Road Surface Measurement Spacing Based on Delaunay Triangulation

By

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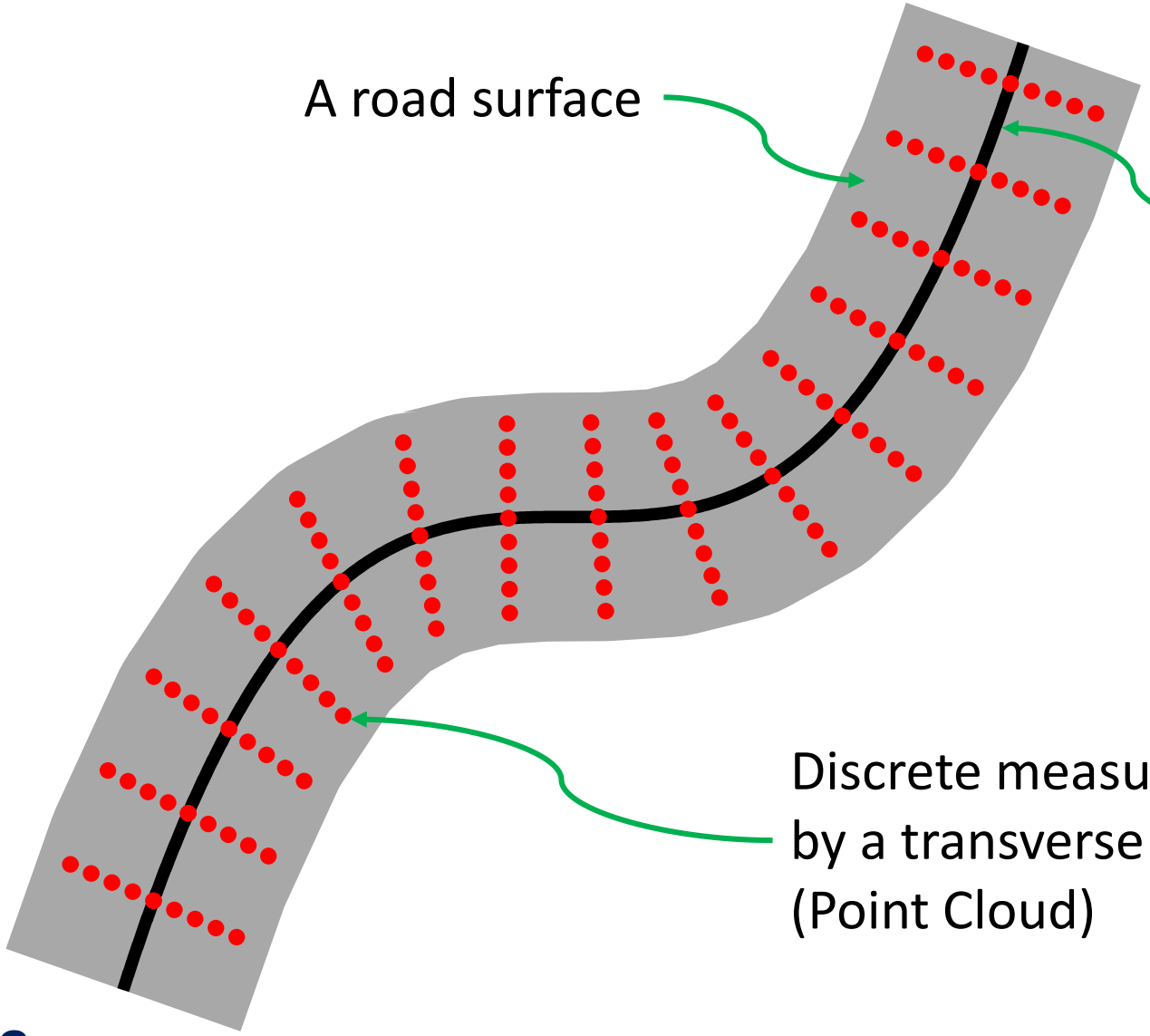
Objective

*Identify the **transverse** and **longitudinal** measurement spacing for a transverse pavement profiler*

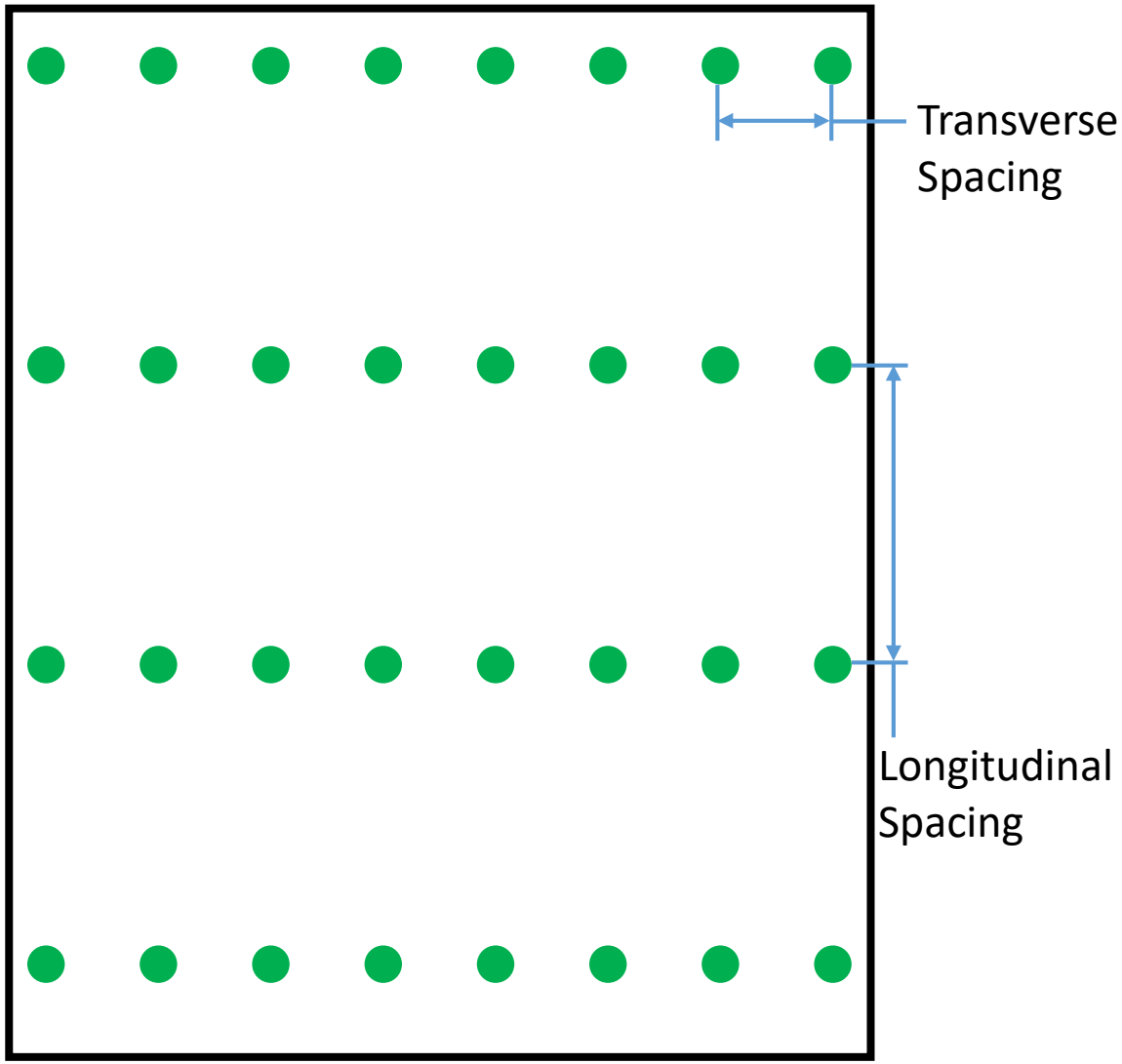
- Need steamed from a FHWA Pooled Fund project

- Desired requirements:
  - Automated
  - Robust

What information do we know?

