RPUG
Road Profile Users' Group

CELEBRATING 250 YEARS OF PROGRESS

HONORING THE PAST. PAVING THE FUTURE.

2026 RPUG CONFERENCE ★ PITTSBURGH, PA ★ APRIL 28 - MAY 1

GEOREFERENCING ATTRIBUTES

JOHN B. FERRIS: VIRGINIA TECH, ASSOCIATE PROFESSOR
ROAD SCHOLAR SOLUTIONS, MANAGING MEMBER

GEOREFERENCING ATTRIBUTES

Road Attributes:

Elevation, Friction, Texture, Color, Roughness…

How should we locate (Georeference) attribute measurements taken at different times by different equipment?

GEOREFERENCING ATTRIBUTES

METHOD SHOULD BE:

- CLEAR AND UNAMBIGUOUS,
- STABLE AND ENDURING,
- COMPACT WHEN DIGITALLY STORED,
- COMPREHENSIVE AND ALL-ENCOMPASSING (DIFFERENT ATTRIBUTES, EQUIPMENT, TIMES)

Hold me accountable to these!

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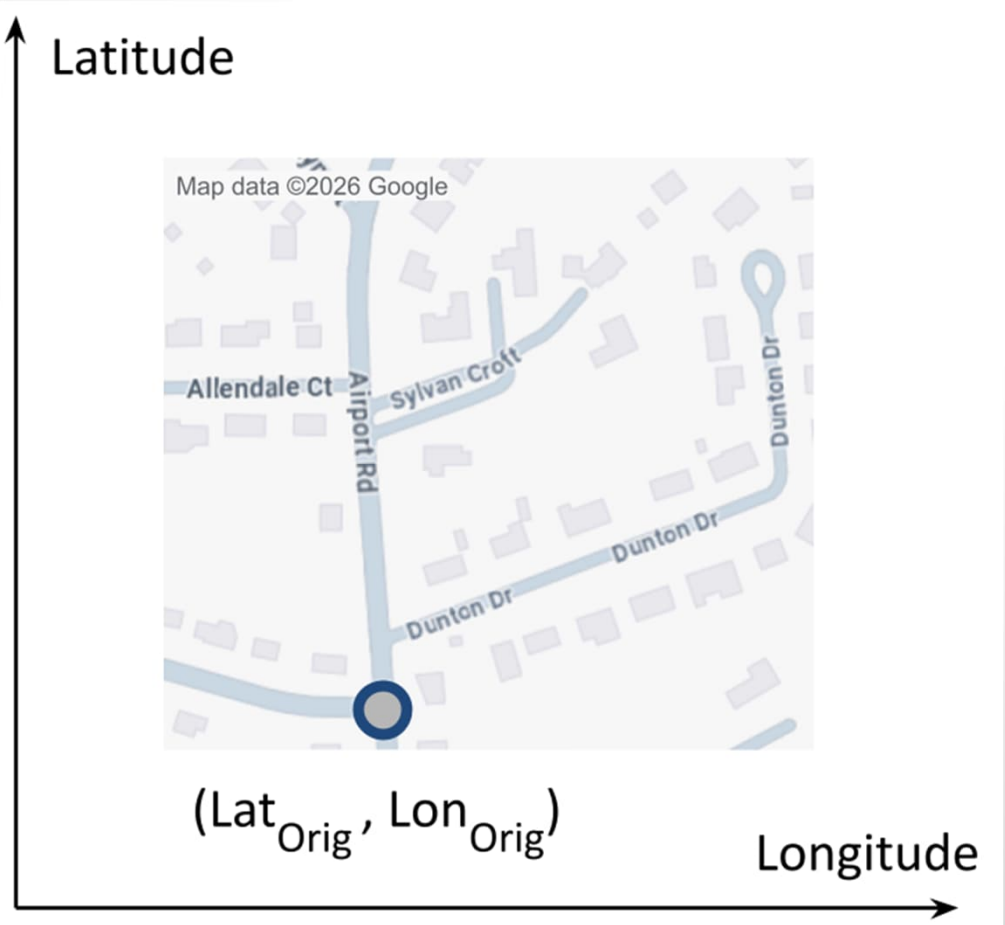
GEOREFERENCING ATTRIBUTES

1. Georeferencing System
    - Coordinate System in Global Reference Frame
    - Stations (Ground Control Points)
    - Spline
    - Path Coordinates
2. Attribute-Specific Grids

1. GEOREFERENCING SYSTEM

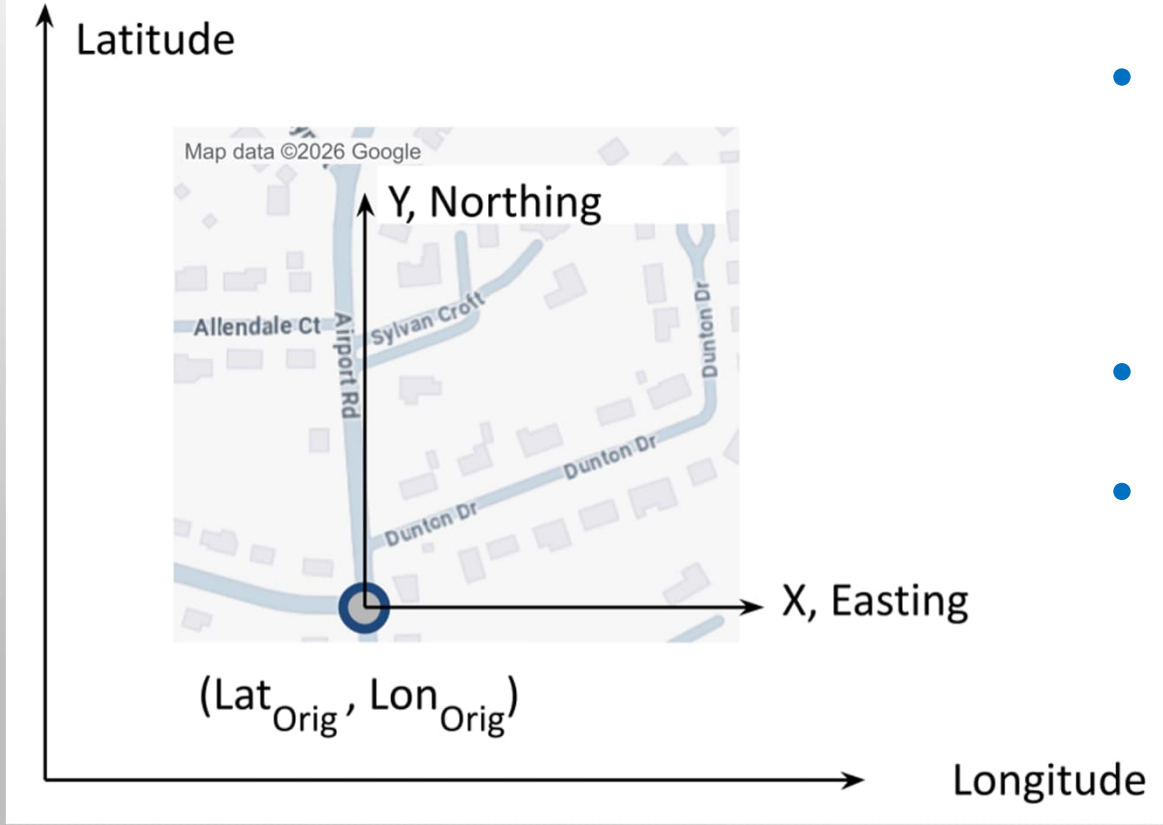
Reference Origin in Global Reference Frame



