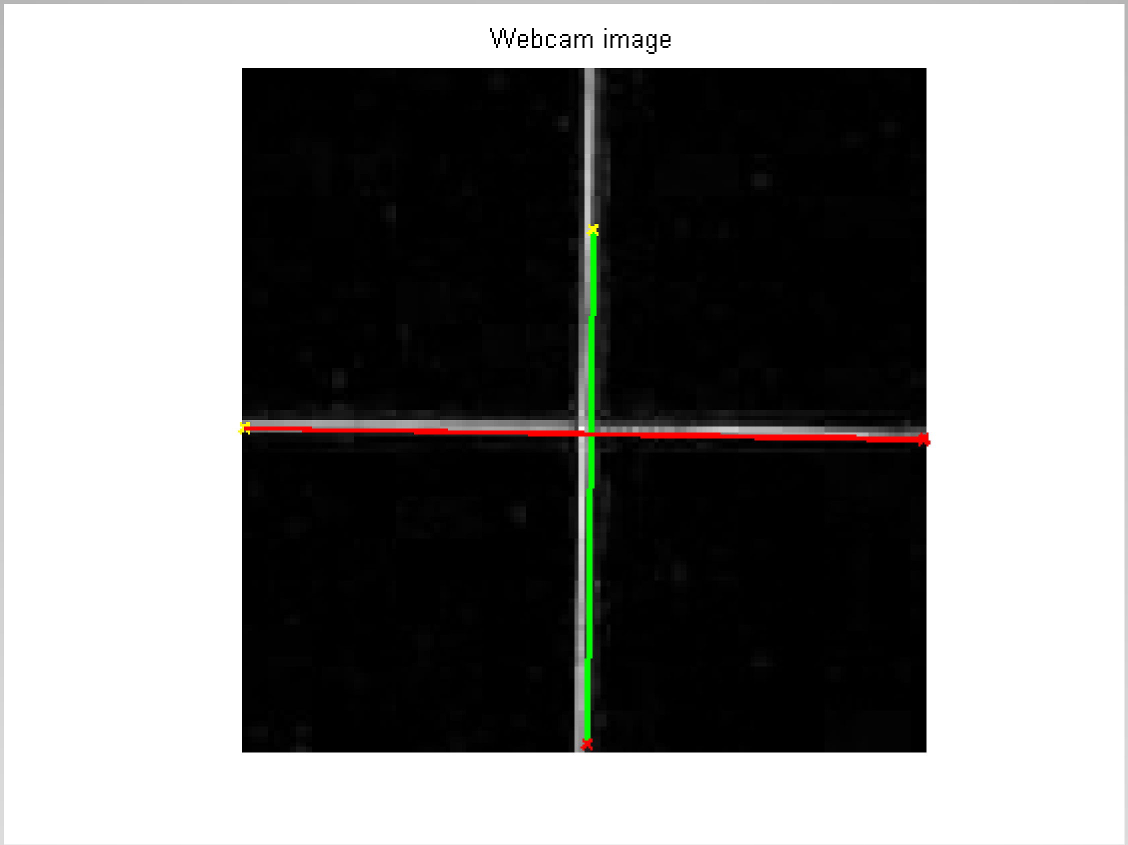
is entered in the array by incrementing the count in each cell along the curve.
- Thus , a given cell in the two dimensional accumulator eventually records the total number of curves passing through it.



- After all figure points have been treated , the array is inspected to find cells having high counts.
- If the count in a given cell (θ_i,ρ_j) is k then precisely k figure points lie (to within quantization error) along the line whose normal parameters are (θ_i,ρ_j) .







Hough Transform

Example.