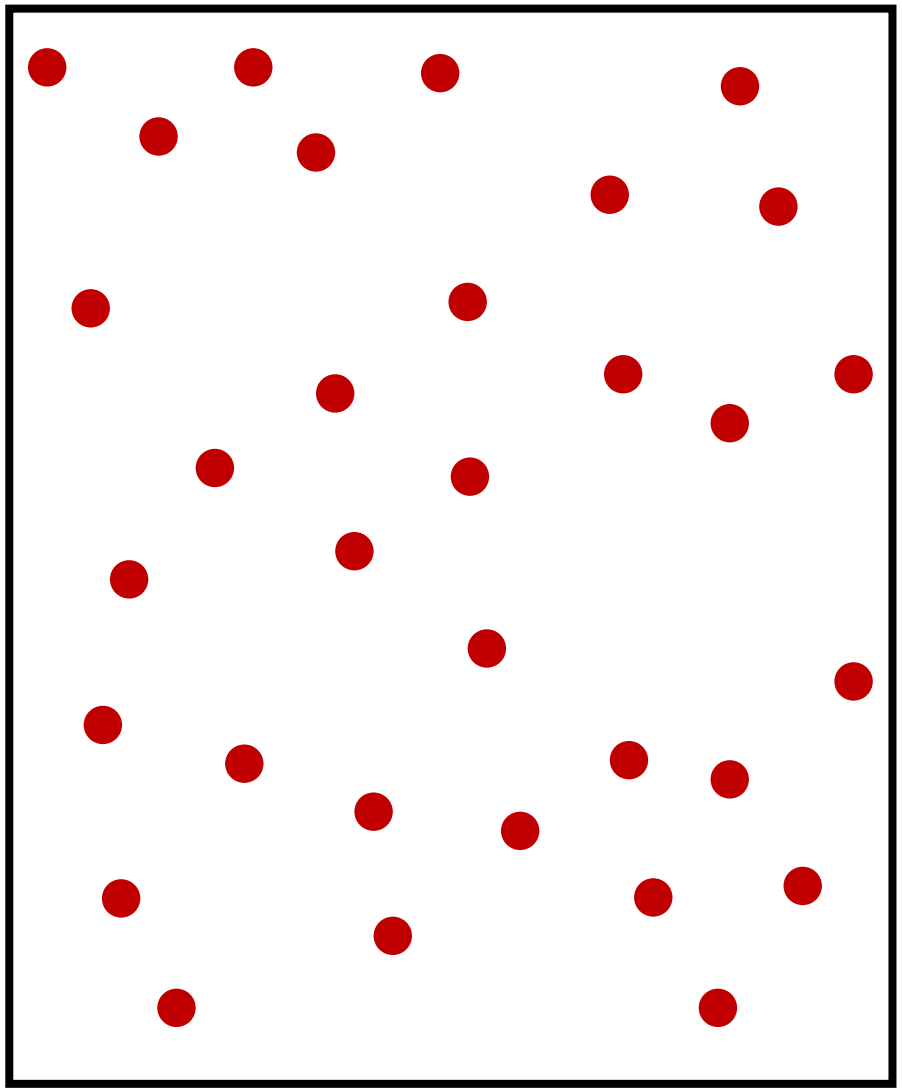


Motivation: Road Scan 1



- Regularly Gridded Data
  - Uniform spacing
  - Easy to visually see the transverse and longitudinal spacing
  - Difference between neighboring data points

Motivation: Road Scan 2



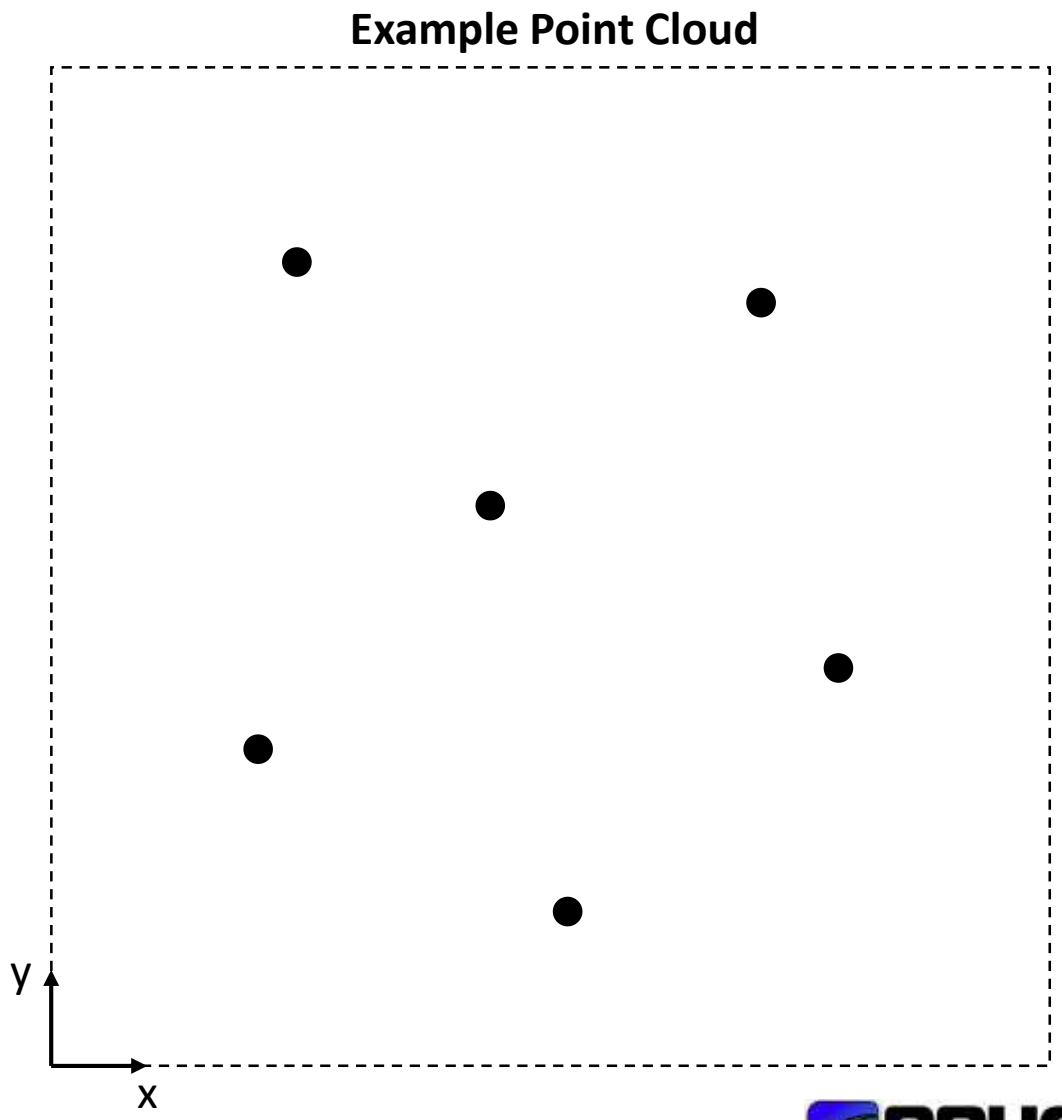
- Irregularly Spaced Data
  - What's the transverse spacing?
  - What's the longitudinal spacing?
  - No visual way of telling what the spacing is

Background: Nominal Point Spacing (NPS)

- A single representative distance between measurements in a point cloud

- Bounds on the smallest spatial feature which can be extracted.