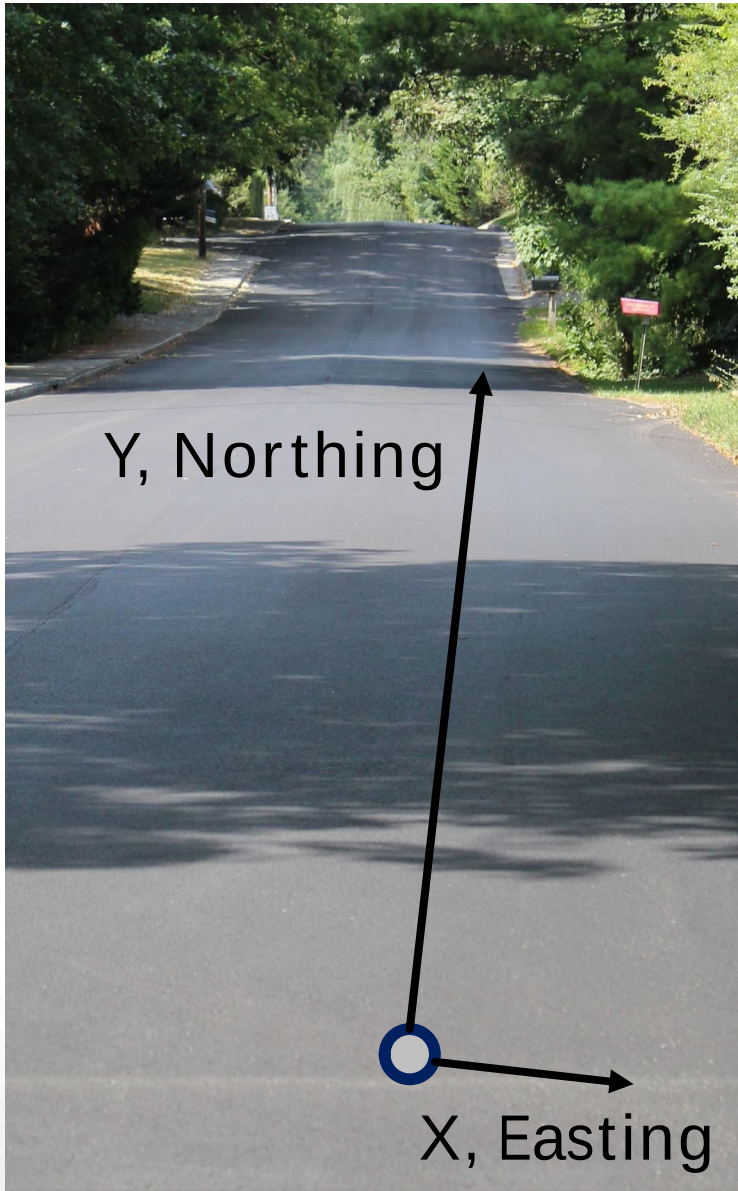
- Start of Road (Lat, Lon, Elev)
- Established by:
  - Transportation Agency
  - Standard
- Example:
  - Lane center
  - Intersection

1. GEOREFERENCING SYSTEM

Reference Coordinate System
Global Coords → Local Coords

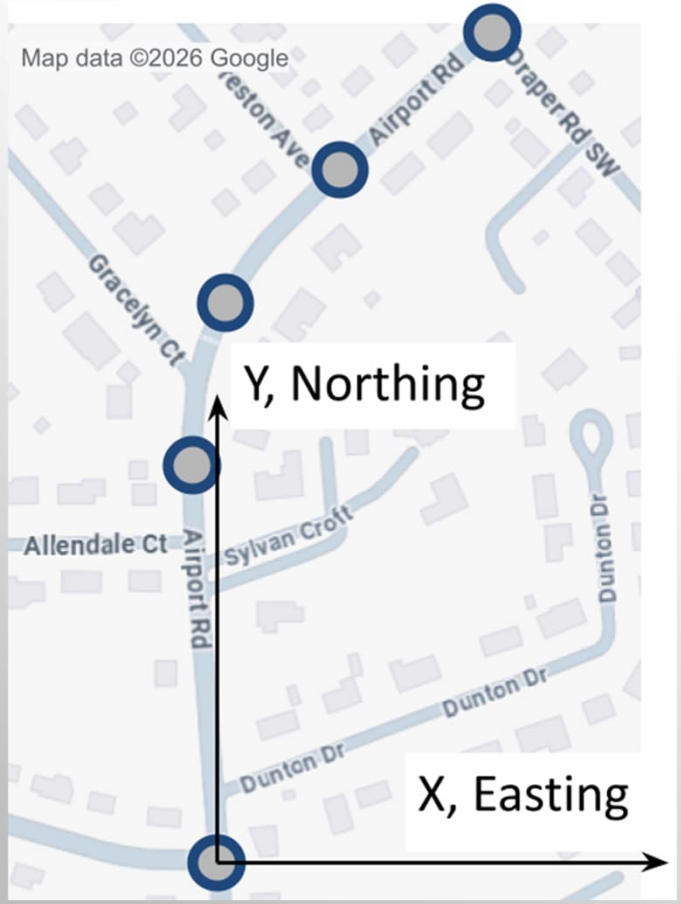


- Both are Earth-Fixed Reference Frames
- Center at Origin
- Local Coords: UTM (meters)

