

A vision based algorithm for track finding.

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Outline

Short introduction

Attribute-Space Connectivity

Advantages

Application to PANDA

Conclusion & future plans

Mathematical Morphology

- ▶ Mathematical morphology is a set-theoretical approach to image analysis.
- ▶ It was developed in the 1960s by Matheron and Serra to analyze microscopic images of ore samples.
- ▶ The binary case (our case):
 - ▶ $\mathbb{E}$ is some universal set (usually $\mathbb{Z}^2$ for digital images) of which
 - ▶ The image domain M is a subset.
 - ▶ The binary image X simply the set of foreground pixels in M .

Connectivity Classes: Informally, a connectivity class C is the set of all connected subsets of some universal set E .

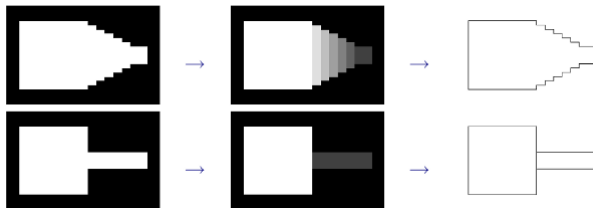
Example



Attribute-Space Connectivity

- ▶ Transform the image into a higher dimensional space $E \times A$ called attribute space, using some operator : $P(E) \rightarrow P(E \times A)$.
- ▶ The mapping is performed by assigning each foreground pixel one or more attribute values, i.e. each $x \in X$ maps to one or more points (x, a_i) with $a_i \in A$.
- ▶ Backprojection will typically work by mapping every tuple (x, a) onto x .
- ▶ Note that A need not be one-dimensional.
- ▶ Each dimension of A may be thought of as analogous to cortical areas representing different properties such as scale, orientation, etc.

Example, width based

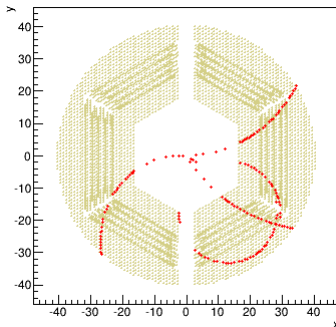
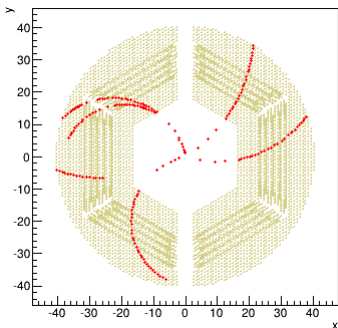


Because each pixel is assigned just one width, we can represent this compactly as a grey-scale image. The partitioning now depends on grey-level difference in the mapped images.

Example Orientation based

 X  $f(x, 0)$  $f(x, \pi/4)$  $f(x, \pi/2)$  $\Omega_\alpha(X)(x, 0)$  $\Omega_\alpha(X)(x, \pi/4)$  $\Omega_\alpha(X)(x, \pi/2)$

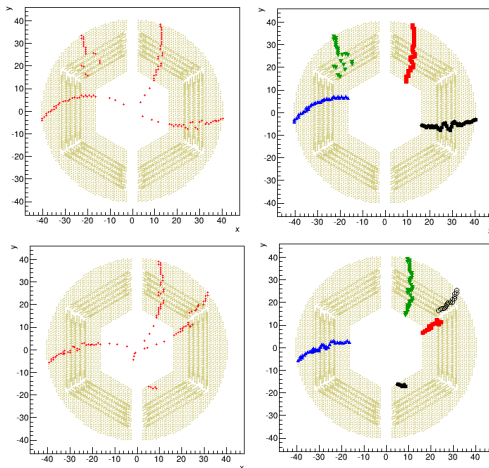
Similarities with PANDA



Advantages for online filtering

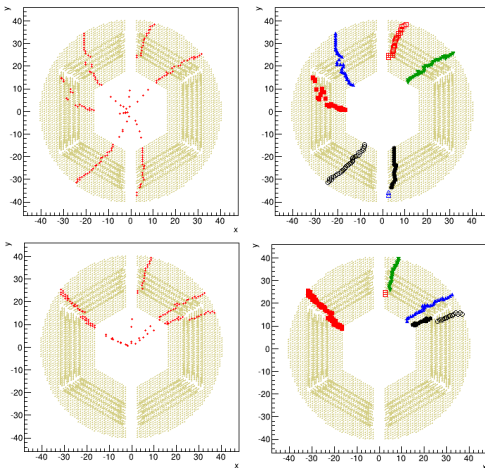
- ▶ Easy to understand principal (algorithm).
- ▶ Linear in the number of involved points (detectors).
- ▶ Depends only on the detector geometry (graph).
 - ▶ Position of the detector nodes (space coordinates).
 - ▶ Neighborhood relation of detector nodes.
- ▶ Simple computing operations makes it very suited for embedded and parallel implementation (Useful for online application, event filtering, data reduction).
- ▶ No time stamp is needed.