- There are several methods for calculating the NPS

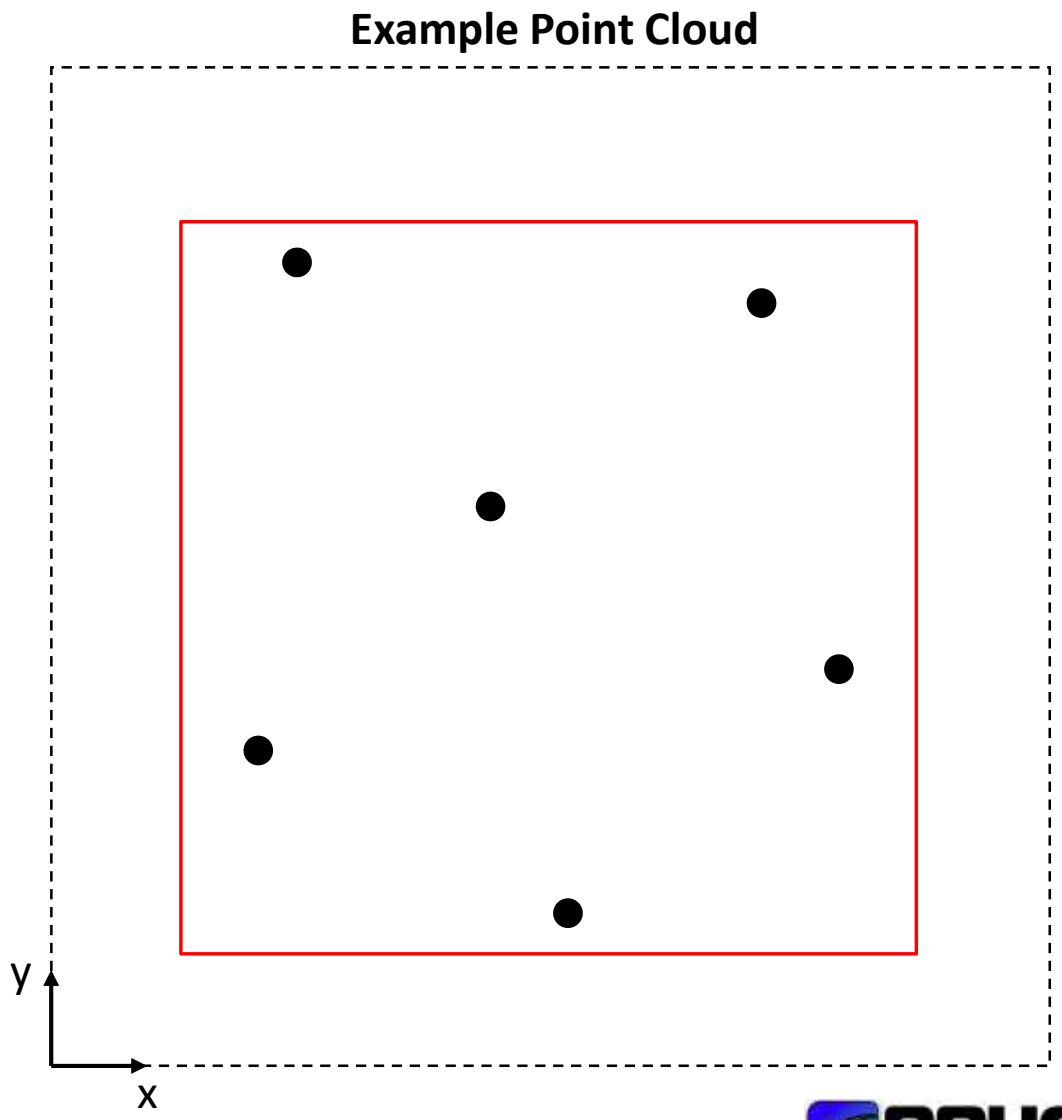


Background: Calculating NPS
Averaging Method

- Define a local area of a point cloud using a polygon

- Identify the point density
  - $\text{Density} = \frac{\text{Number of Measurement Points}}{\text{Area of a Perscribed Polygon}}$

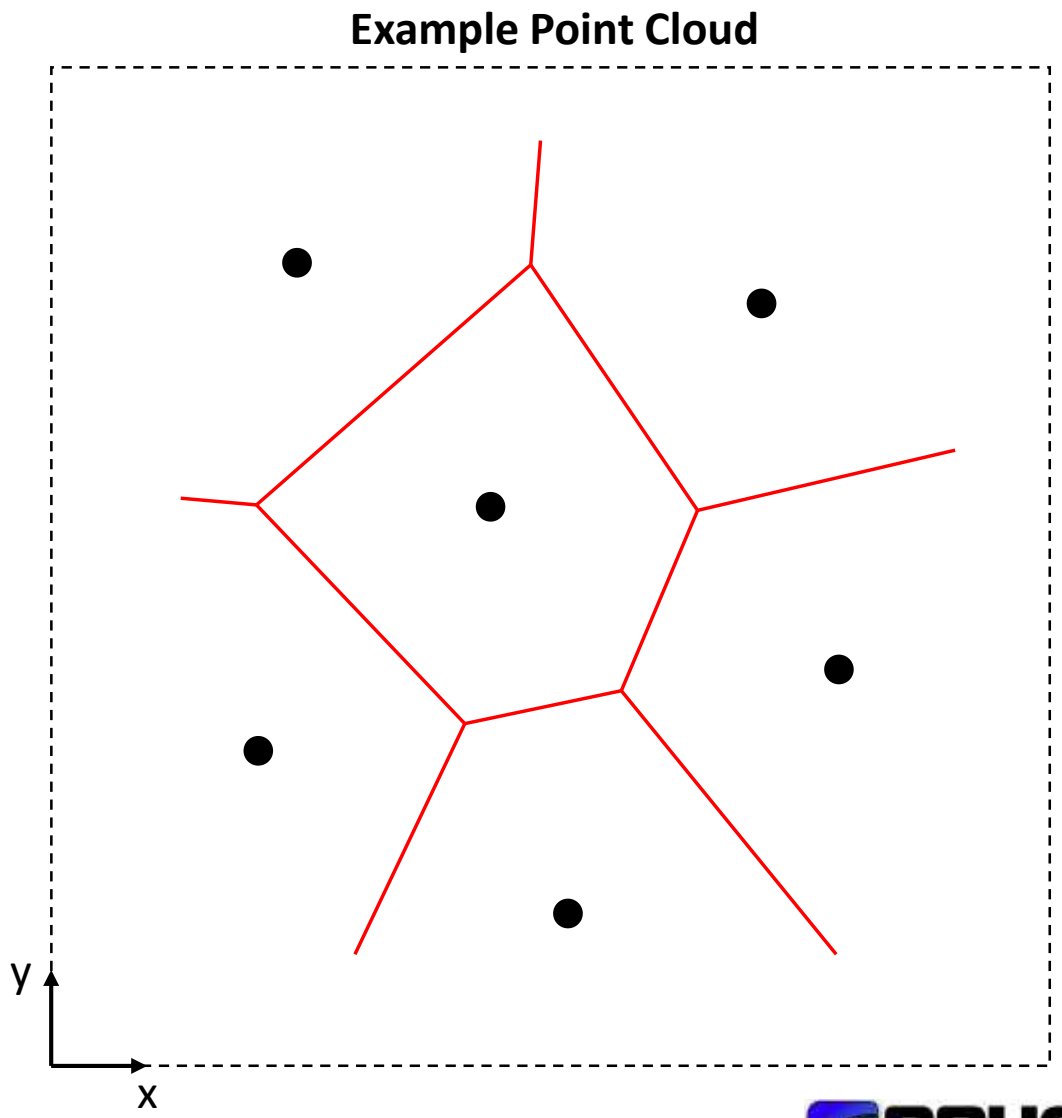
- Average NPS
  - $\text{NPS} = \frac{1}{\sqrt{\text{Density}}}$



