# An Effective Pothole Identification and Measurement System Using Mobile Devices

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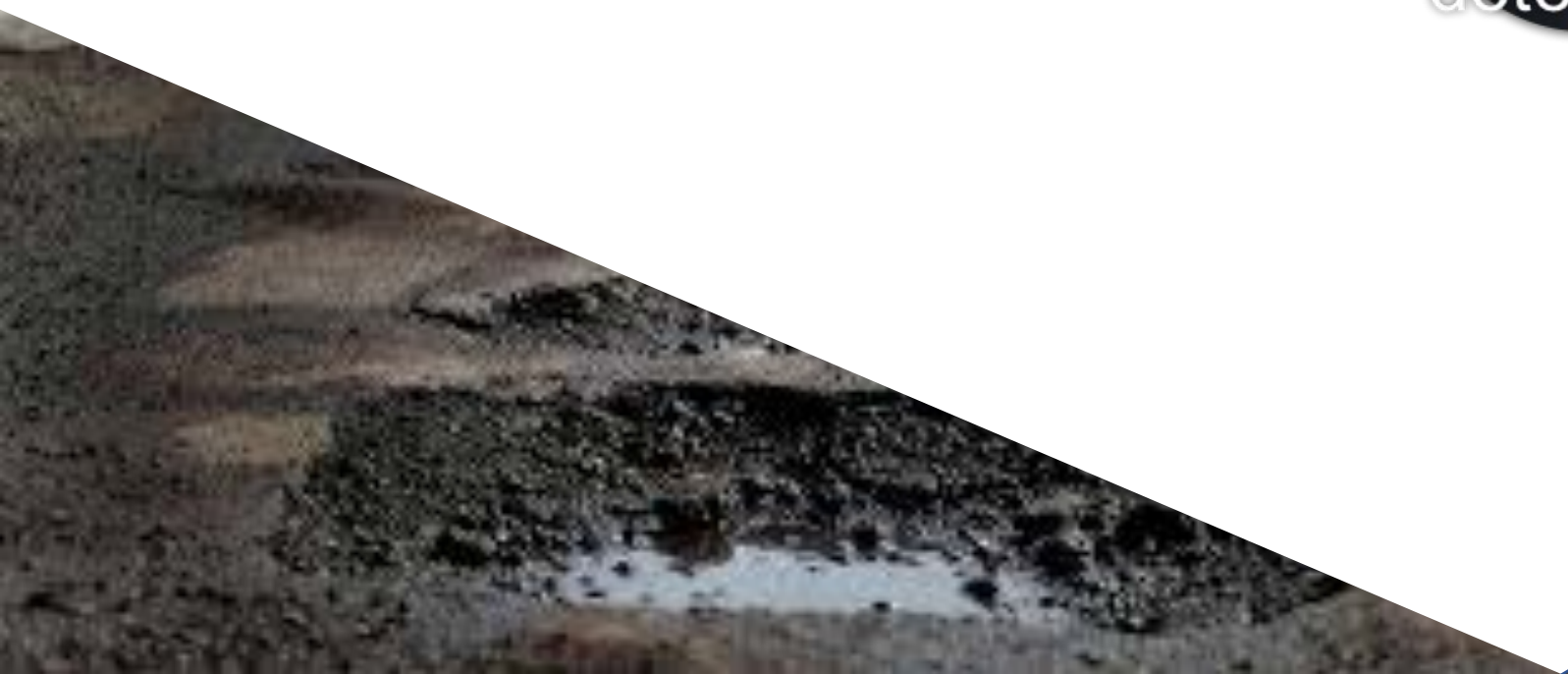
GEOGRAPHY

Potholes cost American drivers over $6 billion dollars per year.
Potholes have become a leading cause of car accidents.


