Track Finding in INO-ICAL Detector using Hough Transform

Vipin Bhatnagar, Jyoti Bala and Kanishka

Department of Physics, Panjab University, Chandigarh, India

HOUGH TRANSFORM

It was initially invented for bubble chamber tracks in 1959. The Hough transform universally used today was invented by Richard Duda and Peter Hart in 1972, who called it a "generalized Hough transform"

The Hough transform is a feature detection technique to detect various track/shapes. Classical Hough transform was concerned with the identification of lines in the image, but later on Hough transform has been extended to identifying positions of arbitrary shapes like circles, parabola etc.

Now-a-days a lot many versions of the Hough transform exist. The most common are kernel-based Hough transform and generalized Hough transform

Why HT Is Important

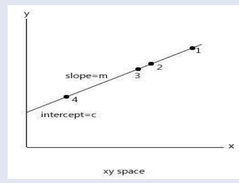
- To detect the track of charged (muon) particles.
- To detect multiple occurrences of shapes like straight line, circle, parabola etc.
- To minimized Reconstruction time

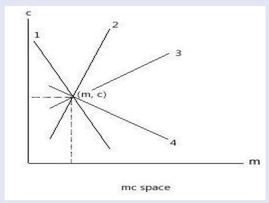
Kalman filter and Cellular Automata filter are based on every combination of tracker hits and huge amount of combination need to be tried before reaching a conclusive result. Suppose there are 1000 hits per layer and no. of combination to try is 10^9. Then for each try at least 100 FLOPS will execute, so 10^{11} FLOPS per events will take larger time as compared to HT algorithm that takes 10^4 FLOPS.

Implementation of HT

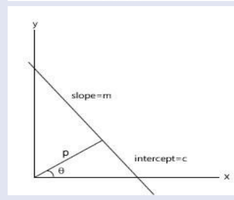
The Hough transform is to draw lines corresponding to each point of xy space. A line is formed using two parameters (θ,ρ). ρ is length of normal from the origin onto the line and θ is the angle this normal makes with the x-axis. The equation of the line is

$\rho = x_1\cos\theta + y_1\sin\theta$ where (x_1, y_1) is a point through which the line passes.

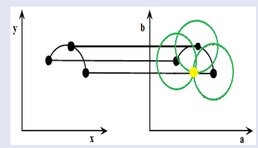




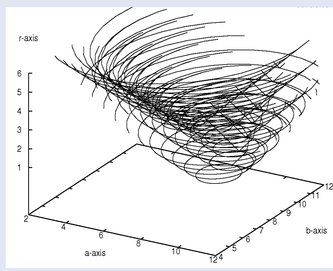
A line in the xy space is equivalent to a point in the Parametric (ρθ) space and a point in the xy space is now equivalent to a sinusoidal curve in the ρθ space. After considering all the lines through all the points, a Hough accumulator with a high value will probably correspond to a line of points.



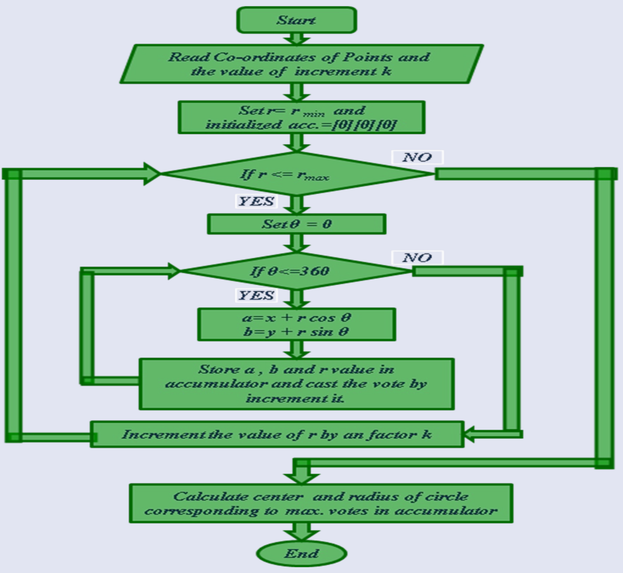
- To find circular track of known radius ,we have to find out just 2 parameters i.e. center of circle. Every point in xy space is equivalent to circle in parametric space of known radius. Lots of circles are drawn but we have to find out where all these circles coincided or meet in order to obtain center of the circle. To cast votes, parametric space is divided into 2-D array such that array with maximum votes corresponds to center of circle.



- To find Arc/Parabolic Track. We treat parabolic curve as an arc of big unknown circle. When the radius is not known ,then locus of points in parameter space will fall on the surface of a cone. Now each point in xy space generates a cone in parametric space. Where r varies from minimum range to maximum range of radius.



