Applied Artificial Intelligence for Real Time Geotechnical Open Pit Monitoring

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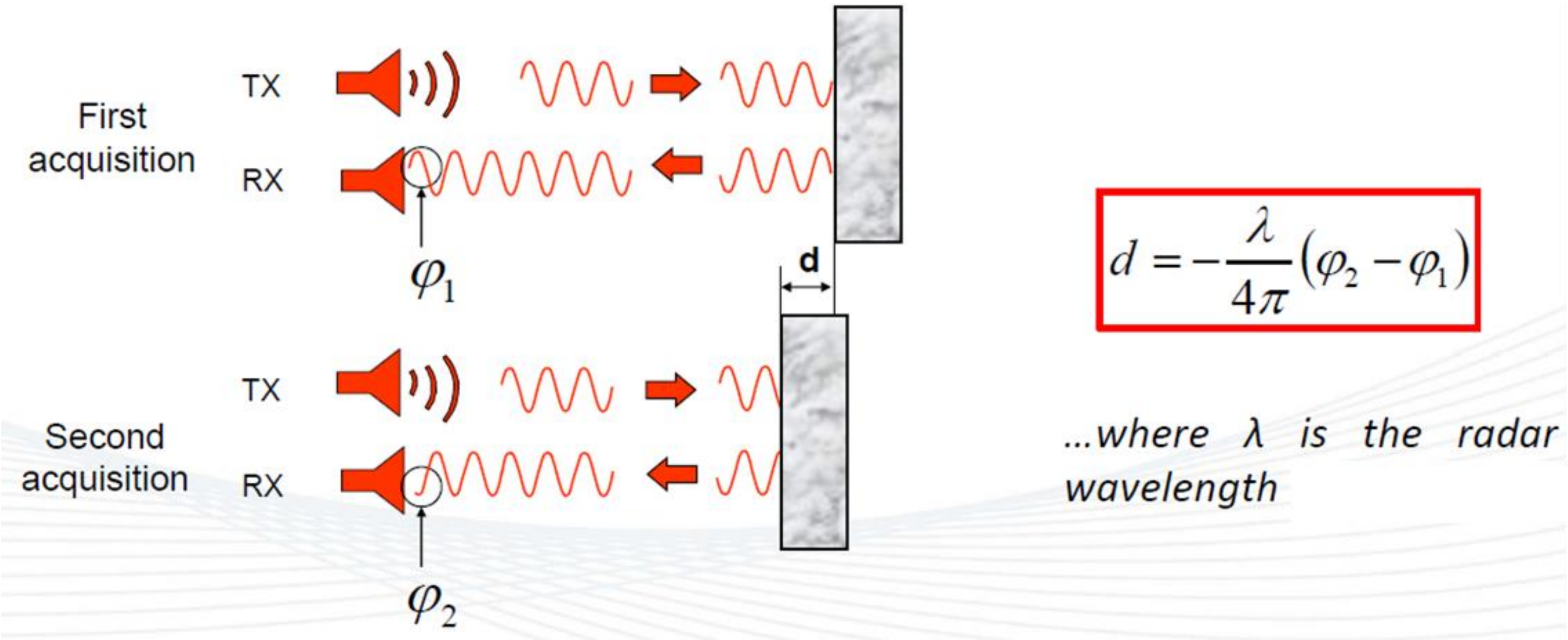
Basic Radar Works

Keypoint: relative displacement

- $Velocity = \frac{Total\ Displacement}{Time}$
- $Total\ Displacement = \sum_{i=1}^{n} d_n = \sum_{i=1}^{n} d_1 + d_2 + d_3 + \cdots + d_n$