Ground Penetrating Radar

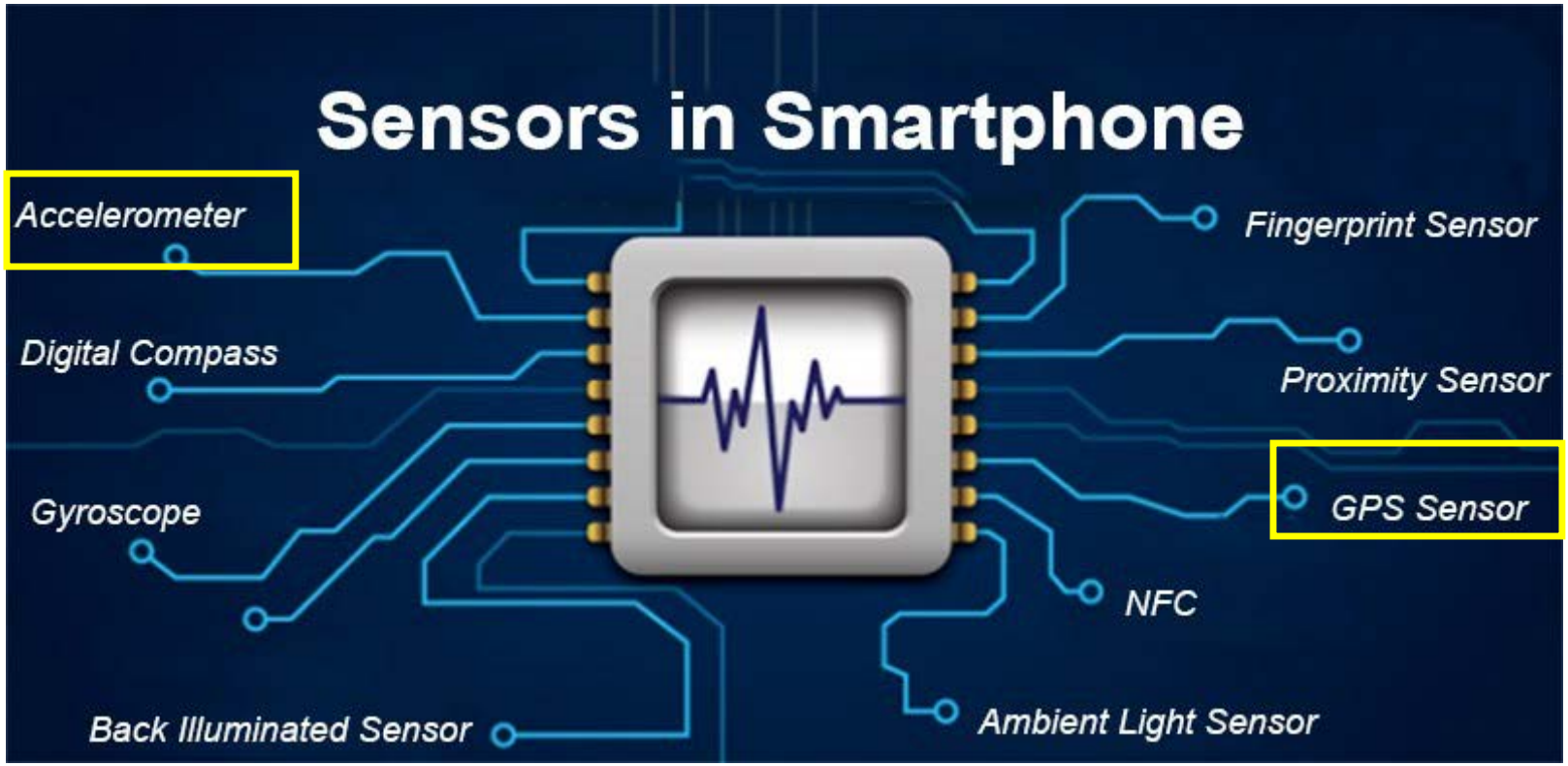

Laser Profilometers

Deflectometer

- Time-consuming
- Labor-intensive
- Costly

How to identify damaging potholes using mobile device?

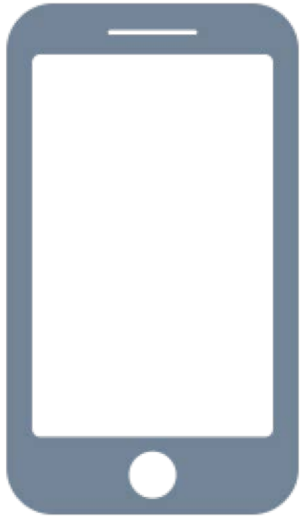
New Pothole Detection Framework
Threshold + Wavelet Analysis