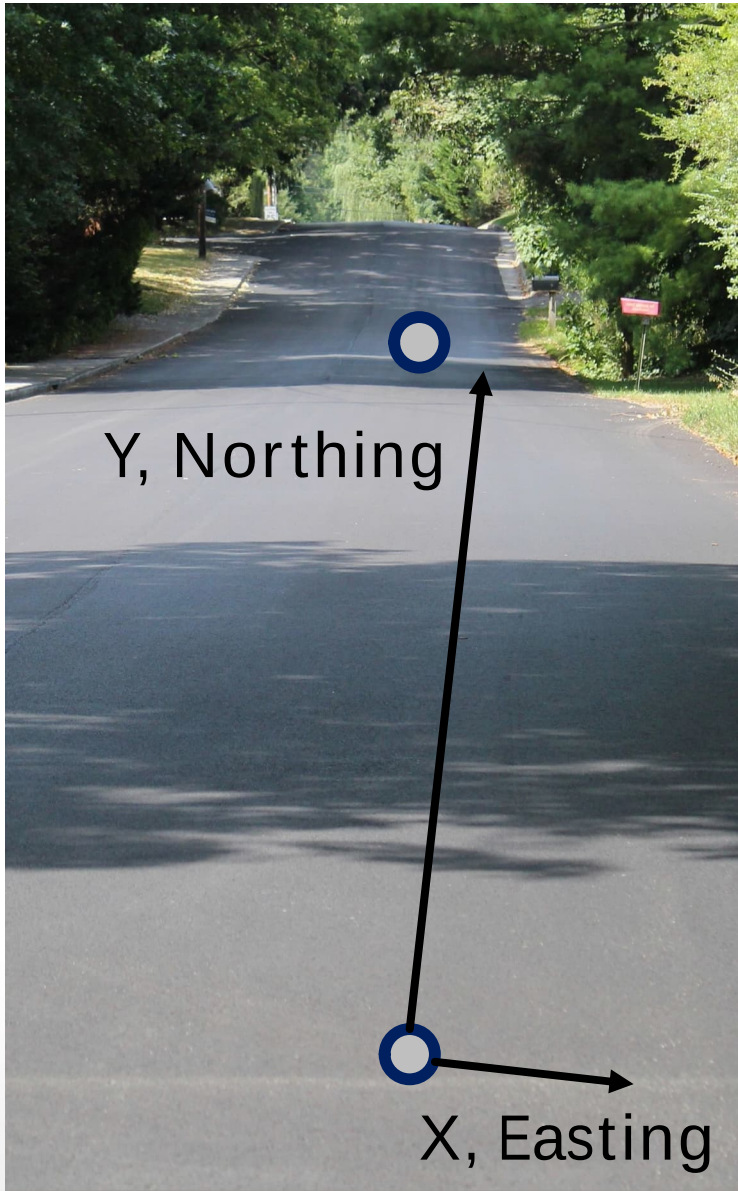


1. GEOREFERENCING SYSTEM

Reference Stations (Ground Control Points)

