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Proposed Pattern Recognition Algorithm for the CMS Inner Tracker

F.Bruyant
CERN/ECP

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Abstract

The proposed algorithm is an adaptation of the filtering techniques developed in the seventies for the data recorded by the Spiral Reader devices, used to digitize Bubble Chamber track images. Preliminary results, soon available in a separate note, indicate that the algorithm should work and might be very efficient, in particular for on-line level 2 trigger applications.

Any physicist over 50 who had the privilege to participate in Bubble Chamber experiments remembers the Spiral Reader measuring device [1] and the techniques of filtering developed in the program POOH. The design proposed for the barrel of the CMS Tracker, with its elements located along a spiral in xy projection, triggers an association of ideas and suggests that some of the algorithms used in POOH could be adapted to the CMS tracker! However, the section "Off-line treatment of measurements performed on CERN's Spiral Readers", p.171-193 of the report [1], shows that the domain of validity of the simple and fast techniques proposed applies to regions not too distant from the vertex, regions where unfortunately the CMS Tracker does not provide any measurements. But, unlike the situation with the measurements of a bubble chamber track image, the tracker measurements (r, φ, z) are "quantized" (particularly the radial distance r in the xy plan), and this makes possible to pre-compute a (finite) number of quantities of interest. Furthermore, the track curvatures are not distorted by any optical projection effects. Then, the idea of histograming a function of the (r, φ) measurements for a sampling of curvatures (centered around 0) can be preserved and should be valid for measurements at all distances from the vertex. A simple function could be: $\varphi - \arcsin(c * r/2)$, where c is the sampled (signed) curvature. When c is close to the curvature of any of the track candidates, the value of the function is nothing else than the azimuthal angle φ_0 of the track at $r = 0$ and is the same for all measurements belonging to the track. One should therefore observe a peak at that value in the histogram generated for the given curvature.

More generally, the function

$$f = \varphi - \arcsin(c * r/2) + 2 * \arcsin(c * r_{ref}/2)$$

can be used, where r_{ref} is the radial distance at which one wants to express the azimuthal angle ($r_{ref} = 0$ at vertex, $r_{ref} = r_{max}$ at tracker outside radial limit). It is expected to give a better resolution for $r_{ref} = r_{max}$ and the lowest resolution at $r_{ref} = r_{average}$.

The following approach is suggested:

1. Define criteria of acceptance for the measurements used for an initial global pass for both the barrel and the end-caps, in order to reduce the number of a-priori useful measurements. In first approximation, defining two constants r_{cut} (of the order of $r_{max}/2$) and z_{cut} (of the order of $z_{max}/2$), one could reject the measurements which do not satisfy the following tests:

   - for $abs(z) > z_{cut}, r > r_{cut} * (1 - (abs(z) - z_{cut})/(z_{max} - z_{cut}))$
   - for $abs(z) < z_{cut}, r > r_{cut} * abs(z)/z_{cut}$

   Ultimately, r_{cut}, z_{cut} and the rejection tests should be derived from the observation of the distribution of r versus $abs(z)$ for a sample of events.

2. For each selected measurement, and each curvature c, enter f and c in a scatter plot (f versus c). In this multi-track environment, the definition of f with the lowest resolution might be the option to use.

3. For each signal (if any!), extract the measurements from the relevant bin(s) and reject the ones not compatible with θ_0, the estimated angle of the track with respect to the z axis at $r = 0$, obtained through a straight line fit $z = s*\tan(\theta_0)$, with the projected arc length $s = 2*\arcsin(c*r/2)/c$, or $s = r$ for c small.

4. For any track candidate extracted successfully, pick-up the compatible measurements not initially selected (either re-histogram with small steps in curvature around the given value of c, or fit a helix and reject the bad measurements, or both). It is expected that the fit results will give a good estimate of the impact parameter of each track with respect to its assumed origin, at least for all tracks coming from the primary interactions or from any close decay vertices.

In practice, given the huge number of hits for pile-up events, the proposed approach should be executed for 3 or 5 domains of rapidity. For the end-cap cells with poor radial precision it is suggested to simulate cell divisions, thus generating temporary artificial measurements, to enhance the peaks and make possible the identification of the trajectories.

Preliminary tests performed by Sunanda Banerjee and Stefan Piperov give encouraging results. They will be summarized in a separate note.

If the algorithm works as expected, this global approach should be faster than any local approach (for instance the one proposed in the MOOSE pilot project [2] for the CMS tracker), possibly by a large factor. Also, it could be adapted easily and very efficiently for on-line level 2 trigger applications.

In case the algorithm would not work, it might reflect that the design of the tracker needs be improved!

Last (but late!), the algorithm might be quite performant for the LEP-L3 Time Expansion Chamber (TEC), given its design and operational conditions.

References

[1] European Spiral Reader Symposium, CERN Yellow Report 72-16

[2] An Object Oriented Approach to CMS Reconstruction Software (to be presented at CHEP95), V.Innocente, M.Marino (CERN).