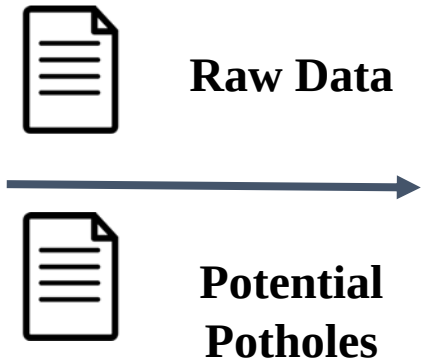
Data Collection

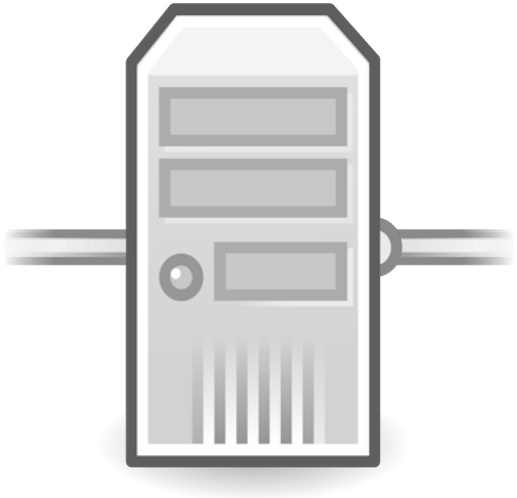
Potential Potholes Detection

Data Uploading



Mobile Sensors' Data Collection



Web-based Data server

Potholes Verification

Size Measurement

Results Fusing

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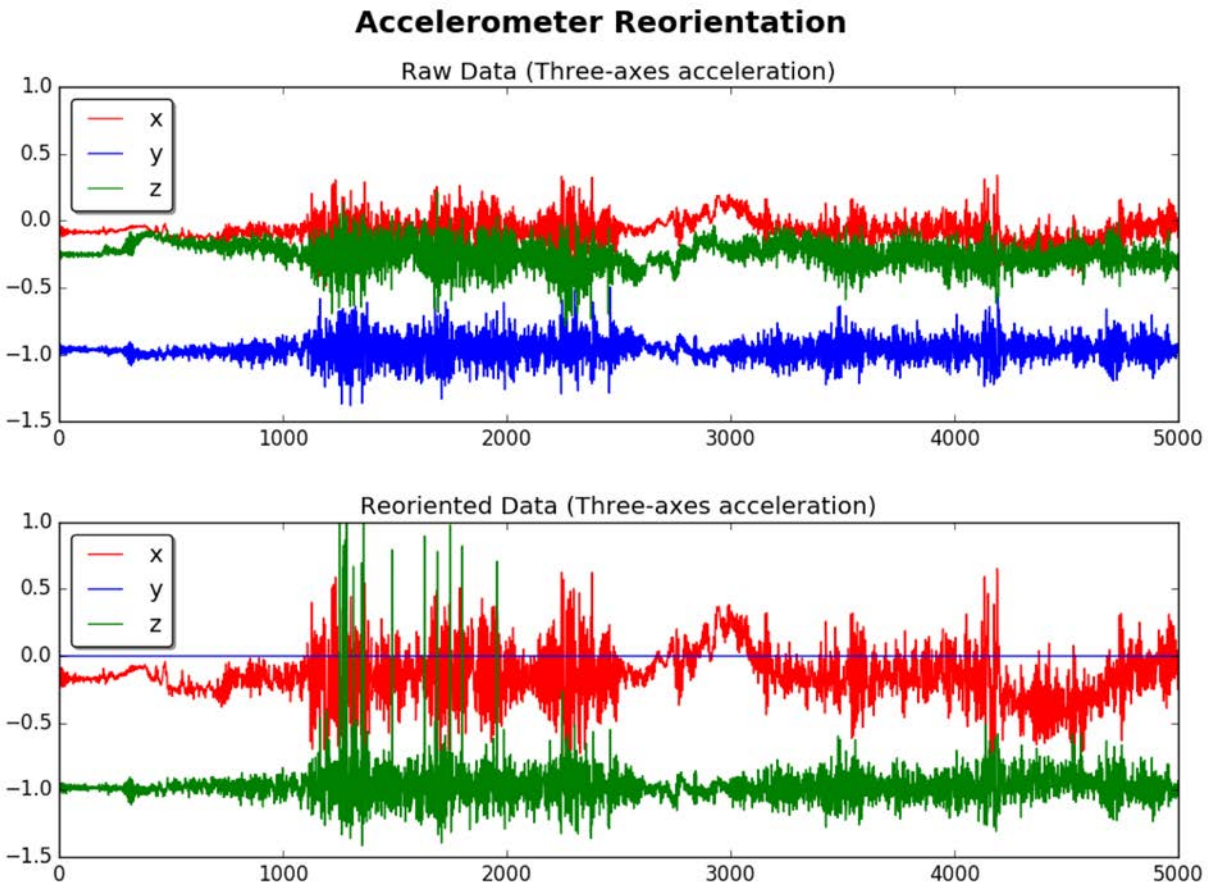