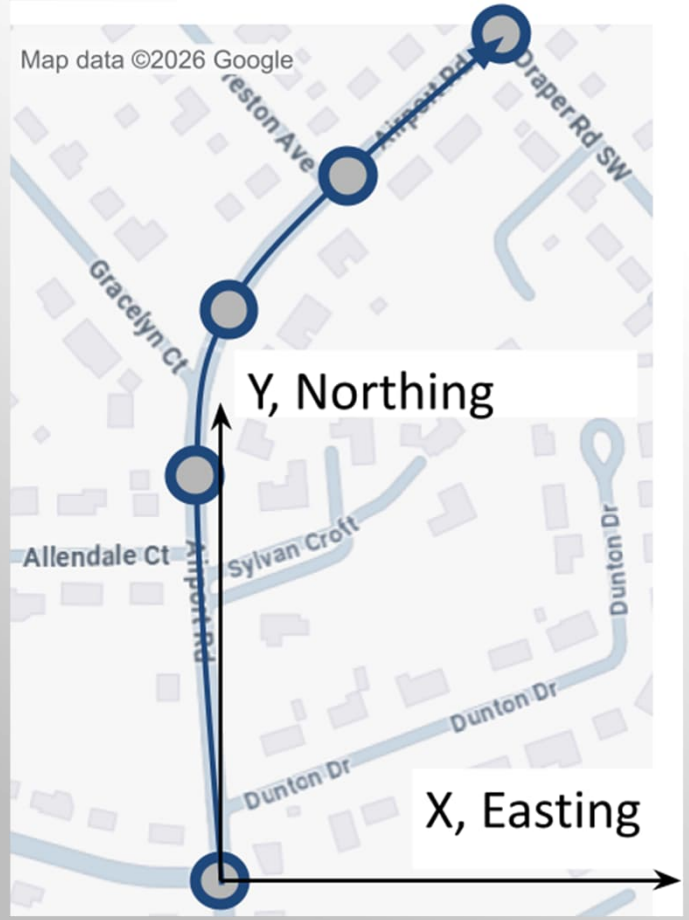


- Number and frequency depend on road curvature

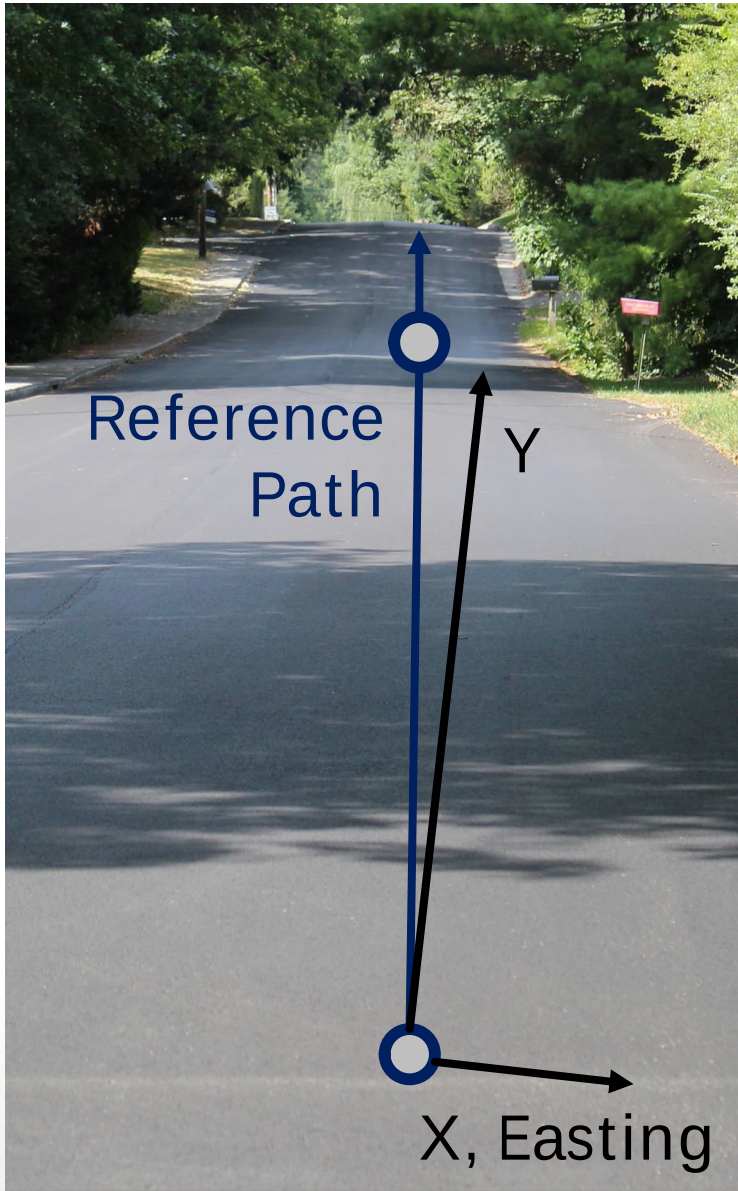


1. GEOREFERENCING SYSTEM

Reference Spline



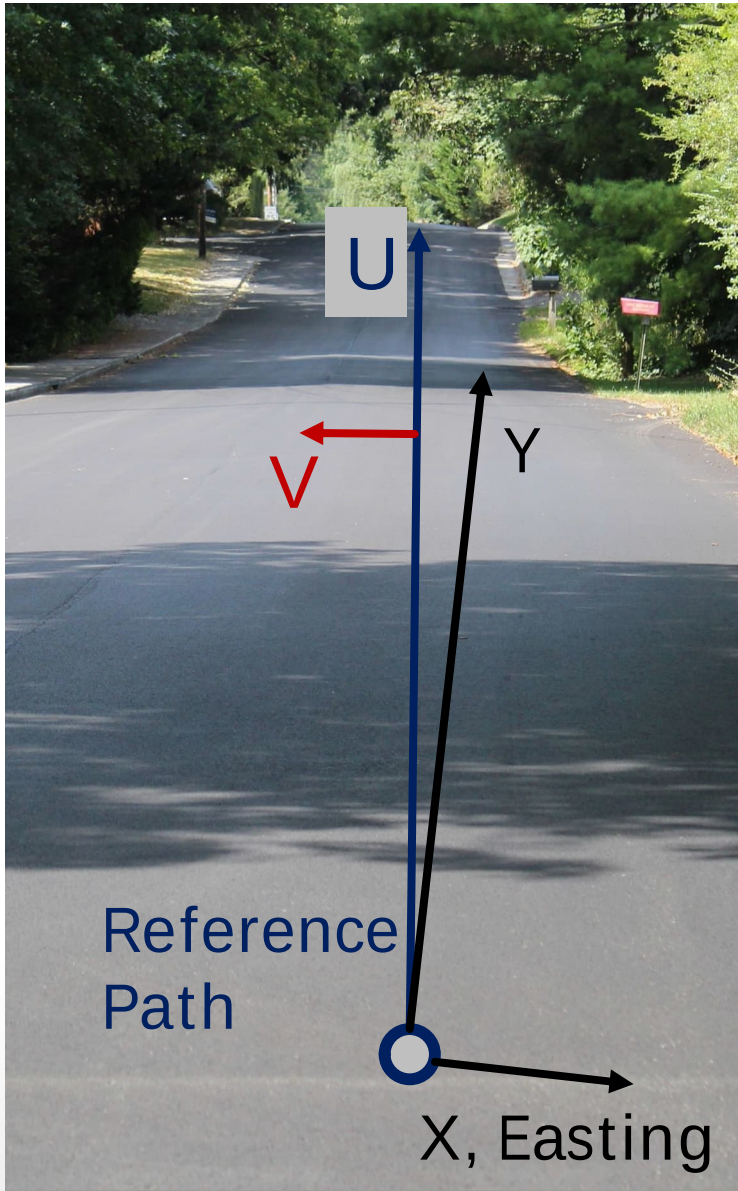
- Defining Spline is critical
- Either
  - Straight line (cities), or
  - Modified Akima
- Specify Reference Stations and Reference Spline
  → Reference Path
- Reference Path
  → *Unambiguous*
  → *Continuous, not discrete*



1. GEOREFERENCING SYSTEM

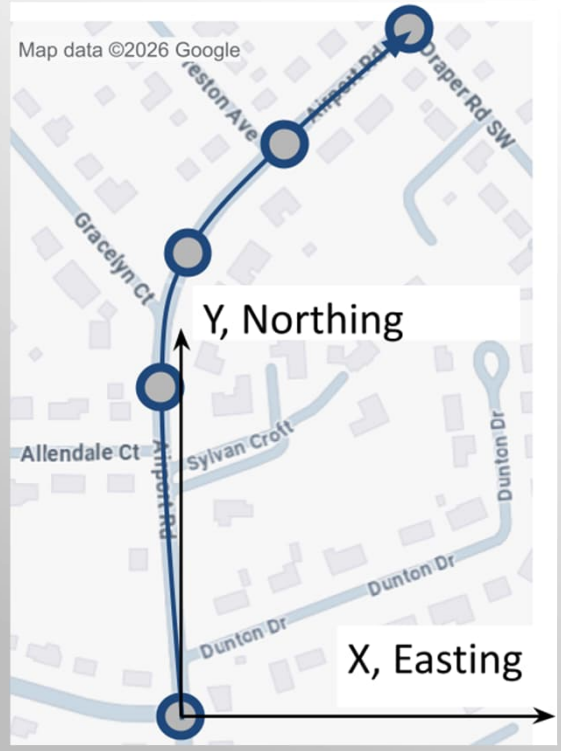
Reference Path Coordinates

- Reference Path Coordinates (U,V) are *continuous, not discrete*
- U: Distance traveled from Reference Origin along Reference Path
- V: Distance perpendicular to U at all points along Reference Path
- (Longitudinal, Transverse)



FILE FORMAT

UNAMBIGUOUS, STABLE, AND COMPACT



Meta Data

1. Reference Path Identifier (unique "name")
2. Origin Location, (LatOrig, LonOrig, ElevOrig)
3. Reference Spline Identifier: "linear", "makima"
4. Distance Units: "meters", "miles"

Data

Reference Stations (Easting, Northing from Origin)

Example:

Meta Data

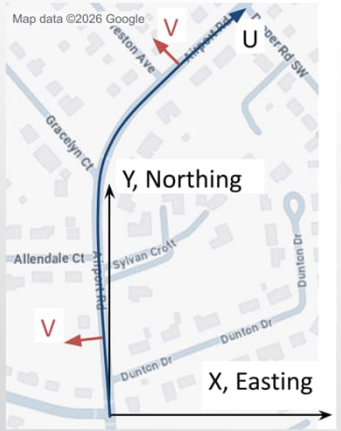
```
VA_Blacksburg_Airport_Southgate_North
37.217273, -80.408295, 650.53
"makima"
"meters"
```