Background: Calculating NPS

Voronoi Diagram

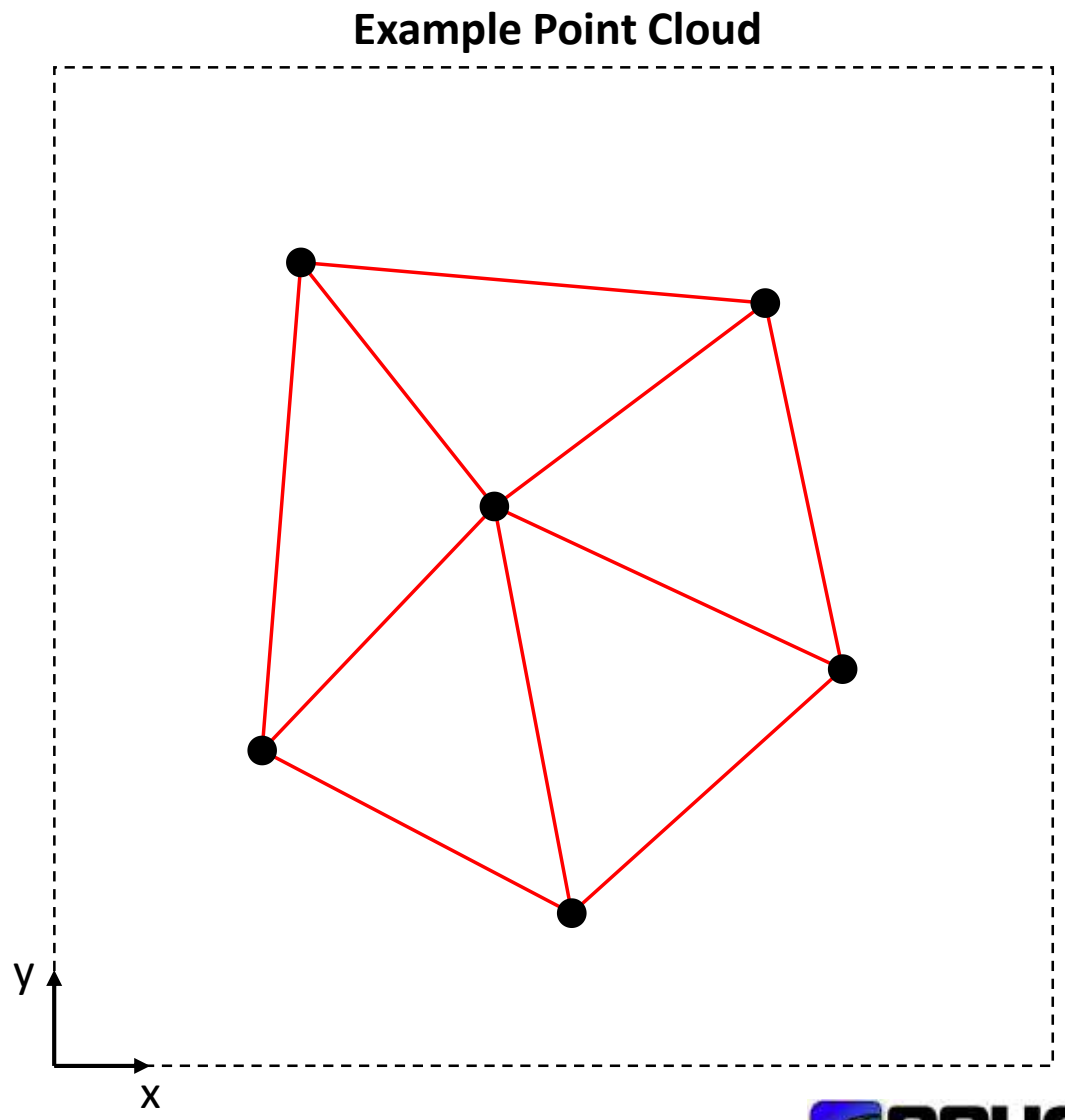
- Create a Voronoi diagram for a given point cloud
  - Unique polygon around each point
- Identify the point density
  - $\text{Density} = \frac{1}{\text{Voronoi Polygon Area}}$
- Average NPS
  - $\text{NPS} = \frac{1}{\sqrt{\text{Density}}}$



Background: Calculating NPS
Delaunay Triangulation

- Create a Delaunay Triangulation between all point cloud points
  - Triangles between points
  - No lines of the triangles cross

- Per measurement point calculate the average edge length to all nearby points
  - $\mathrm{NPS} = \frac{[d_1\ d_2\ d_3 \cdots d_N]}{N}$



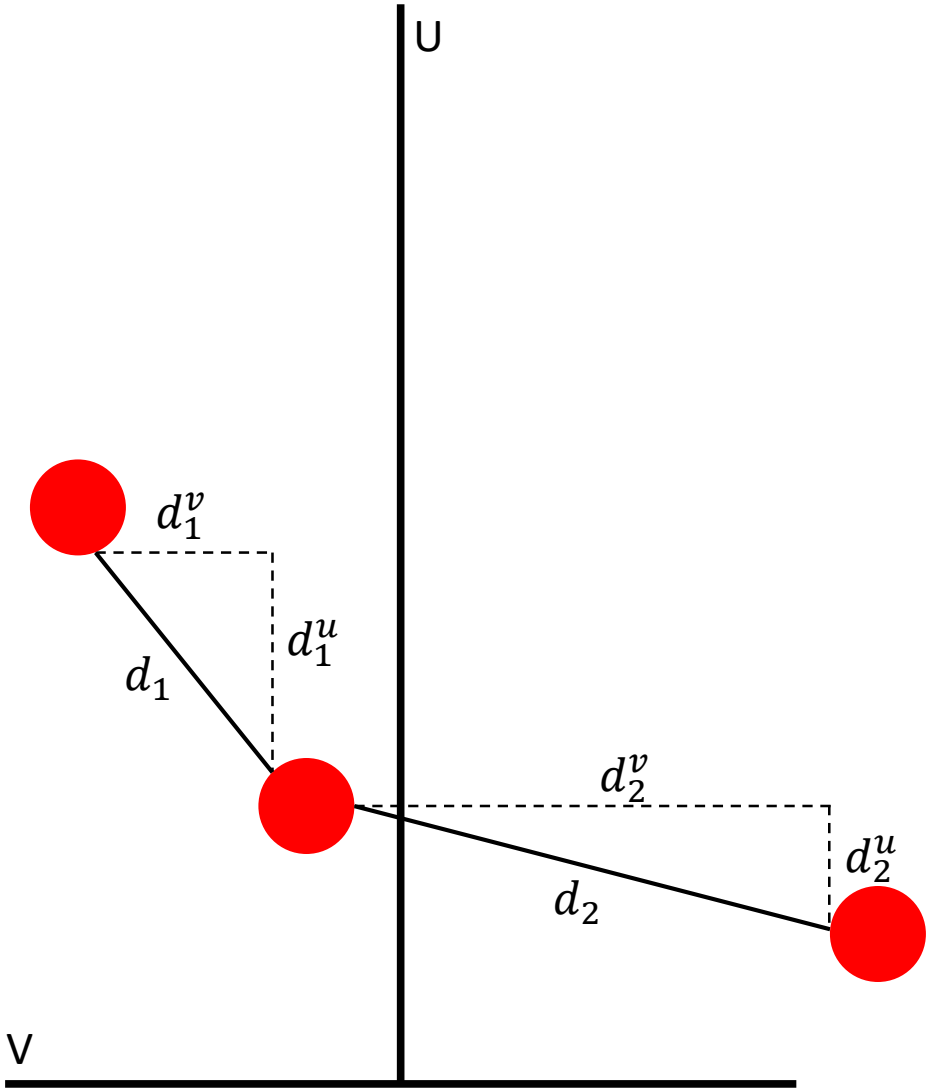
Background: Calculating NPS
Summarizing Comments