Reoriented smartphone' axes align with vehicle's axes (ax=0, ay=0, az= -1g m/s$^2$)

$$\alpha = tan^{-1}\left(a_y' / a_z'\right) \qquad \beta = tan^{-1}\left(-a_x' / \left(\sqrt{(a_y')^2 + (a_z')^2}\right)\right)$$

$$a_{xreor} = c\beta a_x' + s\beta s\alpha a_y' + c\alpha s\beta a_z';$$

$$a_{yreor} = c\alpha a_y' - s\alpha a_z';$$

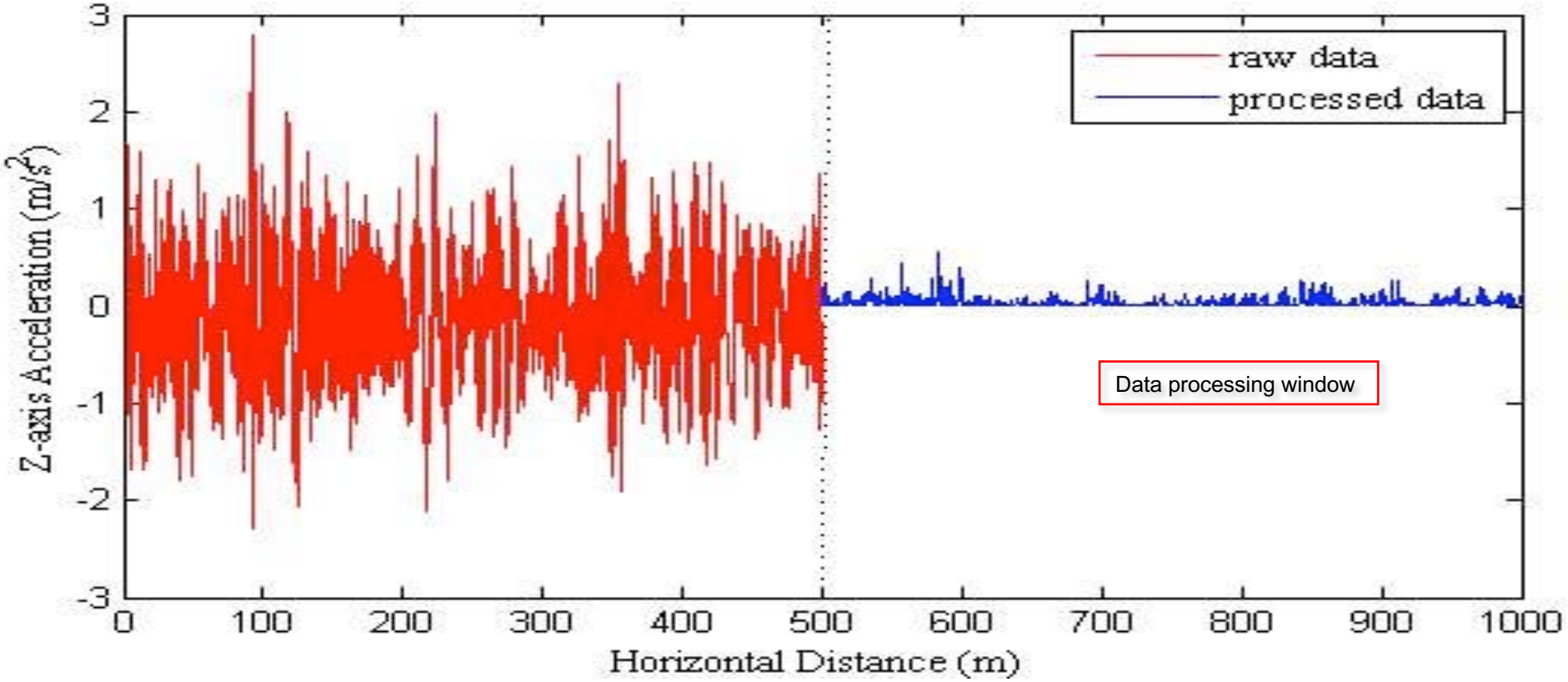
$$a_{zreor} = -s\beta a_x' + c\beta s\alpha a_y' + c\beta c\alpha a_z'$$



1. Astarita, V., Caruso, M. V., Danieli, G., Festa, D. C., Giofrè, V. P., Iuele, T., & Vaiana, R. (2012). A Mobile Application for Road Surface Quality Control: UNIquALroad. Procedia - Social and Behavioral Sciences, 54, 1135–1144. https://doi.org/10.1016/j.sbspro.2012.09.828

In order to wipe off the noise from signals and smooth the raw data, a sliding window **with a size of 0.5 m** is required to applied.

$$\psi_{rms(x)} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} y_i^{\,2}(x)}$$