Data

-13.45	192.85	9.98
-1.52	271.36	10.97
66.02	353.32	3.37
137.2	419.89	-0.45

1. GEOREFERENCING SYSTEM

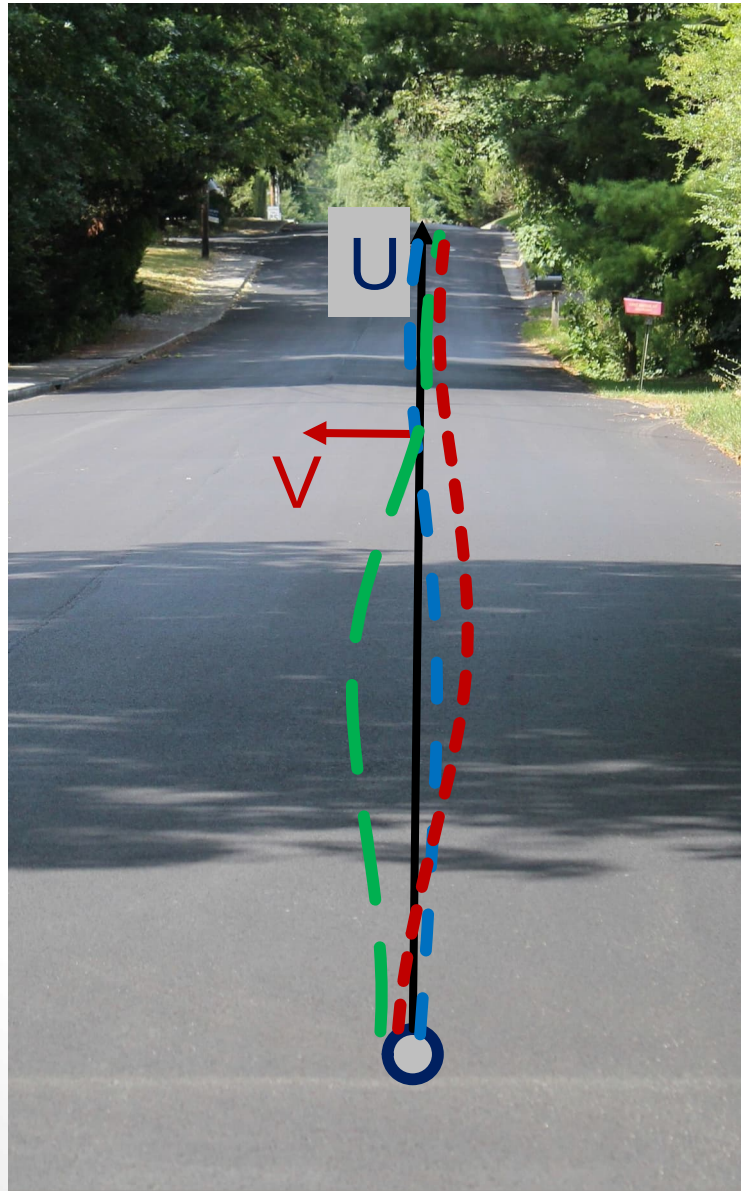
So What?!



(U,V) are natural coordinates for data acquisition (DAQ)

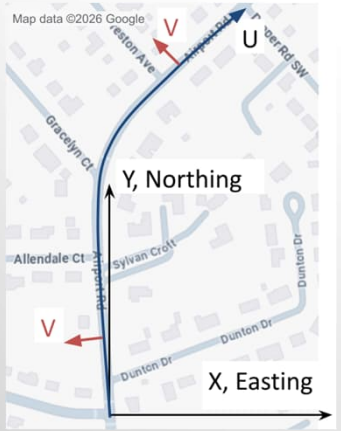
- Reference Path is known exactly
- DAQ location is known exactly
- Small deviations (transverse wander) are easy to correct (scale U, shift V)