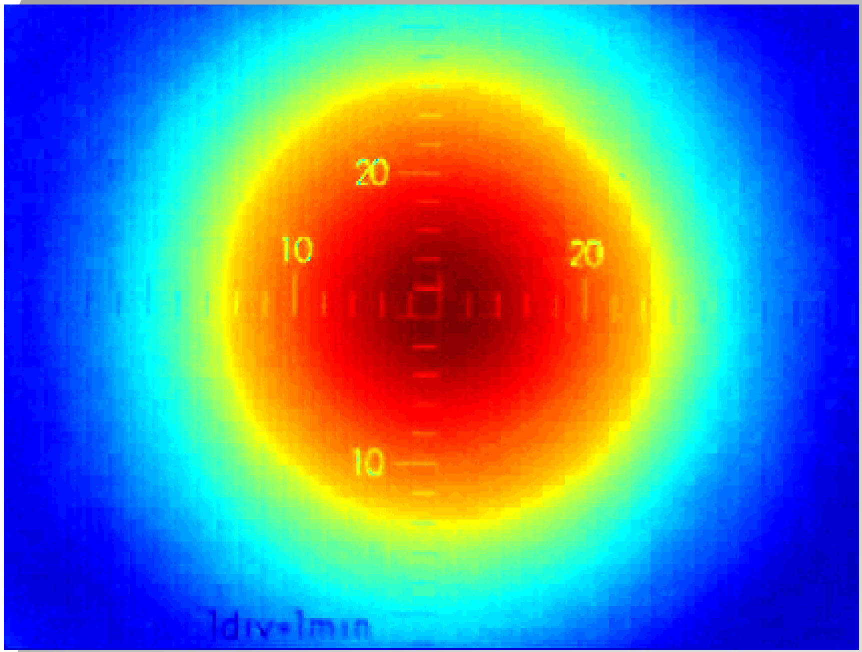
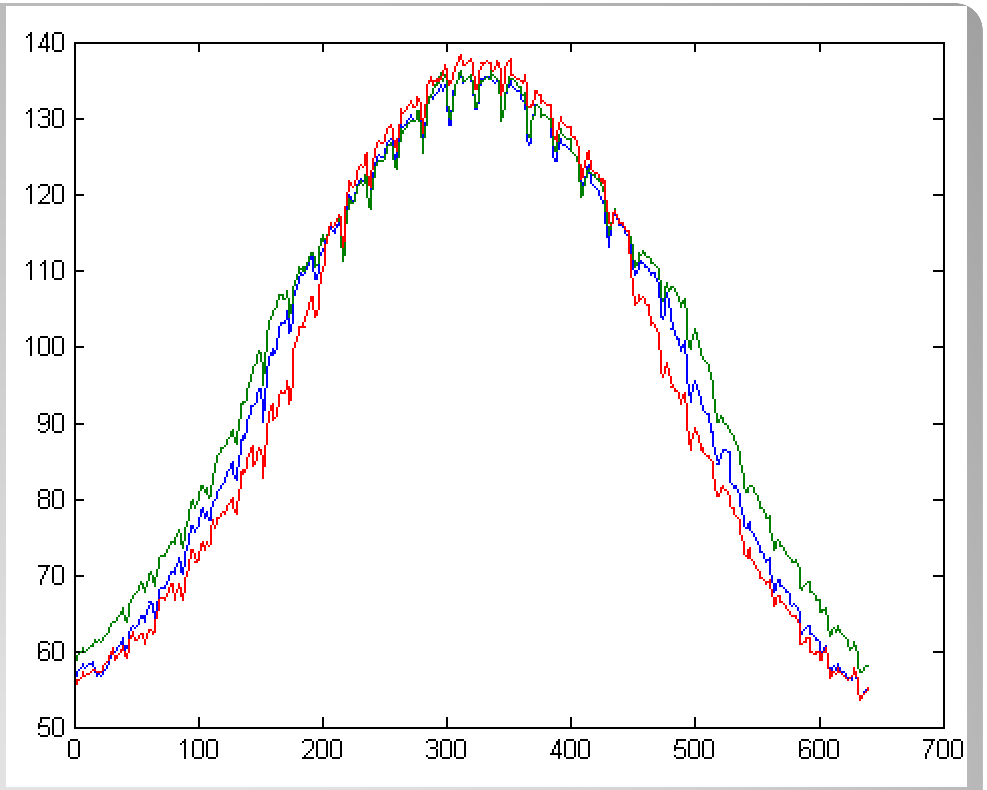
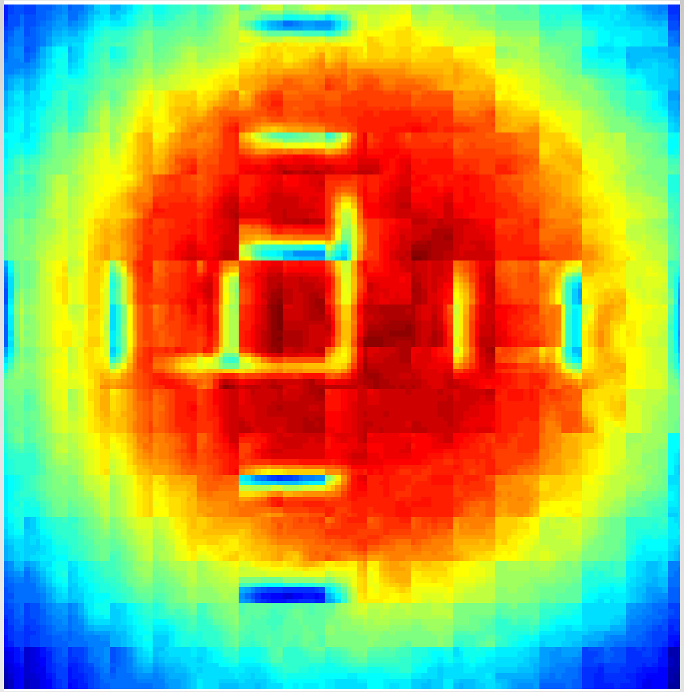