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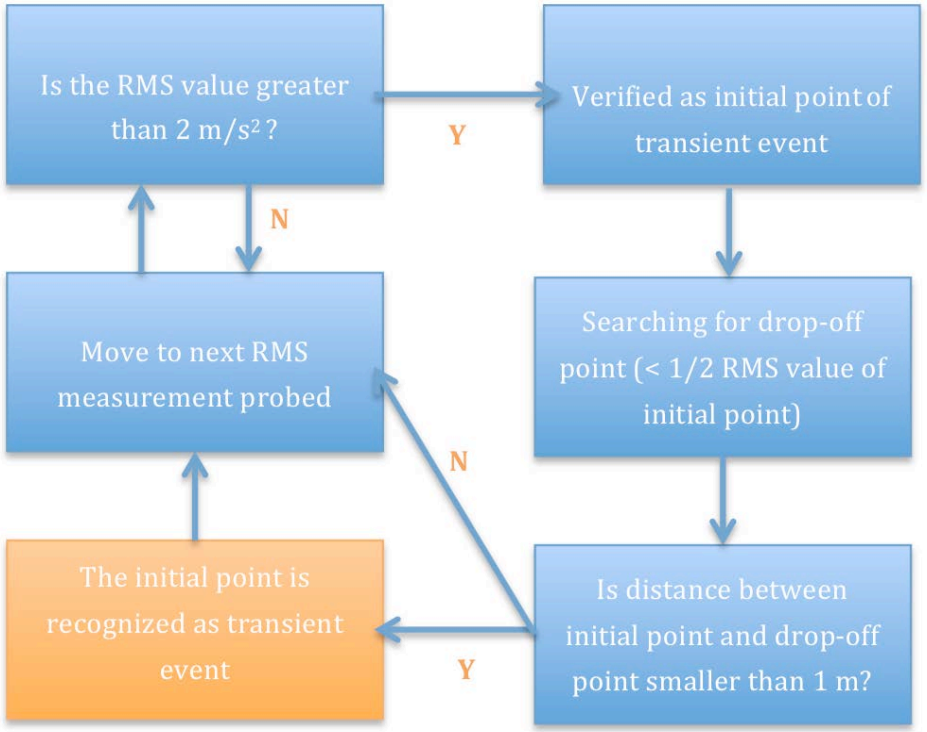
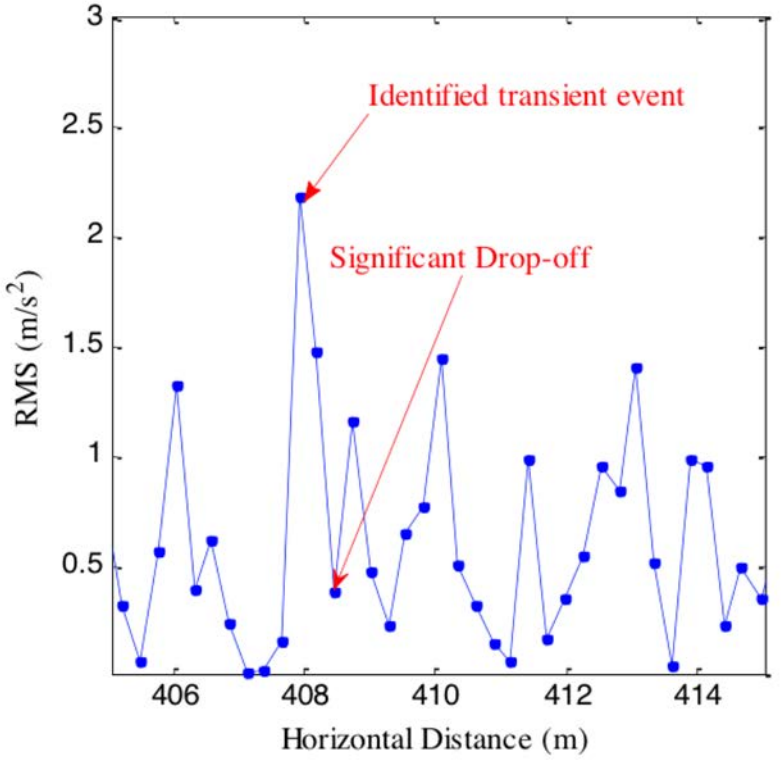
--Large amplitude, short wavelength events in RMS curve