Application to PANDA STT



$0.3 \text{ GeV}/c^2 \mu$

Application to PANDA STT

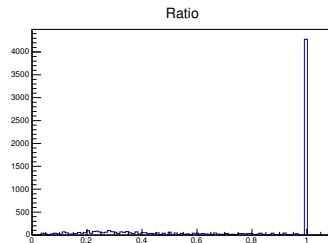
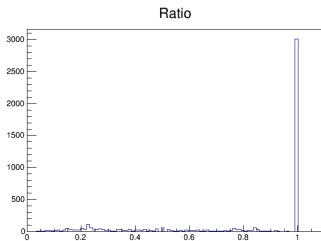


$0.5 \text{ GeV}/c^2 \mu$

Efficiency:

- ▶ Given an image with a total number of active pixels (detectors) equal to A .
- ▶ N true segments $\{R_1 \cdots R_N\}$ with regions $\{A_1 \cdots A_N\}$.
- ▶ A test segmentation with M components $\{T_1 \cdots T_M\}$ with regions $\{\alpha_1 \cdots \alpha_M\}$.
- ▶ $\forall T_j$ find R_K such that $(T_j \cap R_k)$ is maximal.
- ▶ Define $E = \frac{(T_j \cap R_k)}{R_K}$

Efficiency



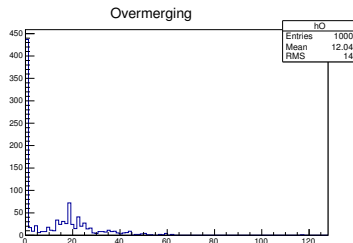
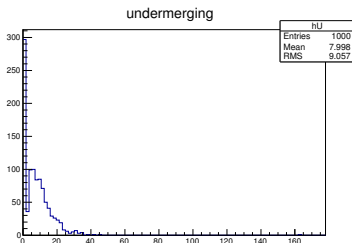
Total segmentation Error

$$\blacktriangleright E_{undermerging} = \sum_{j=1}^M \frac{\{A_K - (T_j \cap R_k)\}(T_j \cap R_k)}{A_K}$$

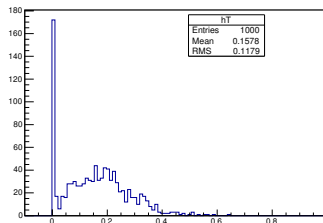
$$\blacktriangleright E_{overmerging} = \sum_{j=1}^M \{\alpha_j - (T_j \cap R_k)\}$$

$$\blacktriangleright E_{total} = \frac{\sqrt{E_{undermerge}^2 + E_{overmerge}^2}}{A}$$

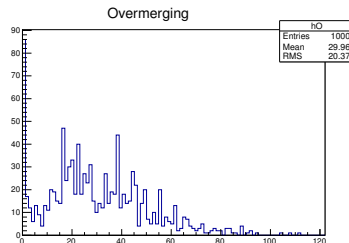
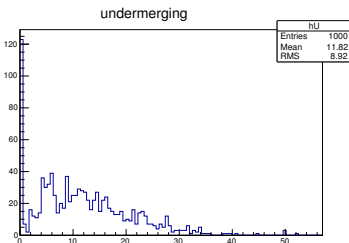
Segmentation Error ($0.5 \text{ GeV}/c^2 \text{ mul} = 5$)



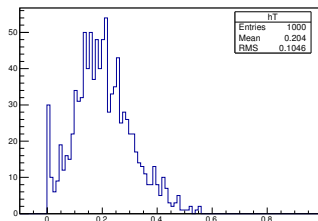
TotalError



Segmentation Error ($1.0 \text{ GeV}/c^2 \text{ mul} = 8$)