Image of the Autocollimator’s ruler



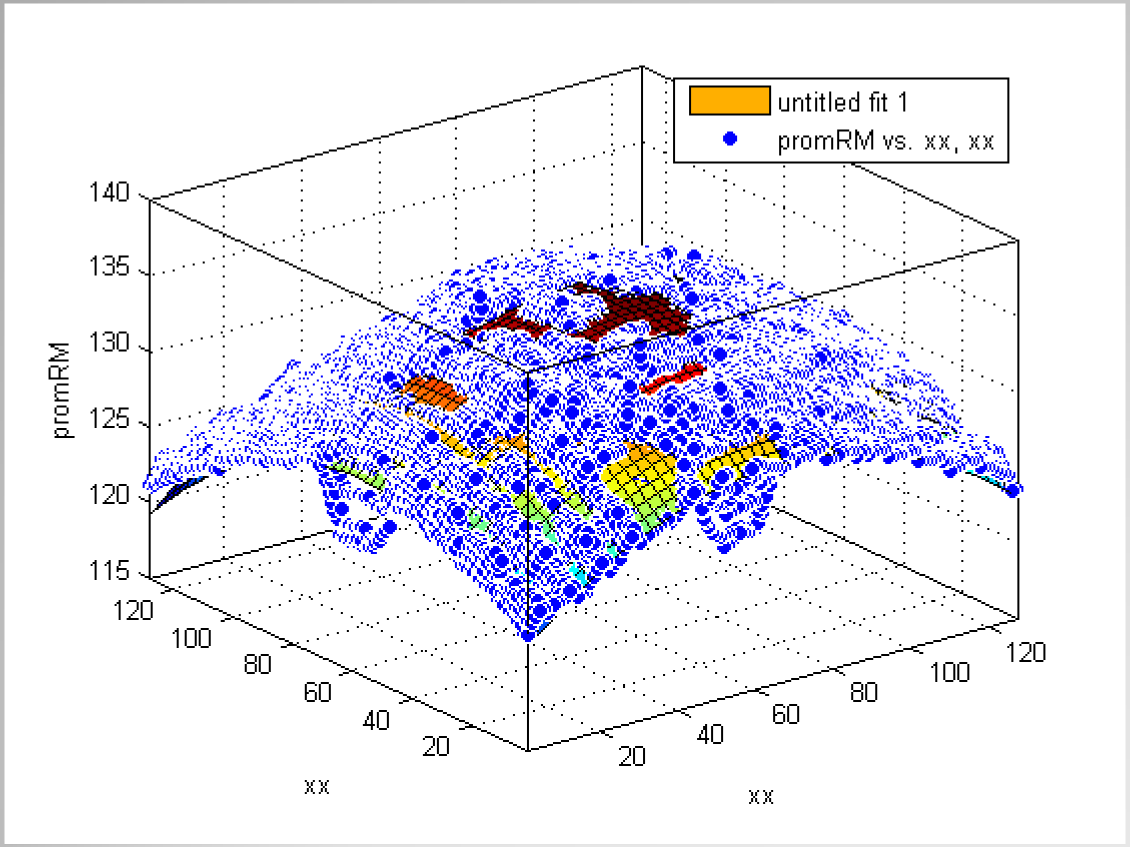
One dimensional cut of the RGB color array