- Draw back of NPS in general
  - Only a single measure is established (no direction is considered)

- Averaging Method and Voronoi Diagrams calculate an average density

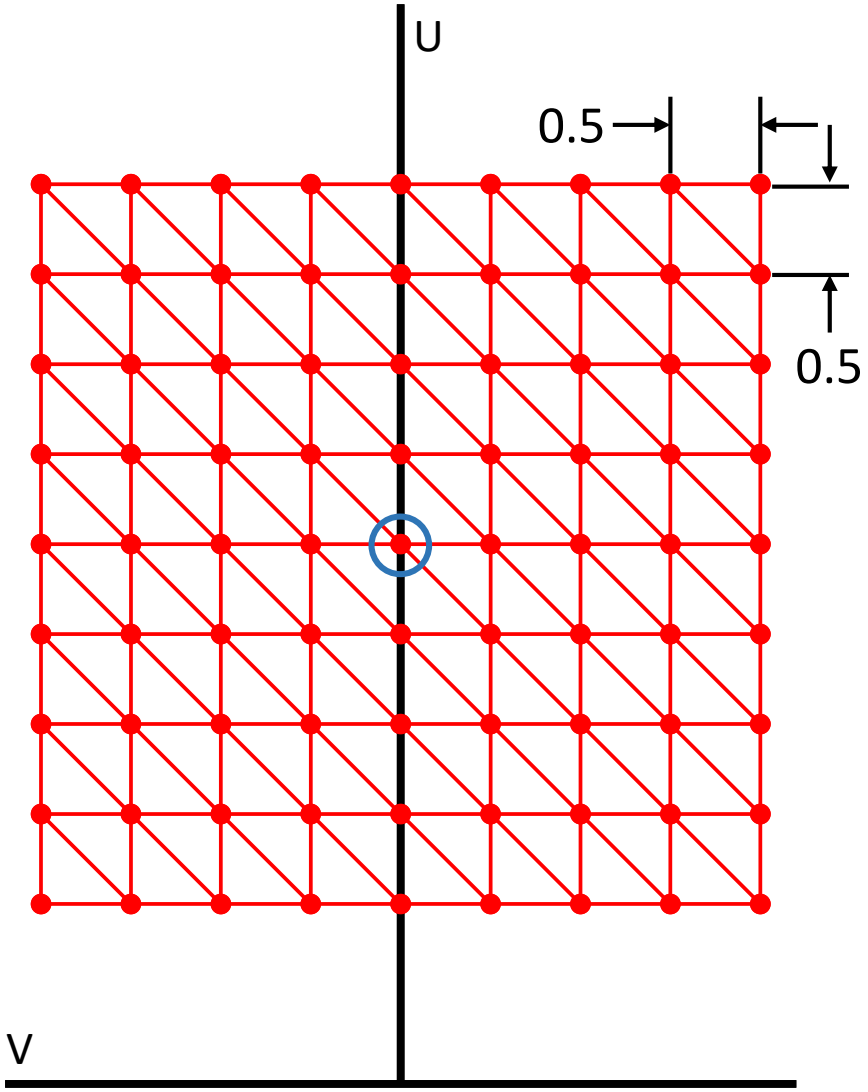
- Delaunay triangulation provides a means of identifying a distance between measurements

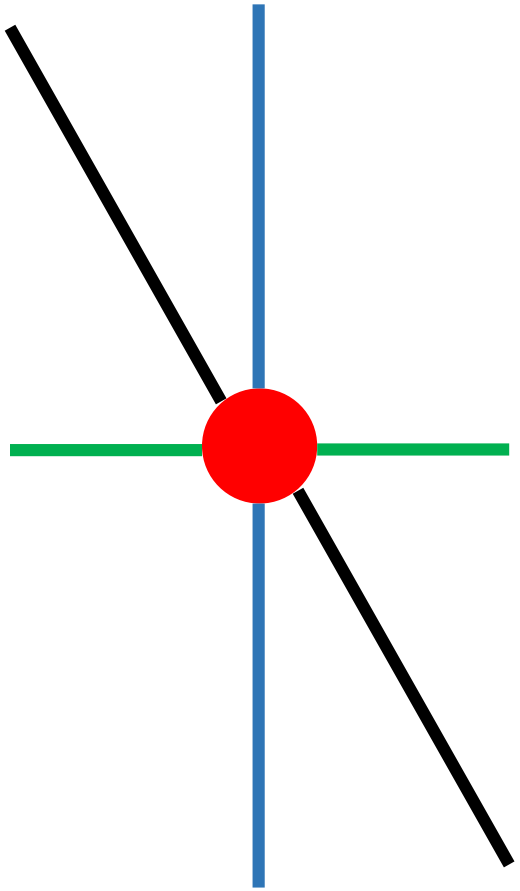
Altering for our Application



- All measures can be considered in a path coordinate system
  - V – Transverse Direction
  - U – Longitudinal Direction
- Each Delaunay edge can be projected onto the (U,V) coordinate system