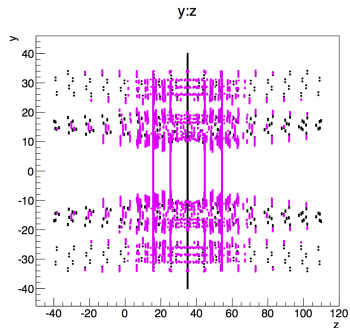
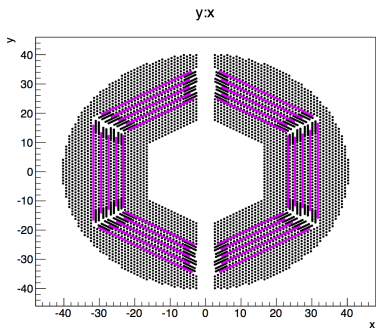


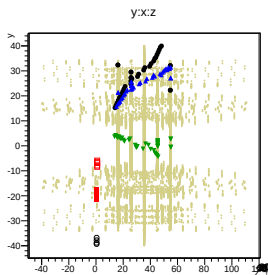
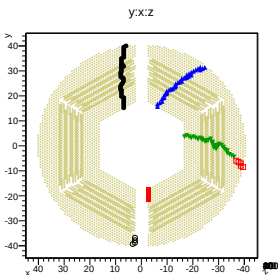
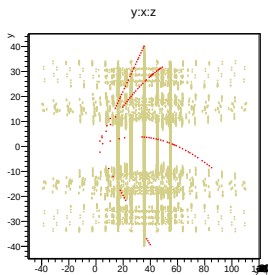
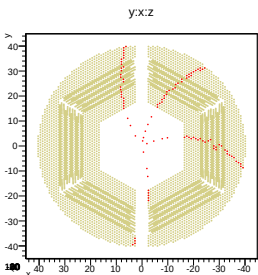
TotalError

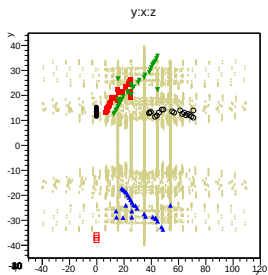
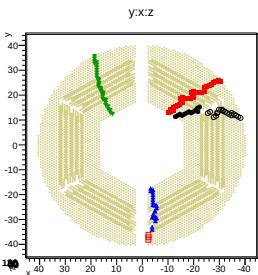
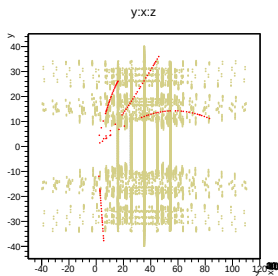
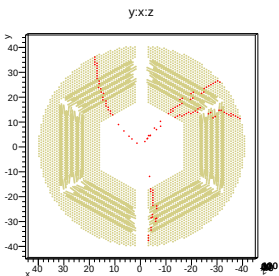


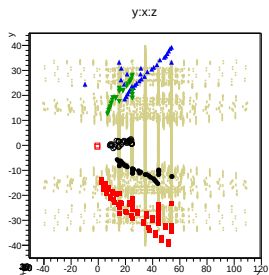
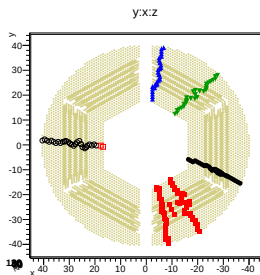
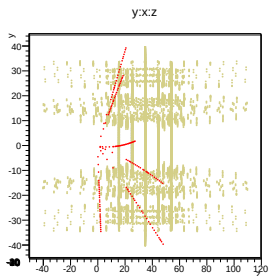
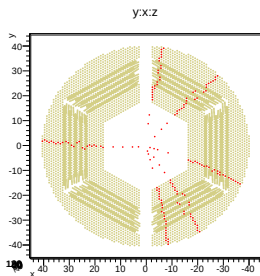
Z coordinates

- ▶ We extend the map by more than 20000 virtual nodes.
- ▶ Virtual nodes are placed at the mean position in xy -plane between tubes with different slope.
- ▶ Their z -coordinates are equal to the intersection position of the wires.
- ▶ Turned active iff both neighbors are active.









Conclusion:

- ▶ The algorithm performs well. Majority of the tracks are recognized and no missing segments.
- ▶ Z-coordinates reconstruction looks promising.

Future work

- ▶ Testing the performance using DPM.
- ▶ By layer, ordered processing of active pixels.
- ▶ Better Z coordinate reconstruction.
- ▶ Allowing gaps during path reconstruction.
- ▶ Splitting undersegmented tracks and merging compatible segments.
- ▶ Including more detectors in the graph.
- ▶ Source code needs to be reorganized.

Questions?