Basic Radar Works

- How radar calculate velocity and displacement

Td = (-1 – (0.5)) = ~1.5 mm

Vel (6 hours) = 0.25 mm/hr

Td = (-1 – (0.5)) = ~1.5 mm

Vel (1 hour) = 1.5 mm/hr

Td = (-6.5 – (-1.5)) = ~5 mm

Vel (6 hours) = 0.83 mm/hr

Td = (-6.5 – (-1.5)) = ~5 mm

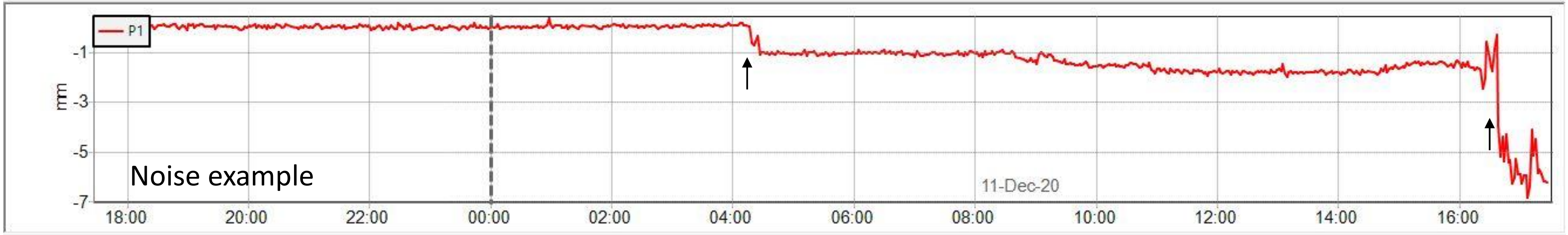
Vel (1 hour) = 5 mm/hr

Note that this point will blink in 1 hour hazard map
because velocity > threshold

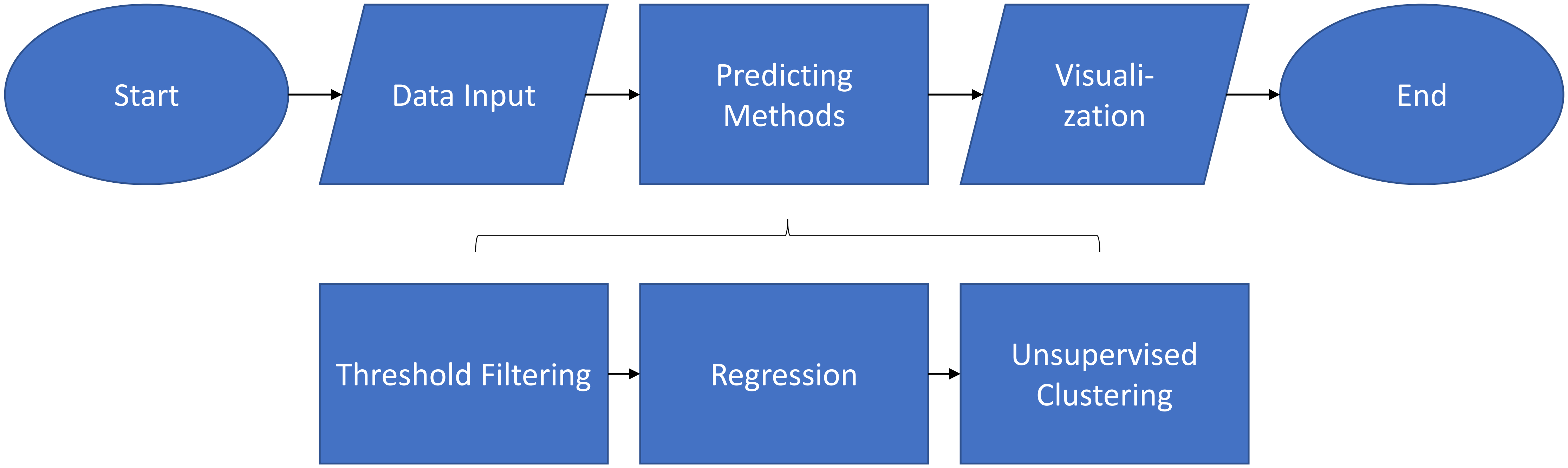
Background

As monitoring engineer we understand that:

- The shorter the time window the better it is to identify real movement
- However, shorter time interval means higher noises encounter (**false prediction**)
- The prediction of real movement needs to be checked manually by engineers by looking at the **time and spatial trend**
- **Why don’t we teach the machine to do these by itself (point 3)**
- This repetitive task is subject to error, as engineers are human not machine, who are inconsistent and prone to procrastinate their task.