Regularly Spaced Data

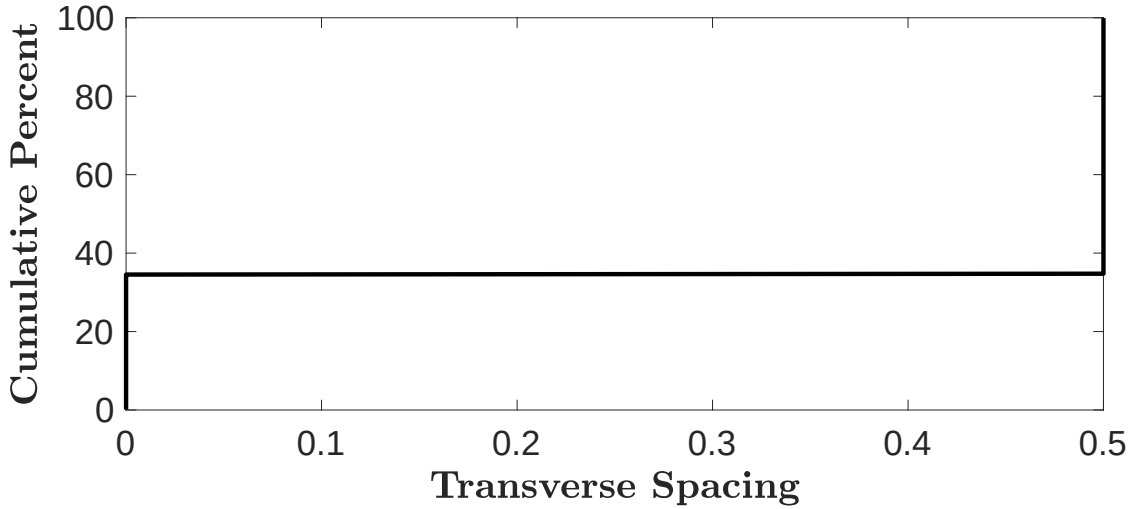


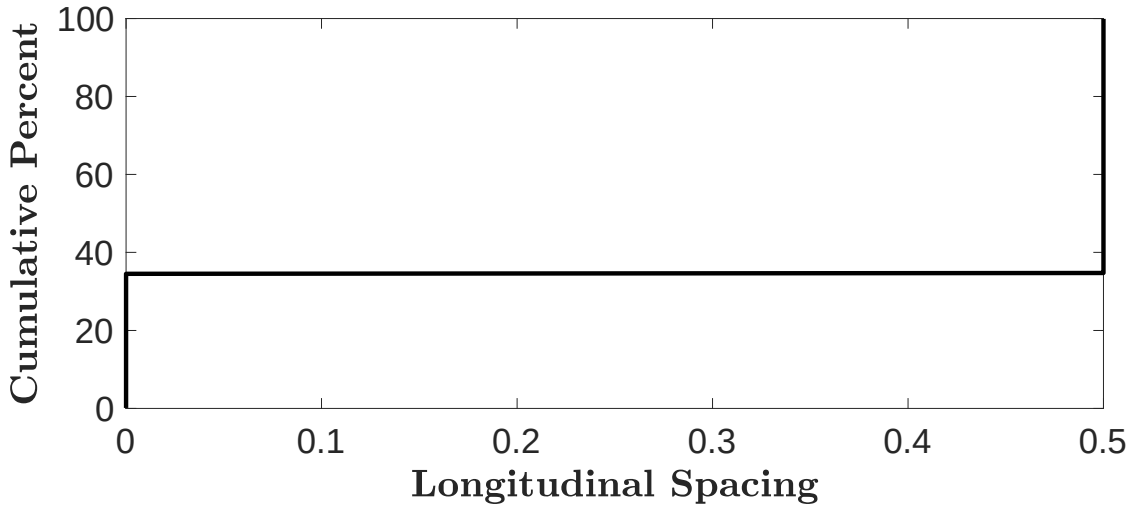


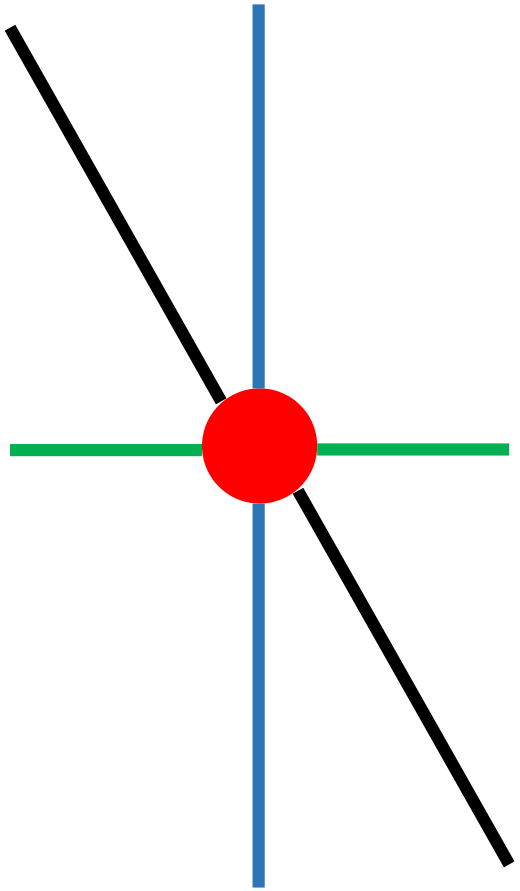
Node Properties:

- 6 Delaunay edges
- 2 Transverse edges
- 2 Longitudinal edges
- 2 Angled edges