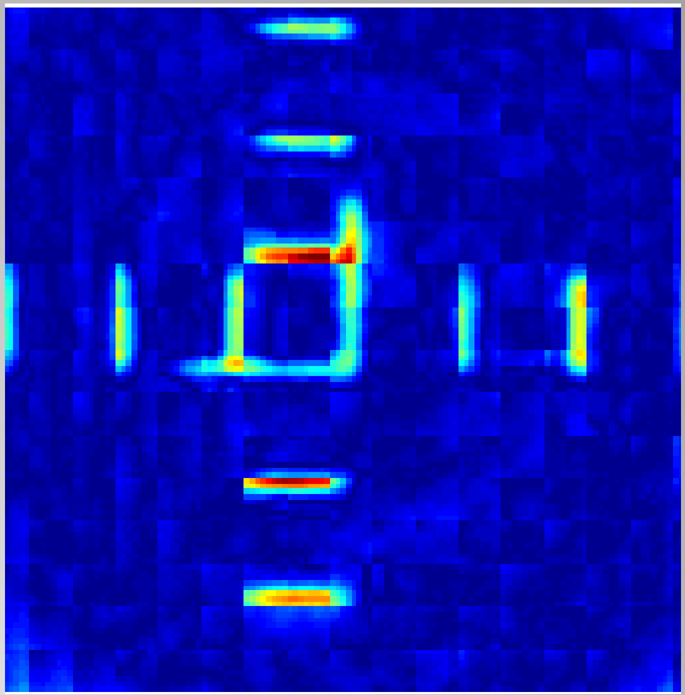
- Background must be erased
- Red chanel chose to start study
- Center piece stracted to diminish optical noise



Examples

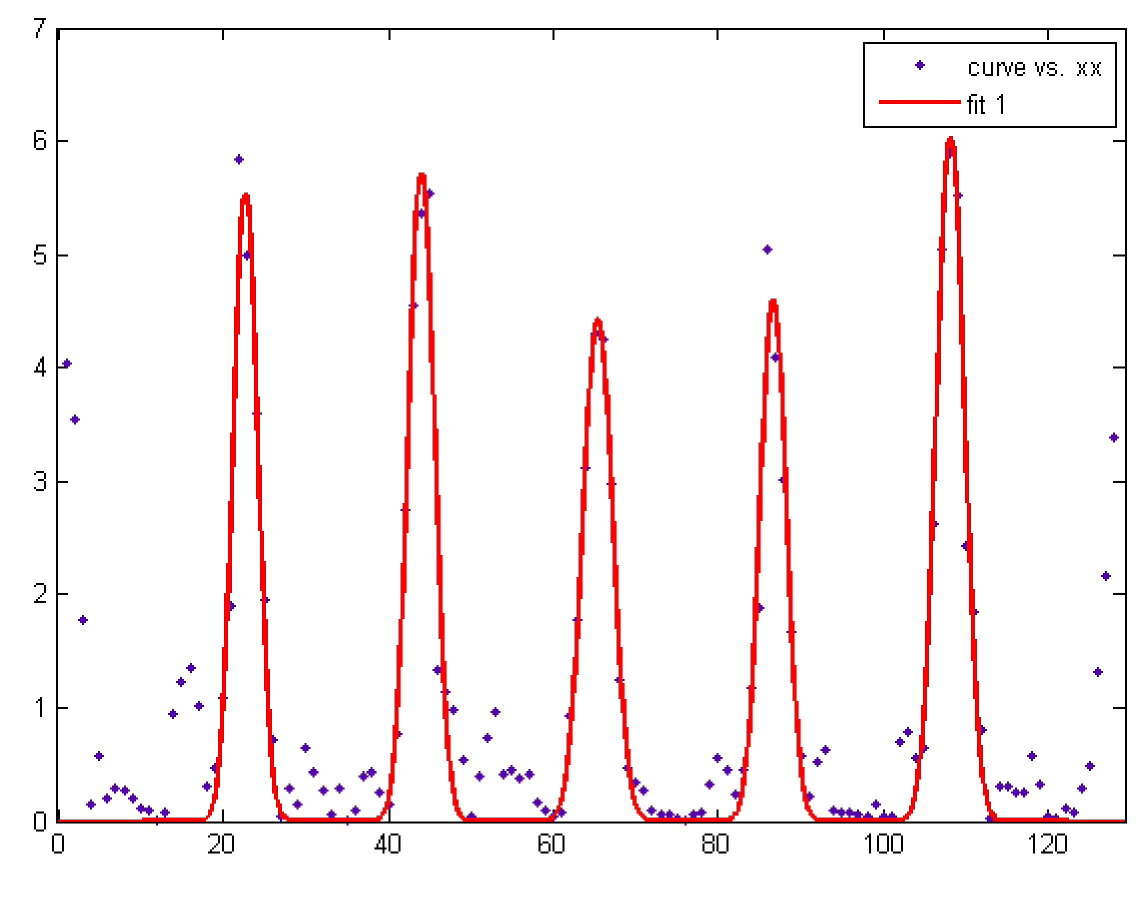
- Results.