Multiple Attributes, at different times, Georeferenced to SAME PATH

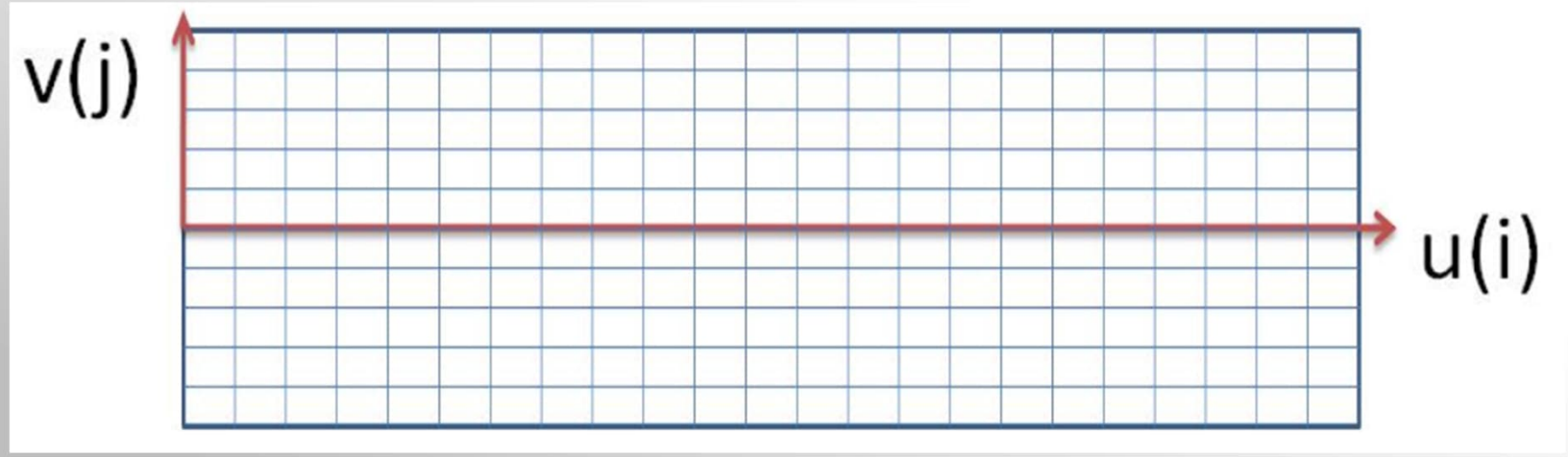


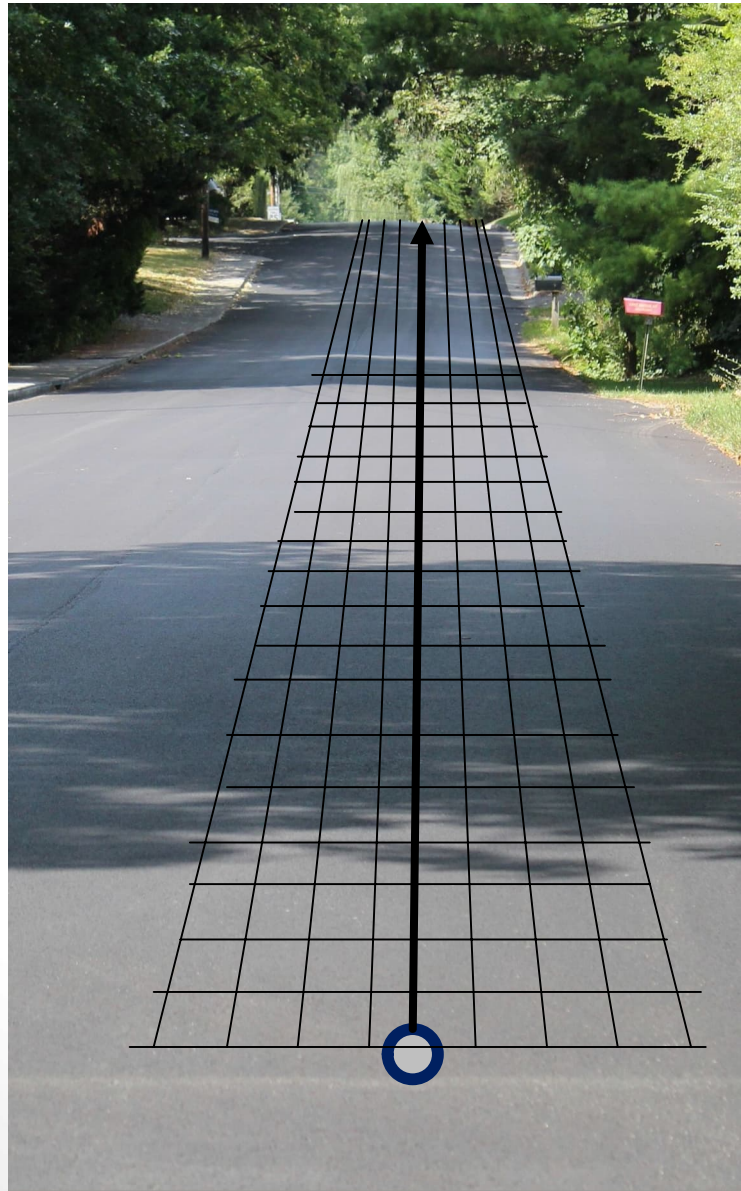
2. ATTRIBUTE-SPECIFIC GRIDS

(U, V) PATH COORDINATES FORM "BACKBONE"



- Form Grid in (U,V) coords for each Attribute
- Attribute determines Discretization
- Example 1: Elevation





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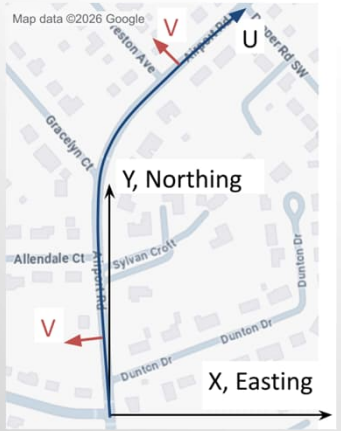
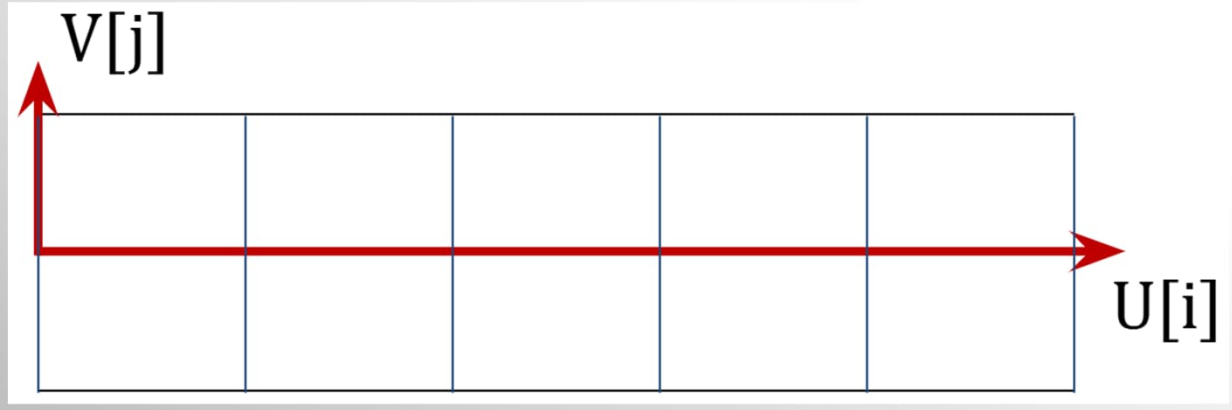
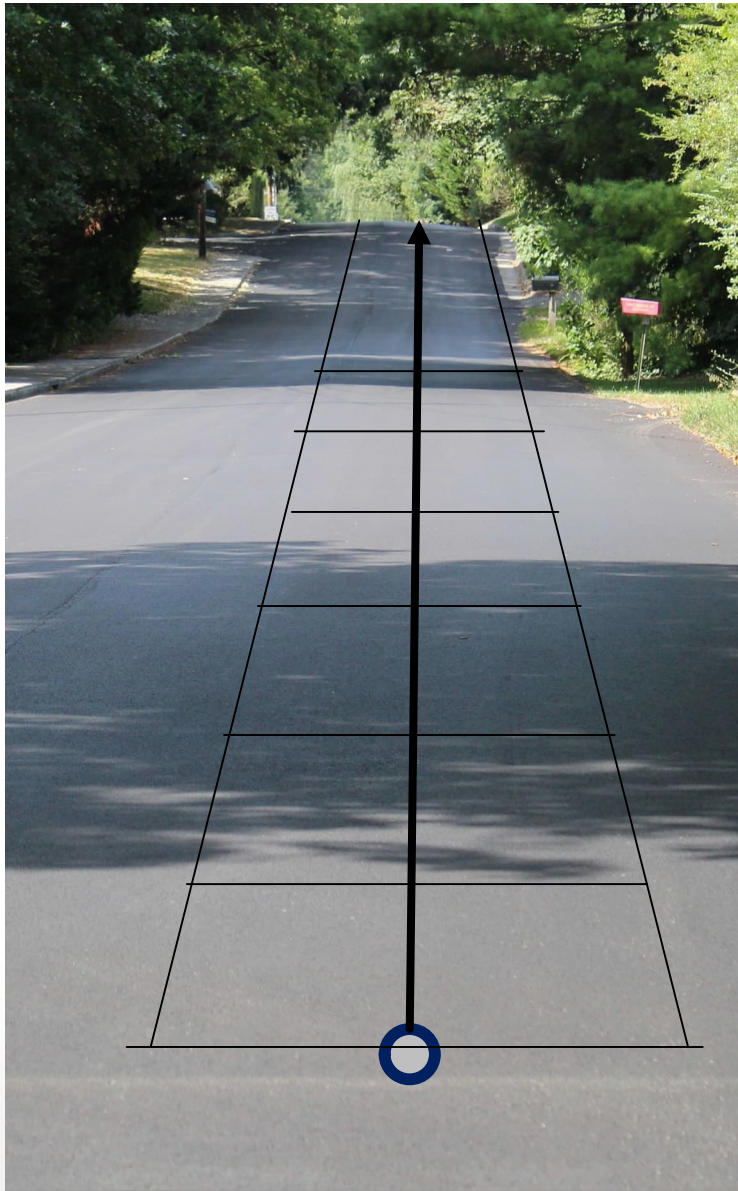
2. ATTRIBUTE-SPECIFIC GRIDS

(U, V) PATH COORDINATES FORM "BACKBONE"



- Form Grid in (U,V) coords for each Attribute
- Attribute → Discretization
- Example 2: Friction





FILE FORMAT

Use *existing* compression methods,

Such as...