Regularly Spaced Data







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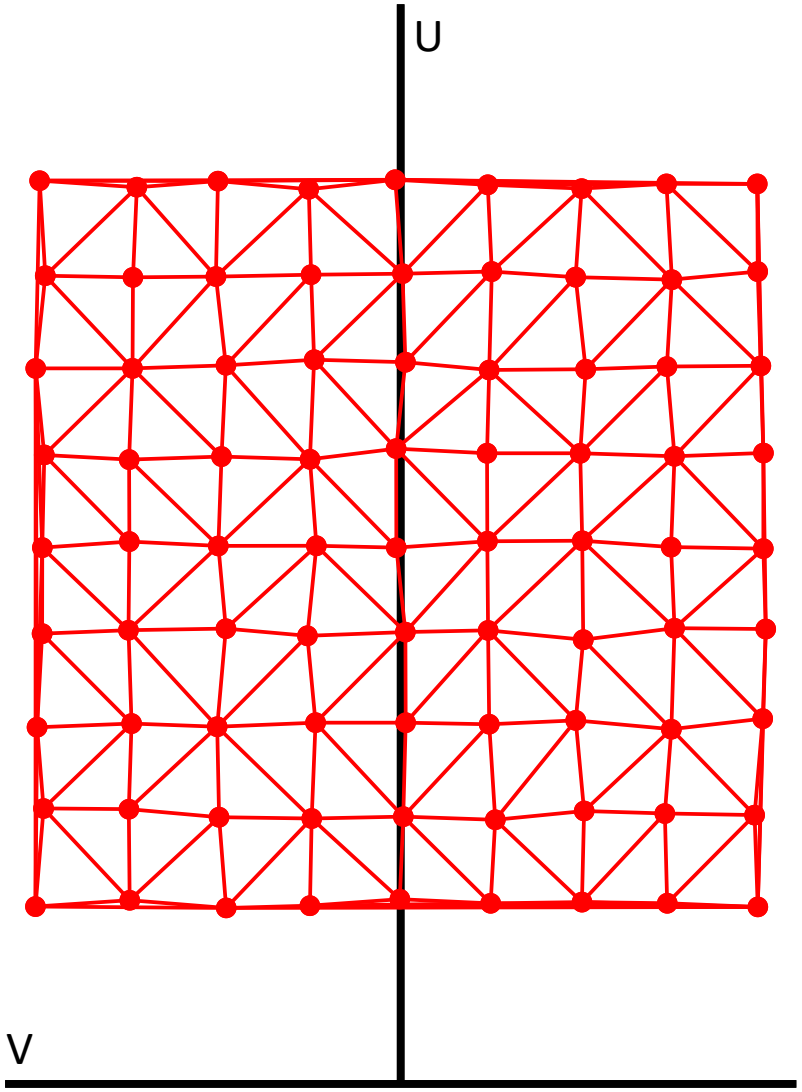
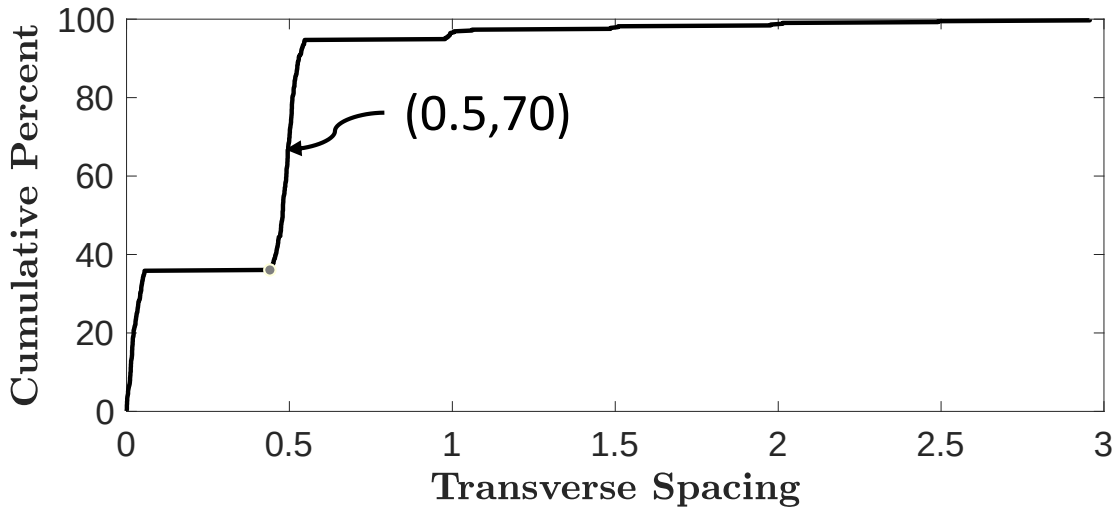
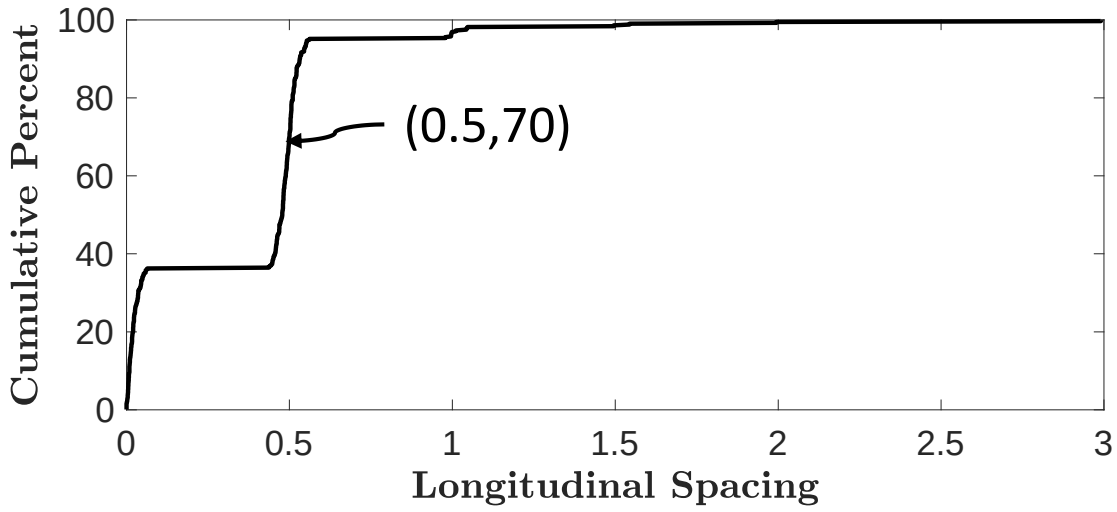
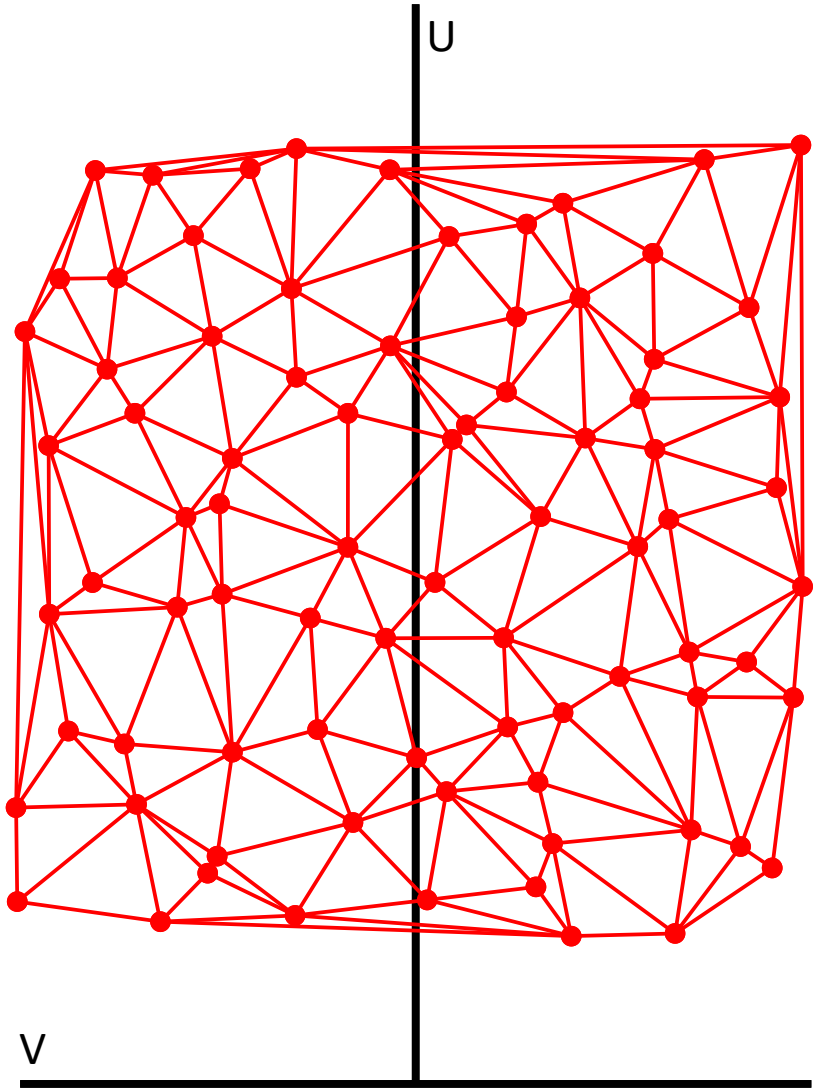
Add a Little Noise