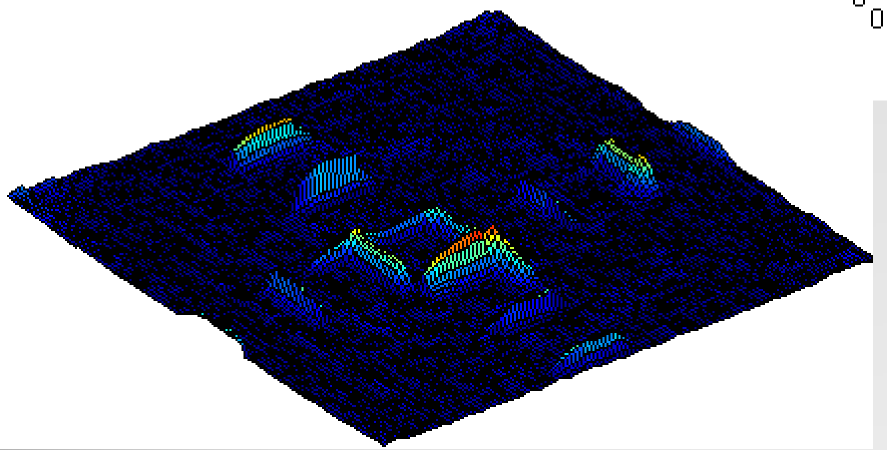




Programming Matlab

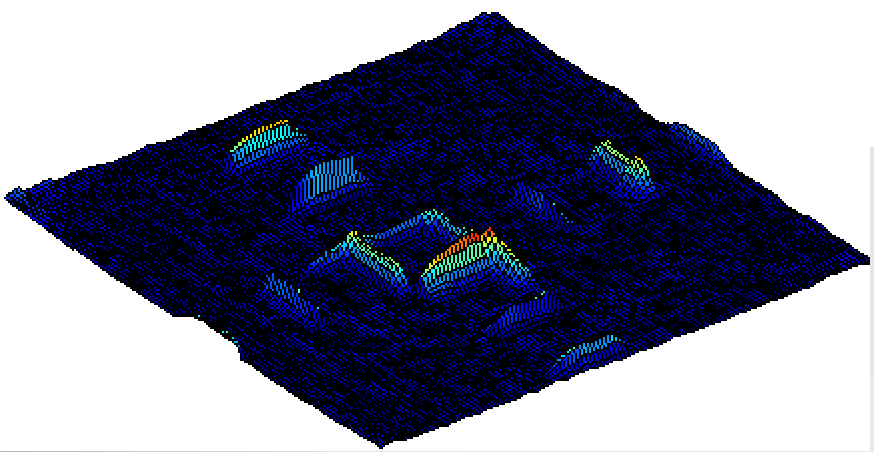
- Horizontal cut

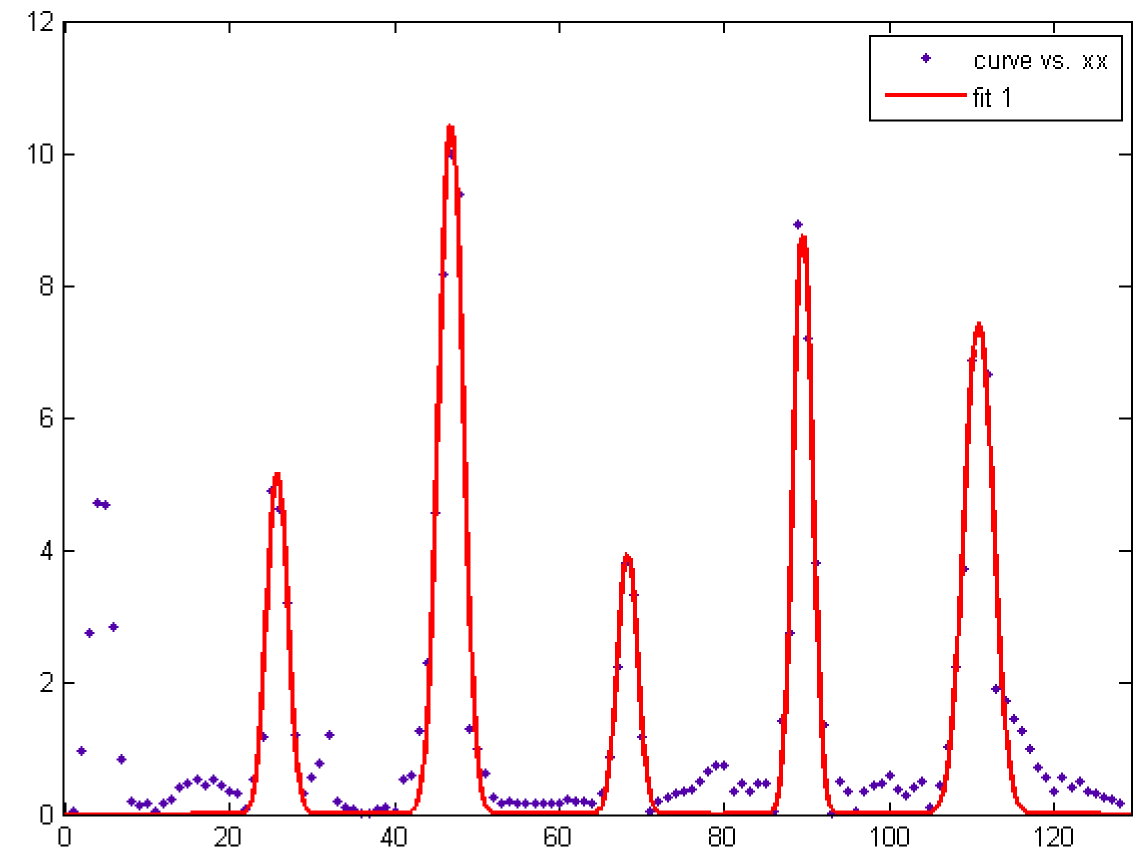




Without background

- Vertical Cut





Without background

- Pixel identification:
  - Center pixel in the cross
  - Center pixel in each line of the ruler
- With both pieces of information the autocollimator measurement is achived.

Both images

- Bibliografia

USE OF THE HOUGH TRANSFORMATION TO DETECT LINES
AND CURVES IN PICTURES

Technical Note 36

April 1971

By: Richard O. Duda
Peter E. Hart

Artificial Intelligence Center

Bibliografia

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1. ROSENFELD, A. Picture Processing by Computer. Academic Press, New York, 1969.

2. HOUGH, P. V. C. Method and means for recognizing complex patterns. U. S. Patent 3,069,654, December 18, 1962.

3. GRIFFITH, A. K. Computer recognition of prismatic solids. Ph.D. thesis, Dep. of Math., MIT, June, 1970.

¡Muchas gracias!

FIN.