HDF5
(hierarchical data format):
e.g., GZIP
On-the-fly compression, partial I/O (read parts of the matrix without loading the whole thing), and metadata.

This is a matrix! ⟶

Meta Data

1. Attribute Identifier (unique "name")
2. Reference Path Identifier
3. Length Units: "meters", "miles"
4. Longitudinal Node Locations, U(i)
5. Transverse Node Locations, V(j)

Data

Matrix of data (U(i) is row, V(j) is column)

Example:

Meta Data

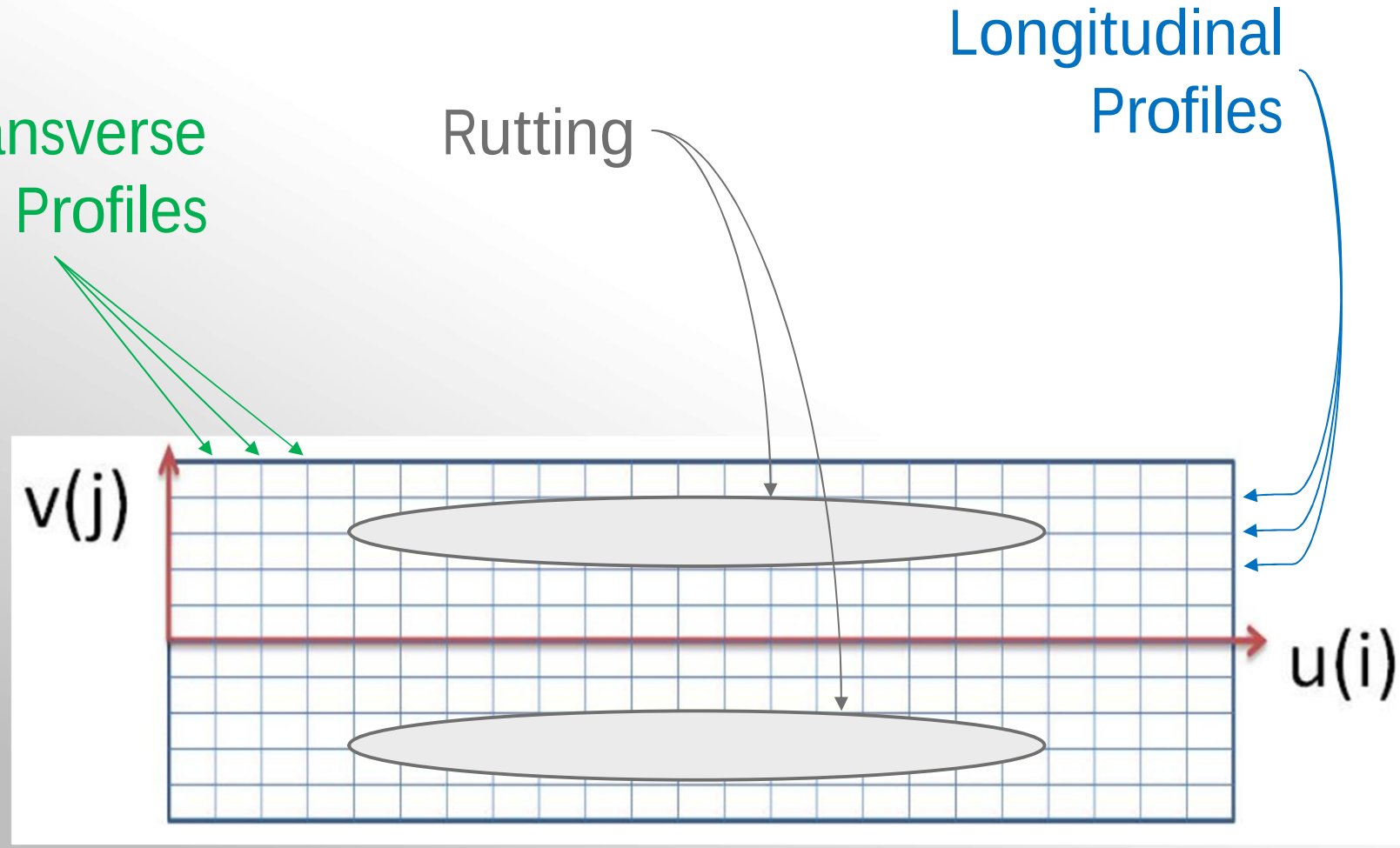
Elevation_Airport_Southgate_North
VA_Blacksburg_Airport_Southgate_North
"millimeters"
0 : 500 : 420000
-2000 : 10 : 2000