FLOWCHART AI MONITORING



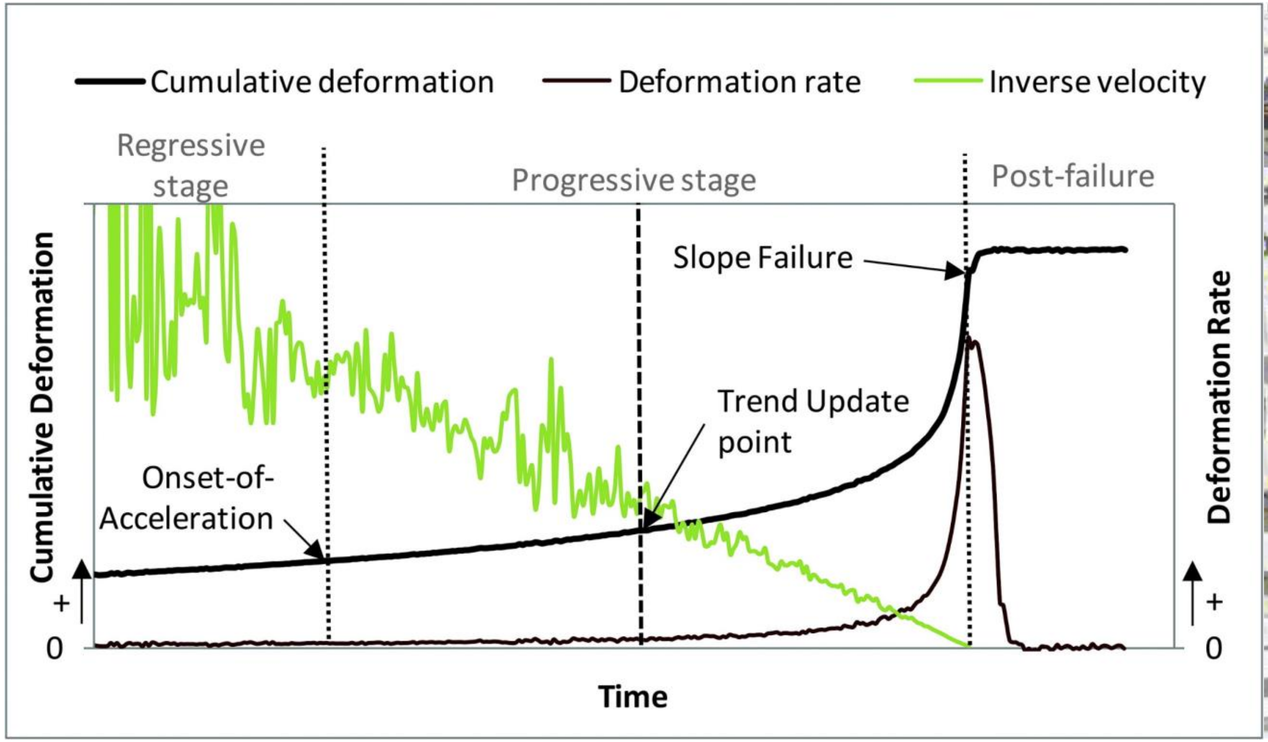
BASIC BACKGROUND THINKING

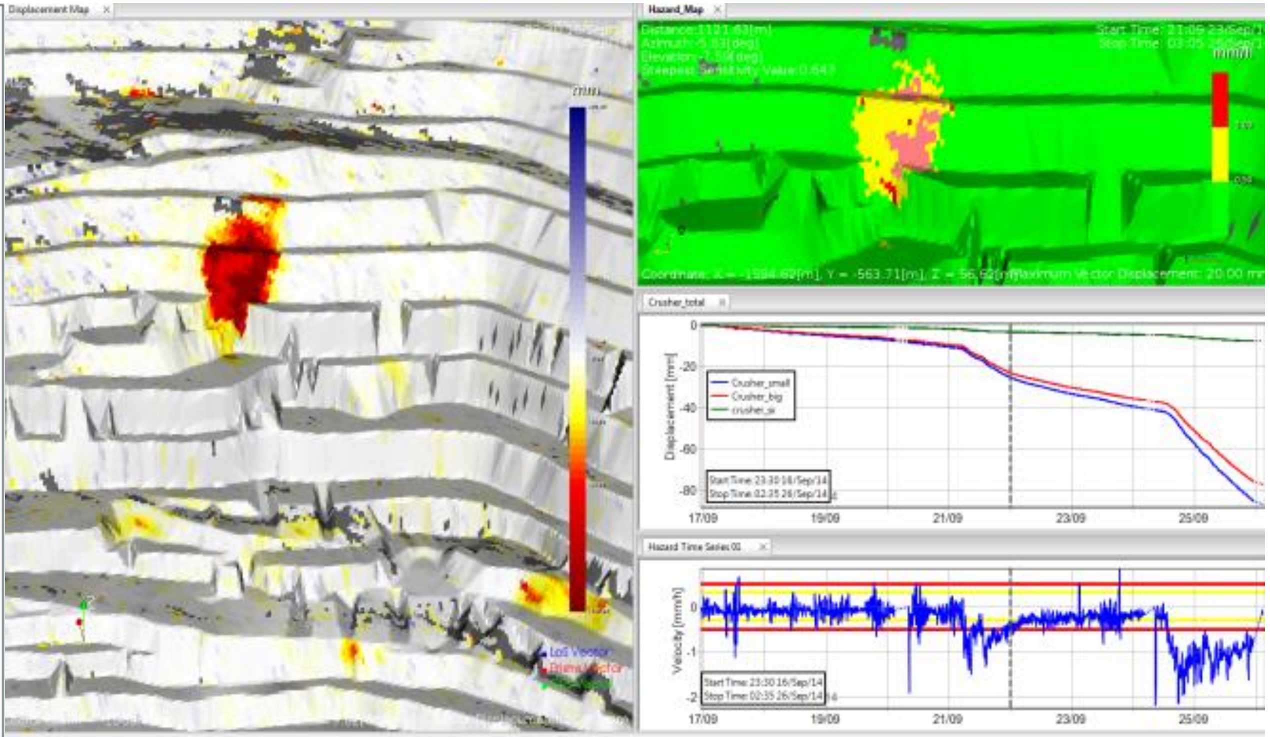
- PREMISES:

EVERY REAL MOVEMENT (HOTSPOT/FAILURE) HAVE HIGH CORRELATION WITH TIME, HOWEVER NOT EVERYTHING CORRELATED WITH TIME IS REAL MOVEMENT