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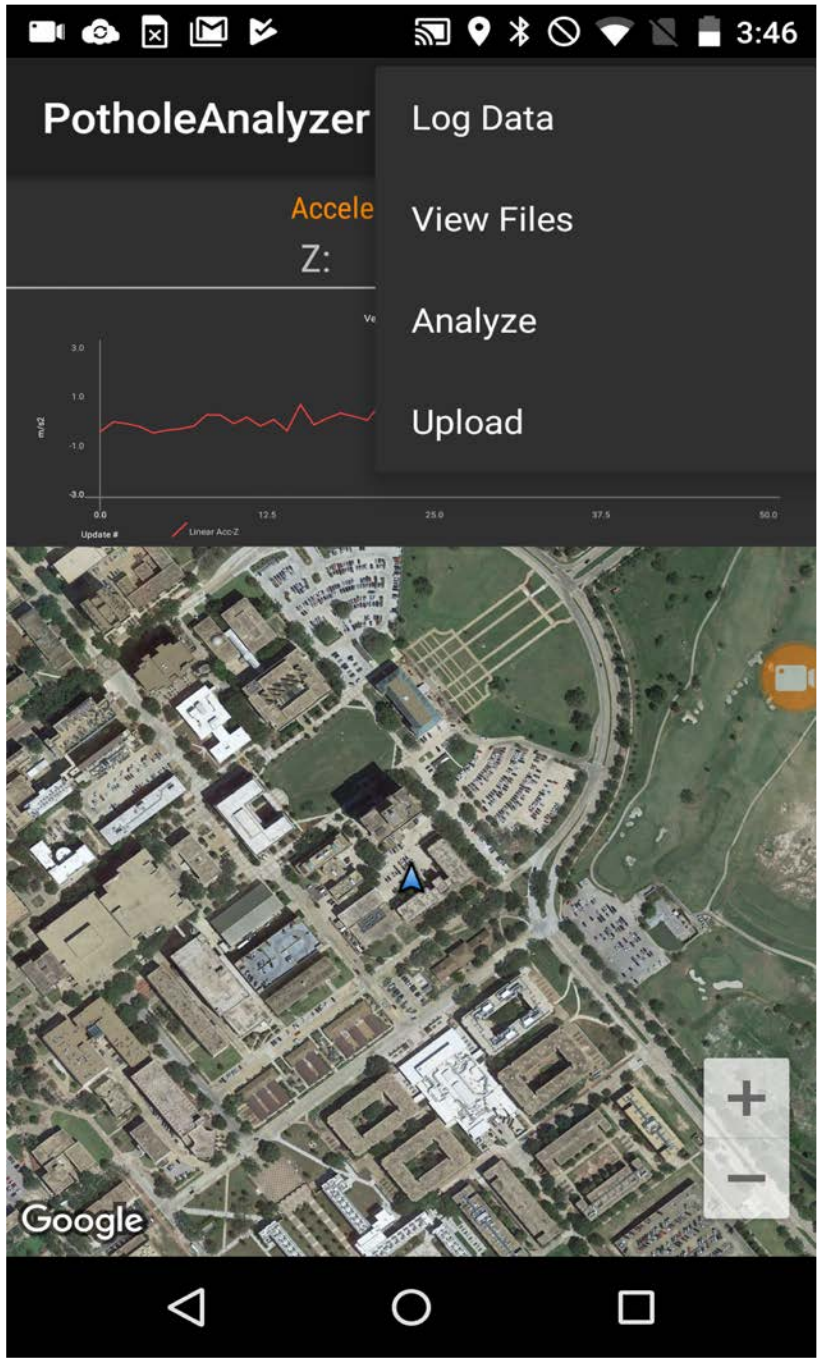
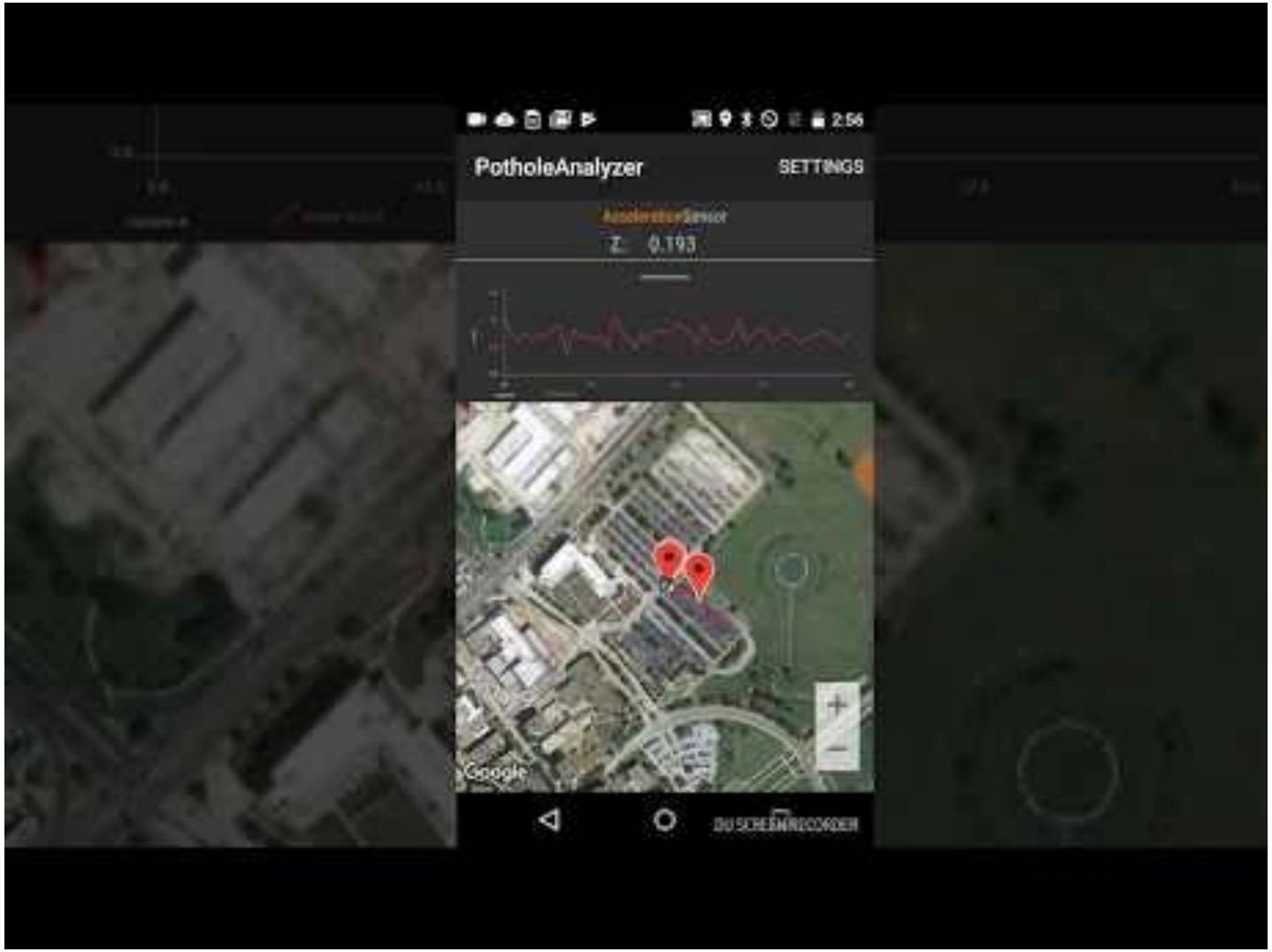
2 sensors:

- GPS Receiver & 3-axis Accelerometer

4 Functions:

- Log Data
- Analysis
- View Files
- Data Uploading






https://youtu.be/ervn5tVb_VU

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## 2-phase Pothole Detection Framework

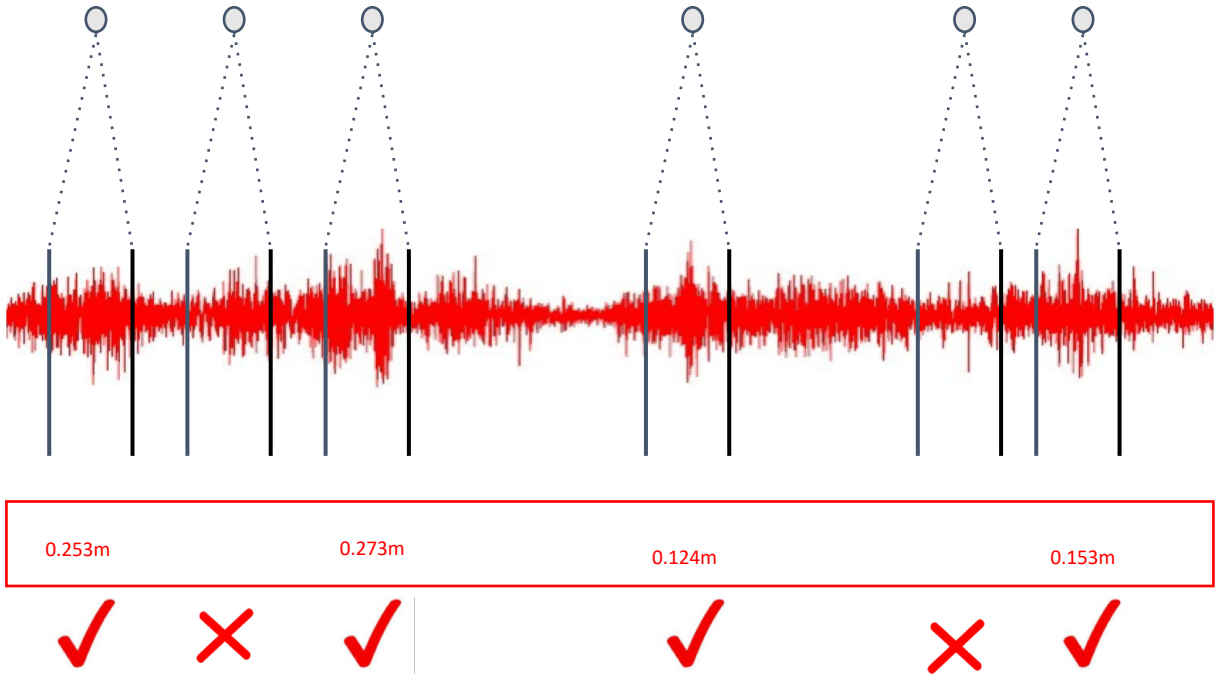
**Phase 1:** Mobile-based Threshold Analysis