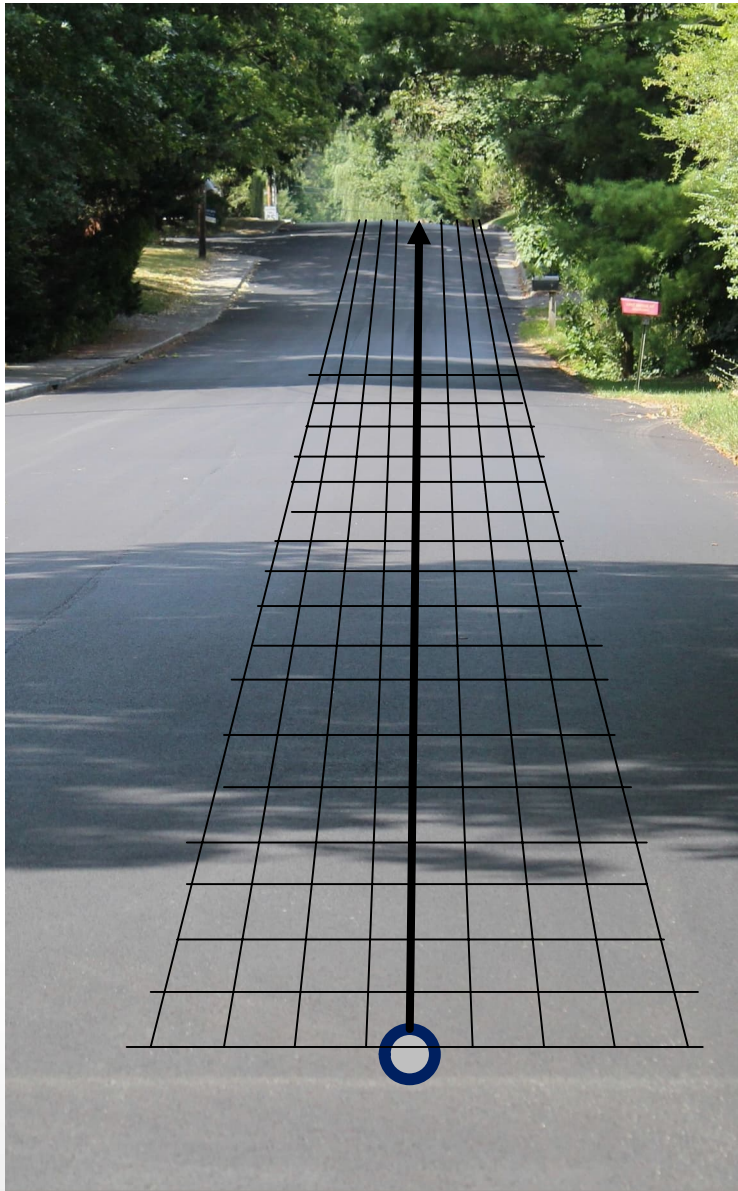
Data

4.4	0.6	3.5	5.4	...
3.4	7.5	3.6	3.5	...
⋮	⋮	⋮	⋮	

2. *ATTRIBUTE*-SPECIFIC GRIDS

So What?!





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2. *ATTRIBUTE*-SPECIFIC GRIDS

IMAGES!

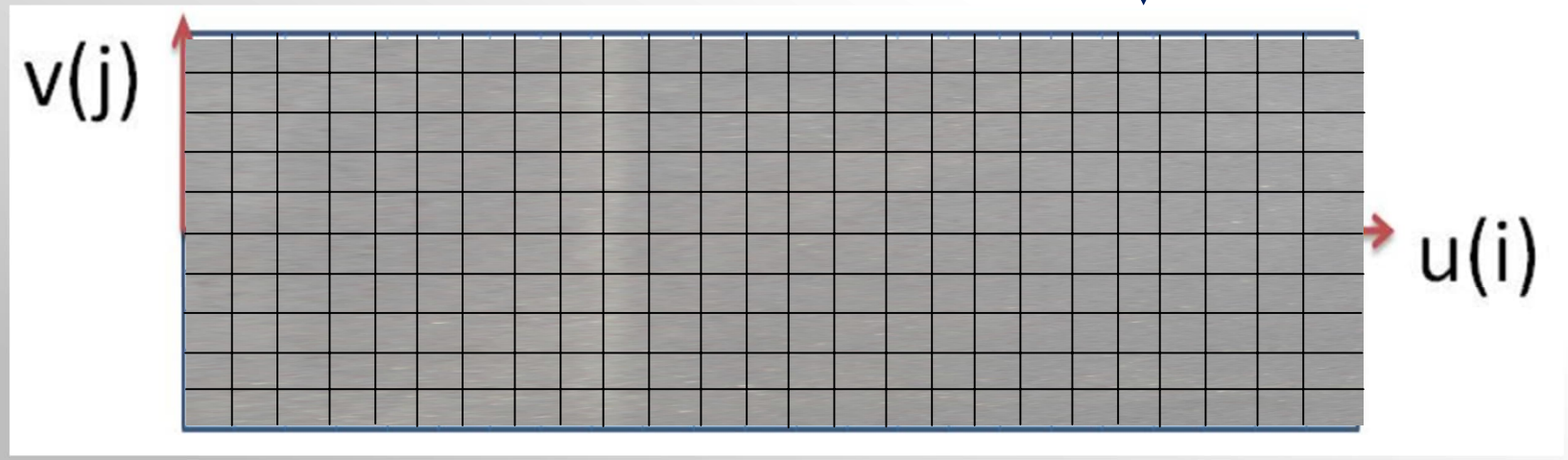
3 MATRICES

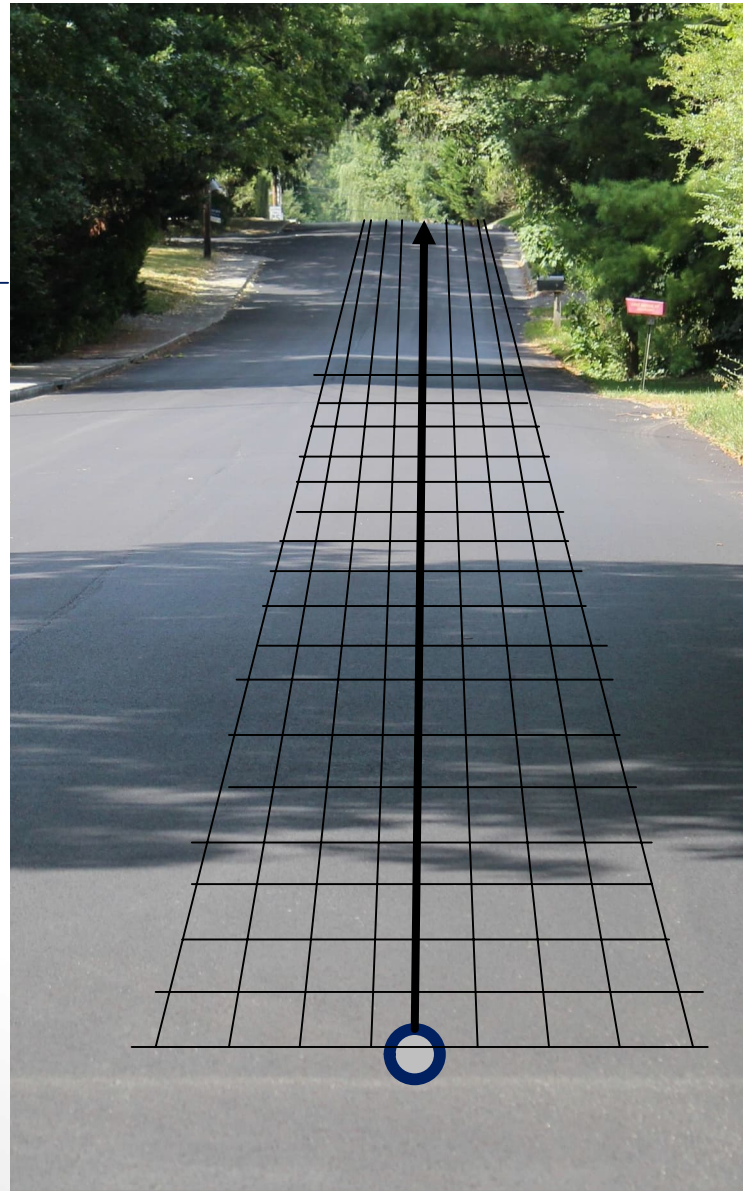
Blue
Red
Green

OR

Magenta
Cyan
Yellow

Inverse Perspective Mapping (IPM) (birdsEyeView)





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GEOREFERENCING ATTRIBUTES

- Reference Path is unambiguous, stable, compact, comprehensive (*All* Attributes)
- Each Attribute has a Grid defined on *the* Reference Path for the road
- Can Analyze Road using all available data from all times in the database

Thank you!

Details are Here

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