EVERY REAL MOVEMENT (HOTSPOT/FAILURE) HAVE HIGH SPATIAL CORRELATION, HOWEVER NOT EVERY HIGHLY SPATIAL CORRELATED SIGNAL IS REAL MOVEMENT

Character: Noise vs Real Movement





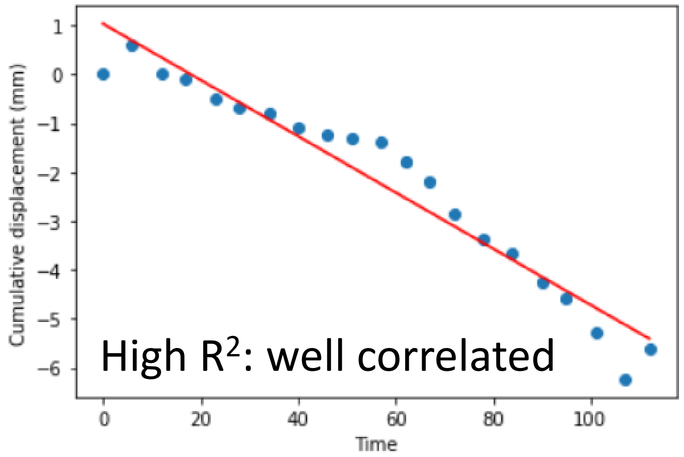
1. Time correlation (Fukuzuno, 1985)