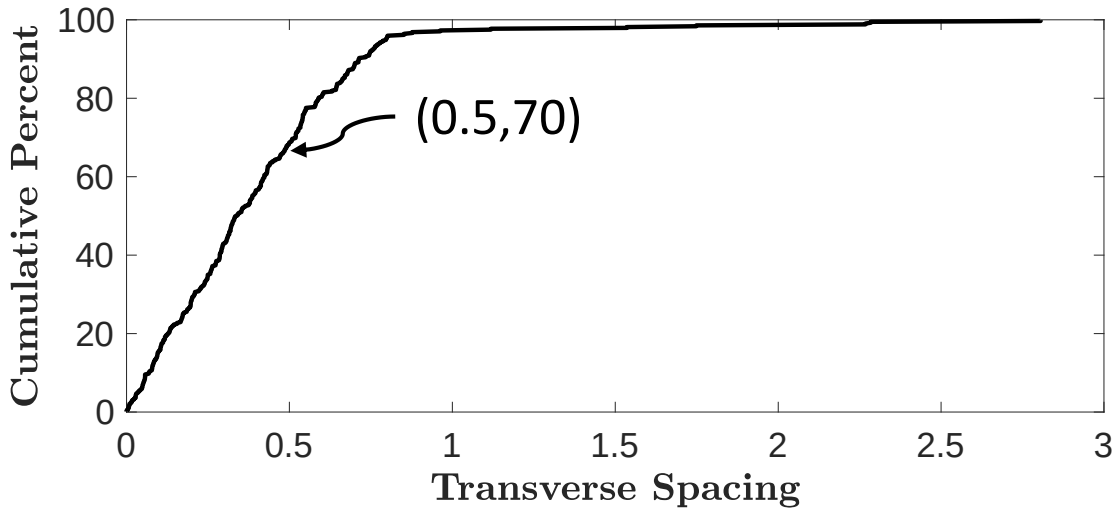


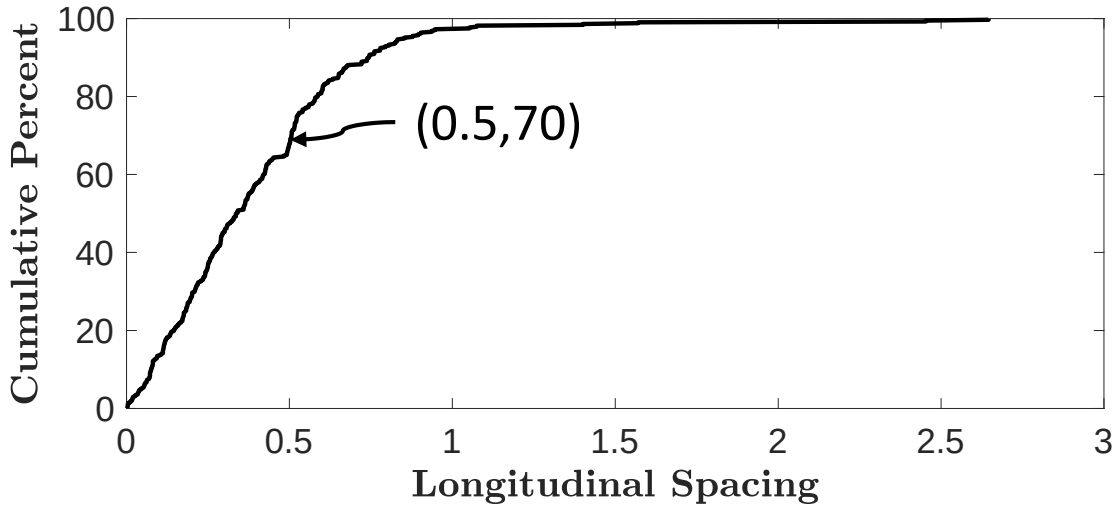




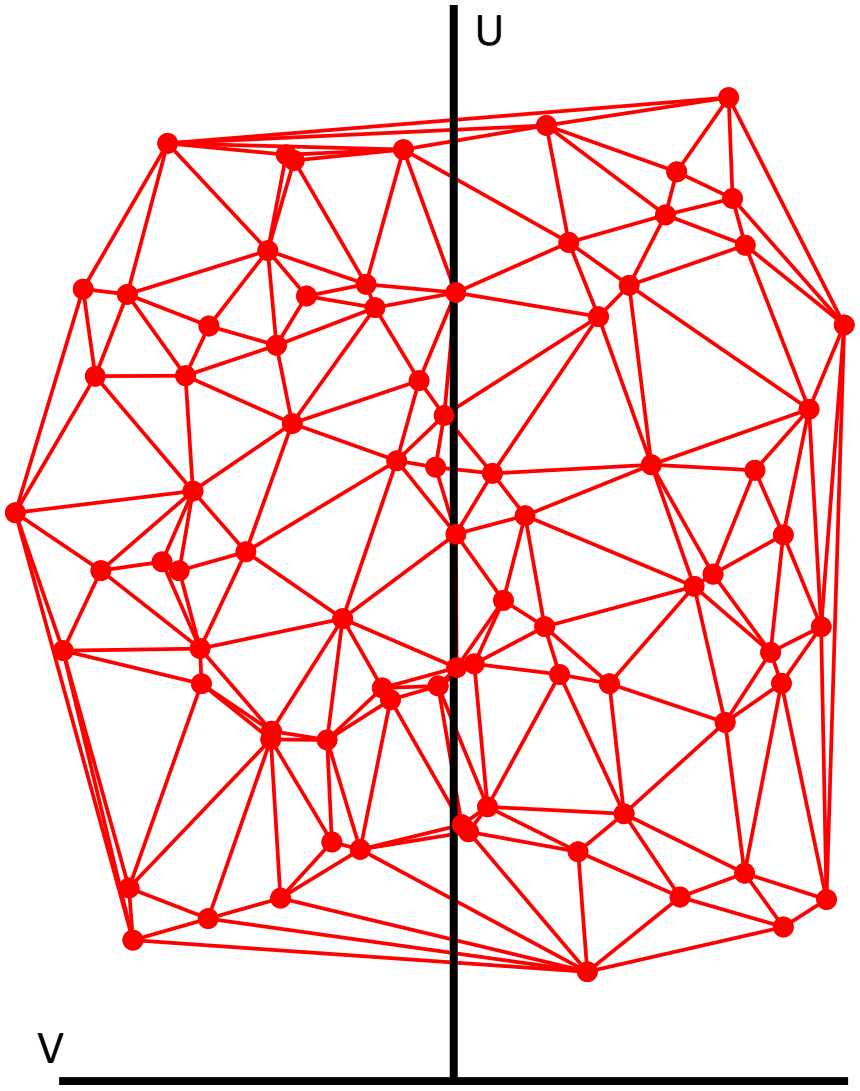
Add More Noise

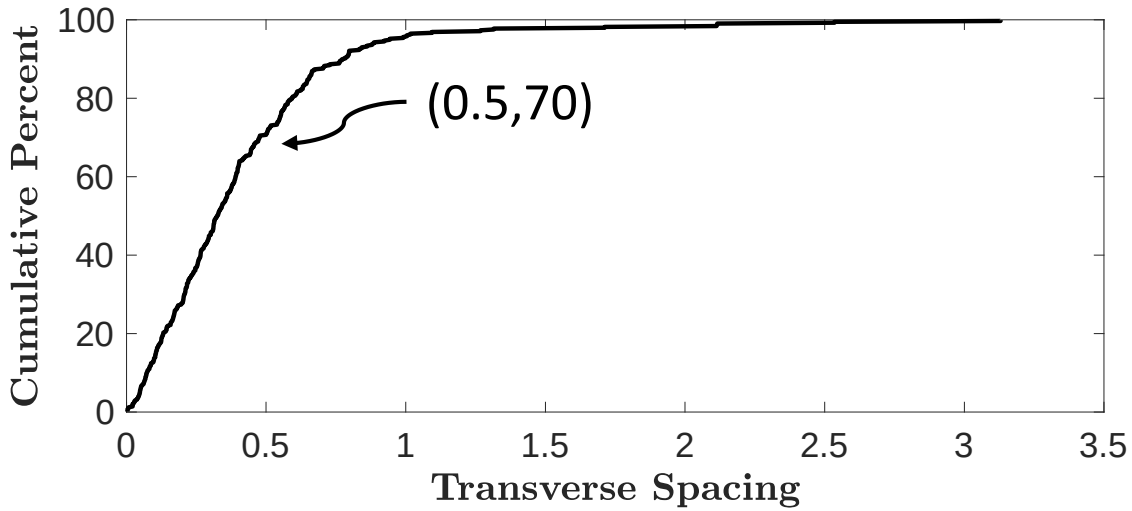


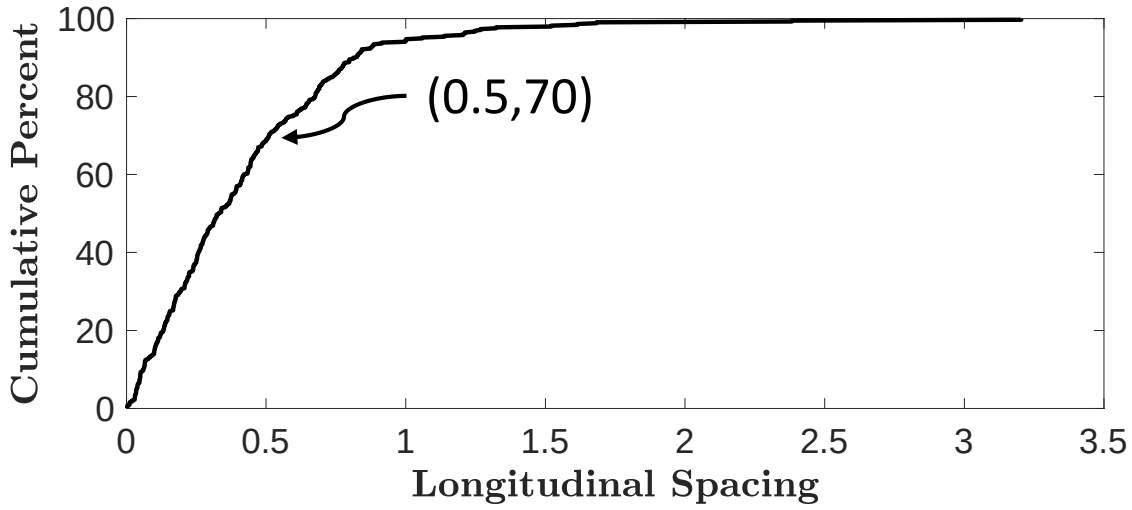




Completely Random Data







Concluding Statements

- Delaunay triangulation allows for connections to be made between measurements regardless of the spacing
- Each Delaunay edge can be projected onto the transverse and longitudinal axes
- There is still work to be performed before this analysis method can be implemented