Unknown circular track/arc with Serial HT



Need of Parallel HT

- The main disadvantage of Serial HT is that it requires large storage for the voted Hough space. It doesn't contribute significant performance improvement as the voting procedures just follow the sequential route thus ending up taking more processing time.
- The easy availability of the parallel computing tools now a-days on the desktops as well as the High Performance Computing Cluster (HPCC) motivated us to go ahead with the parallelization of the HT algorithm.

By using multiple instructions multiple data with shared main memory, we show that the parallel HT improves the performance by a factor shown in table 1.

Unknown circular track/arc with Parallel HT

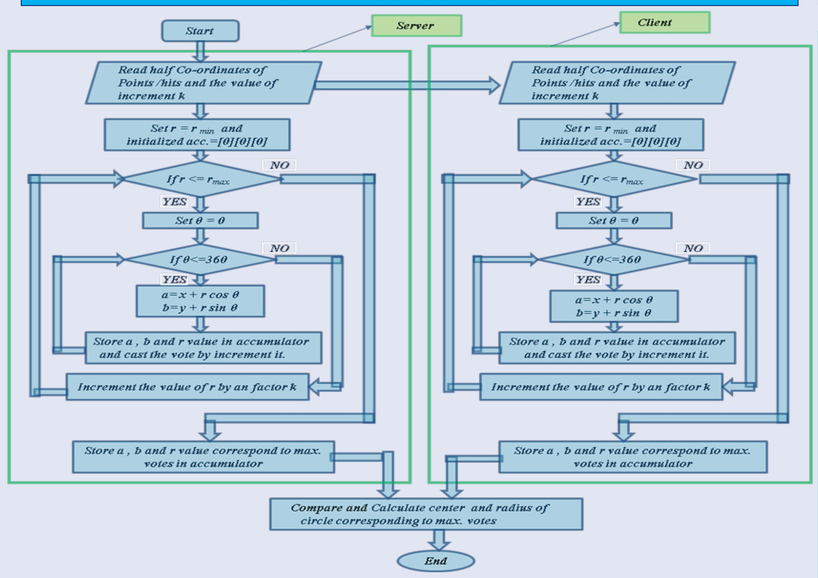
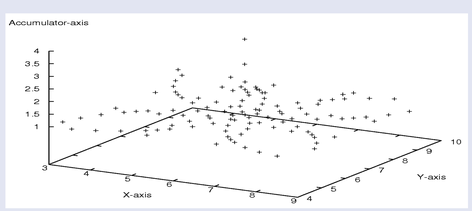


Table 1: Real Execution Time

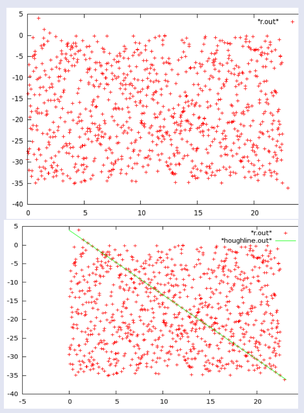
Track	*Serial HT*	*Parallel HT*
Straight-Line	9.883 sec.	5.507 sec.
Known Circular	5.151 sec.	2.103 sec.
Unknown Circular	4.757 sec.	3.132 sec.
Arc/ Parabolic	5.989 sec.	3.231 sec.

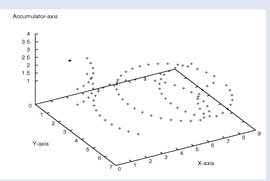
Graphical Result

Votes in accumulator for an arc of circle using Serial HT

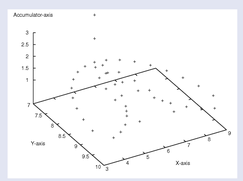


A Particle Track With noise





Votes in Head node accumulator using parallel HT



Votes in Slave node accumulator using Parallel HT

Track found using HT

HT Codes with INO-ICAL data in Serial & Parallel Mode on HPCC

Specifications of data used:
INO-ICAL codes- inoical0_300611, VICE1.0

μ- events	5000
Energy taken (without smearing)	3 GeV
Zenith angle of μ- (without smearing)	0°
Azimuthal angle φ (smeared)	0-2π
Vertex taken	(100,100,0) cm with no smearing

Results: with serial and parallel mode

- Centre value- 3.34018, 5.43432
- Radius- 6.9
- Execution time to run HT code with INO data: 1.646 sec (serial) and 0.795 sec (parallel)

Summary

- HT can be used to detect tracks besides the image boundaries only, as it was meant, originally, for that.
- Serial HT implementation is simple to achieve though the computing time taken to detect the tracks is more.
- Execution time in the parallel HT is much less, using multi-processor system than that of the serial task running on a single core.
- The implementation of the parallel HT algorithm, though based on shared main memory, allowed us to avoid the overheads due to processor accesses because of the separate pools used for the variables' storage.
- Though the parallel Hough transform is just using two processors in the present work yet the gains achieved are from 35% to 58%.
- HT codes are can be runned with INO data in both serial and parallel.

References

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