2. Spatial correlation (image: idsgeoradar.com)

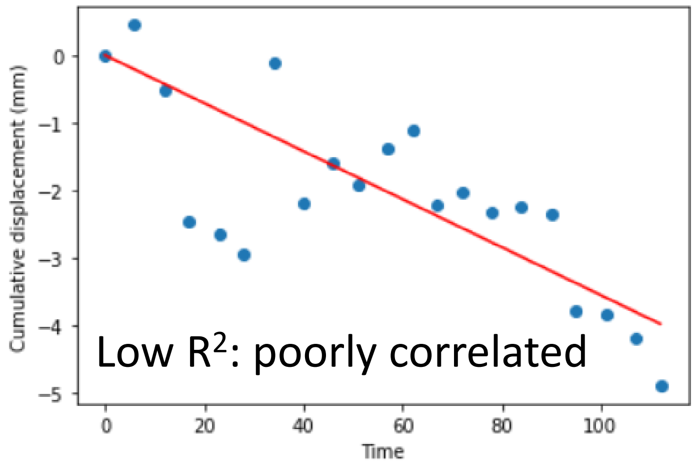
Time Correlation (Trend)

- The easiest way to determine correlation is **REGRESSION**
- There are many forms of regression: linear, polynomial, exponential, etc
- We use linear regression as: We try to identify the movement as fast as possible during the linear phase.
- Basic math of regression: $R^2 = 1 - \frac{SSE}{TSS}$ $MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2$

$SSE = n \times MSE.$ $TSS = \sum_{i=1}^{n}(y_i - \bar{y})^2$



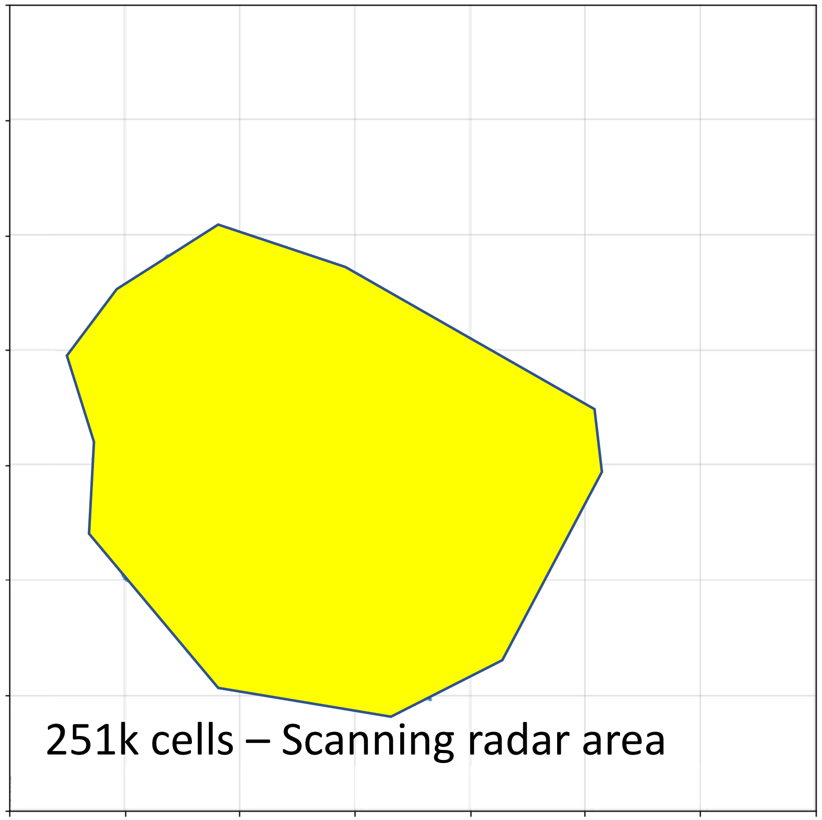
R2 score is 0.9388377602885791



R2 score is 0.5476347700431419

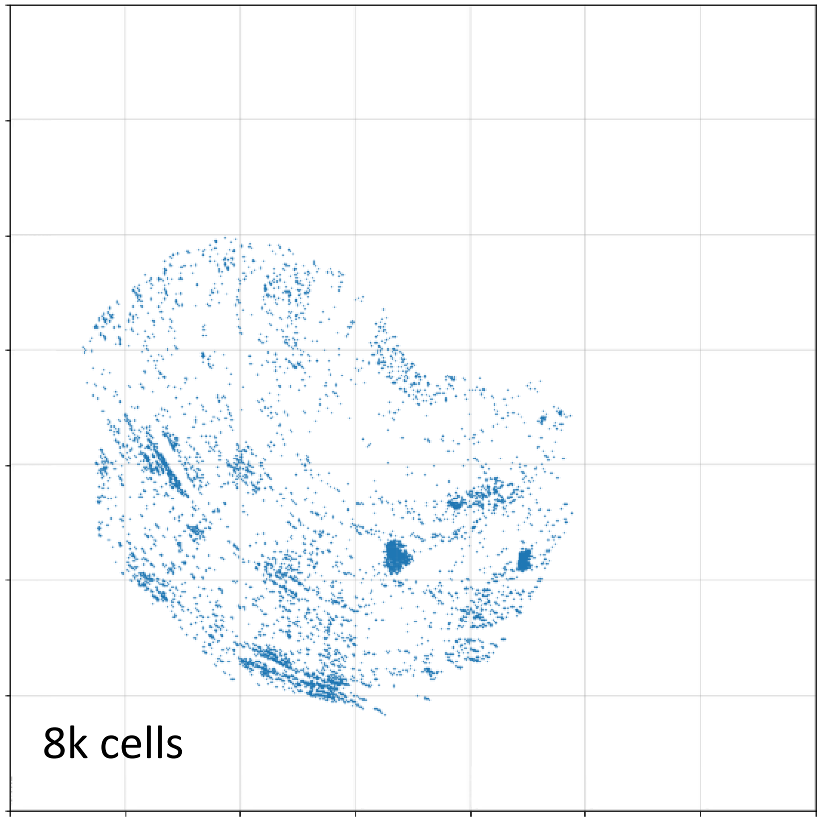
Traditional Radar Filtering

- However, calculating regression for hundred thousand of cells per radar need much **computational power**.
- Solution: manually filtered candidate cells with normal filtering first



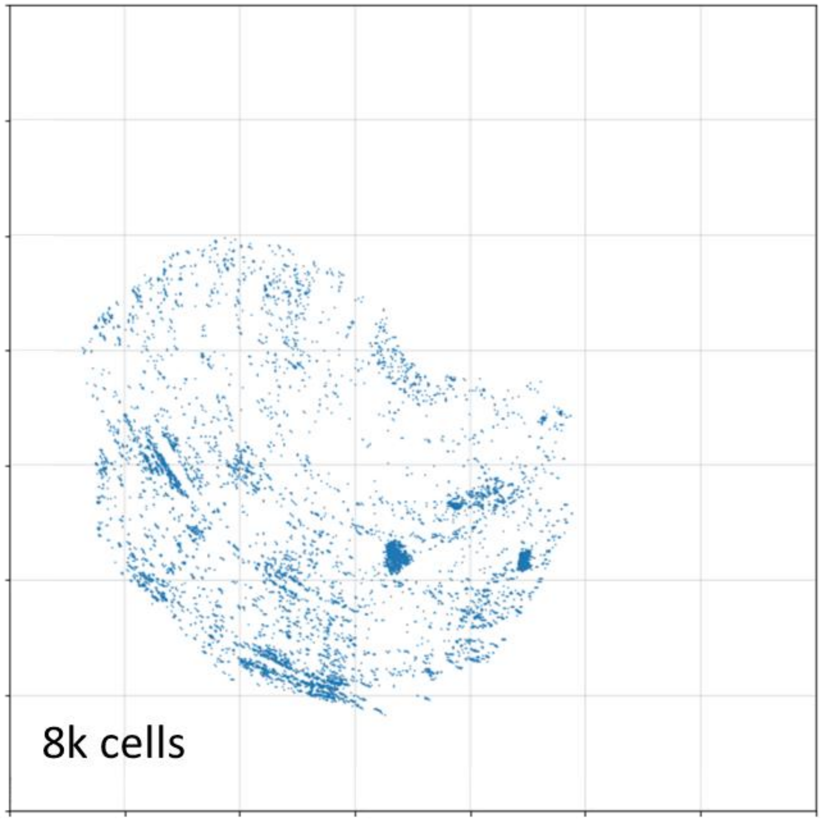
Normal filtering,

Example:
Cut off vel > 1.5 mm/hr
(97% reduction)



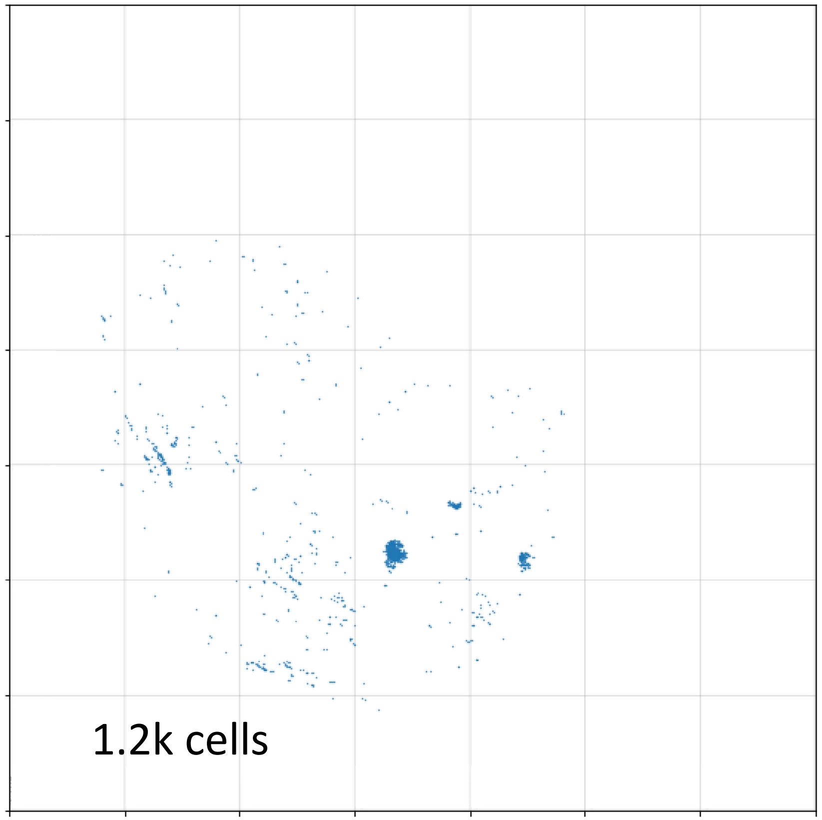
Regression

- Regression is applied for each filtered cells, resulting in R^2 score
- Filtered the cells by high R^2 only (user experience, trial & error) – **Expert judgement**



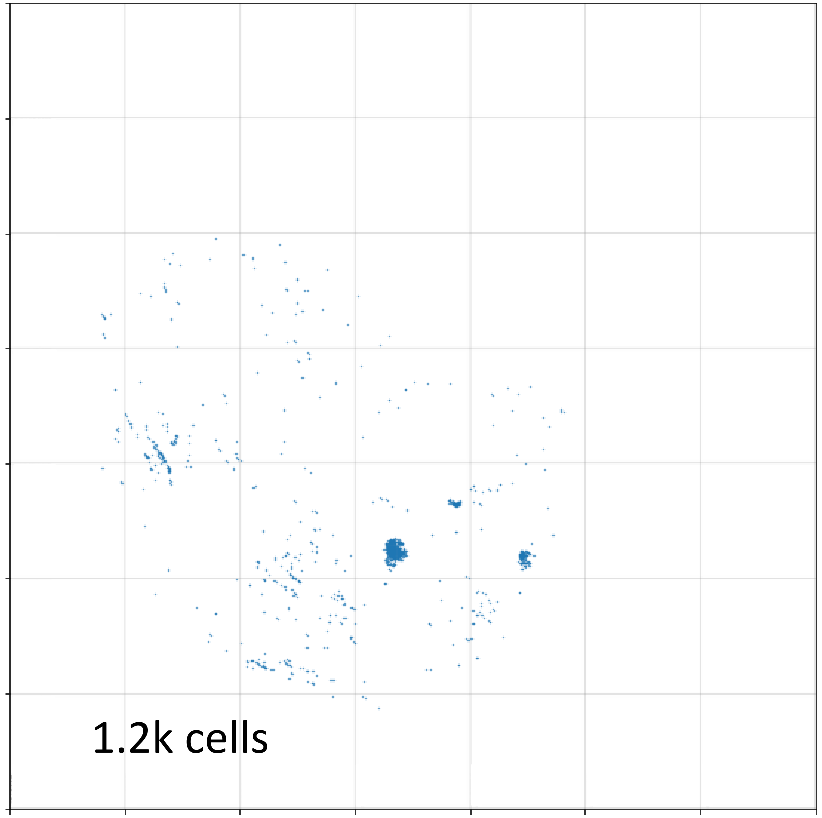
Regression filtering.

Example: $R^2 > 0.85$
(85% reduction)



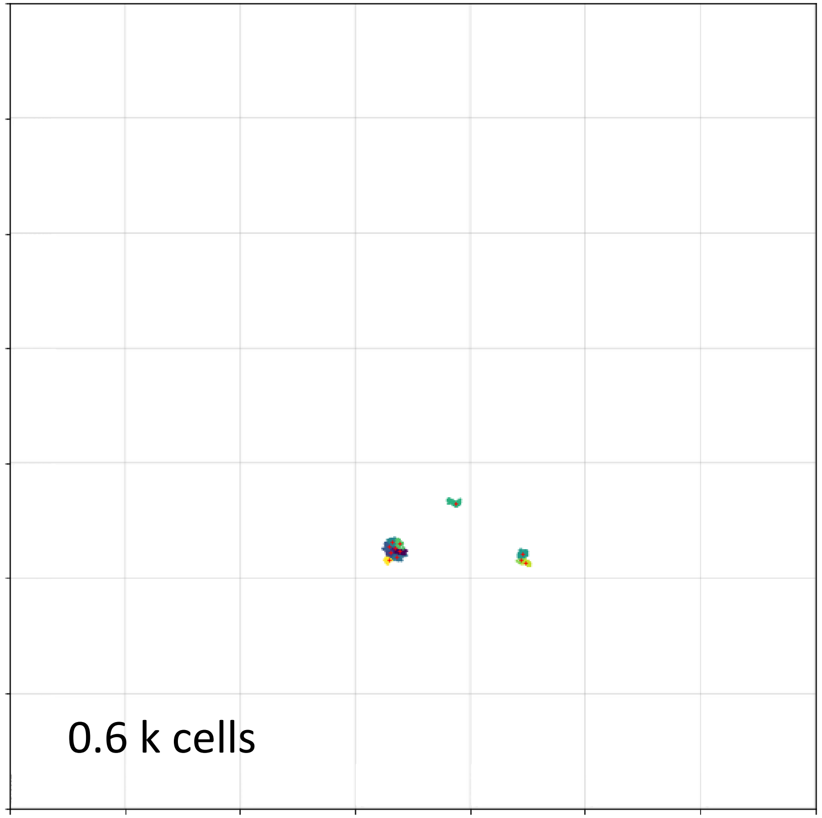
Meanshift Clustering (Machine Learning)

- Spatial correlation could be achieved by applying unsupervised meanshift clustering to help differentiate real movement with noise.
- Parameters: fixed bandwidth and distance value (based on trial error and average failure size) on a fixed surface area.



Clustering

Example:
Bandwidth = 0.002, min = 10
(50% reduction)



Summary

1. Instead of only using traditional velocity cut-off for TARP response, we use additional **methods**, which are **time** and **spatial correlation** to identify failure faster and more accurate.
2. Human supervision is still **needed** to confirm the real movement and determine the correct parameters, which depend on geotechnical aspects.
3. There are still spotted area of non-failure predicted as failure. It happens because we currently use **5-6 minutes subsampling data**. Improvement is expected when using real time data, however higher computational cost will be needed.
4. Improvement and further research can be done by applying multiple timeframes analysis to get more accurate prediction.