**Phase 2:** Wavelet Analysis

File1: Potential Potholes

File2: Raw Data

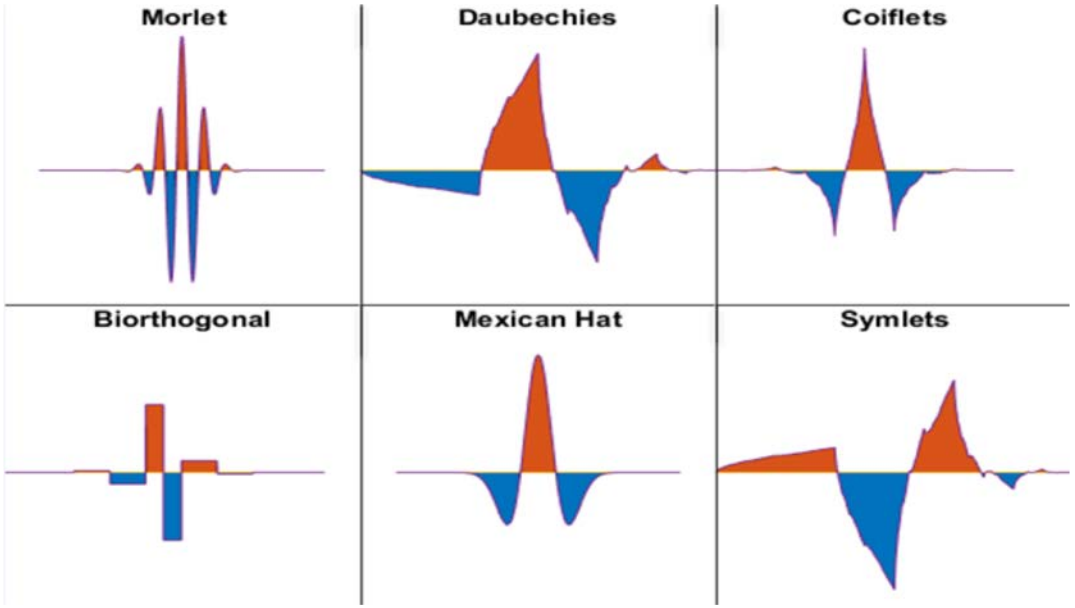
**Wavelet Analysis**

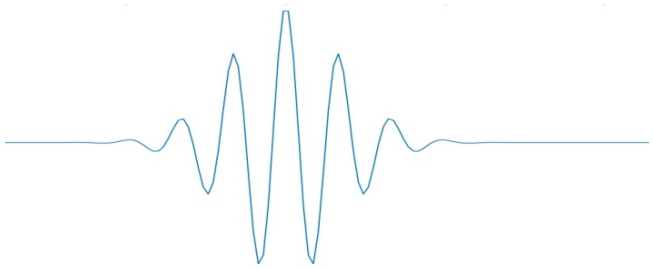


**Wavelet analysis** characterizes the scale-dependent periodicity of a signal. It both reveals **the frequency component of the signal** and identifies **where a certain frequency exists** in the spectrum.

**Time series signal -> Spatial scale signal**

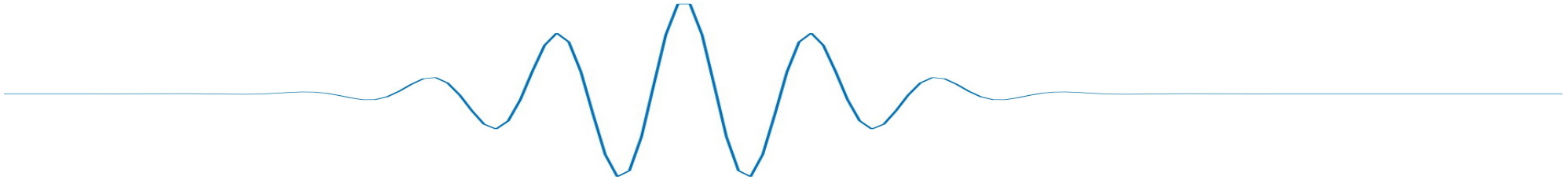
- Estimate pothole size
- Improve accuracy of detection



$$\psi(x) = (\pi b)^{-0.5} e^{2\pi i c x} e^{-\frac{x^2}{b}}$$

A **compressed** wavelet corresponds to a small size (high frequency)



A **stretched** wavelet corresponds to a large size (lower frequency)

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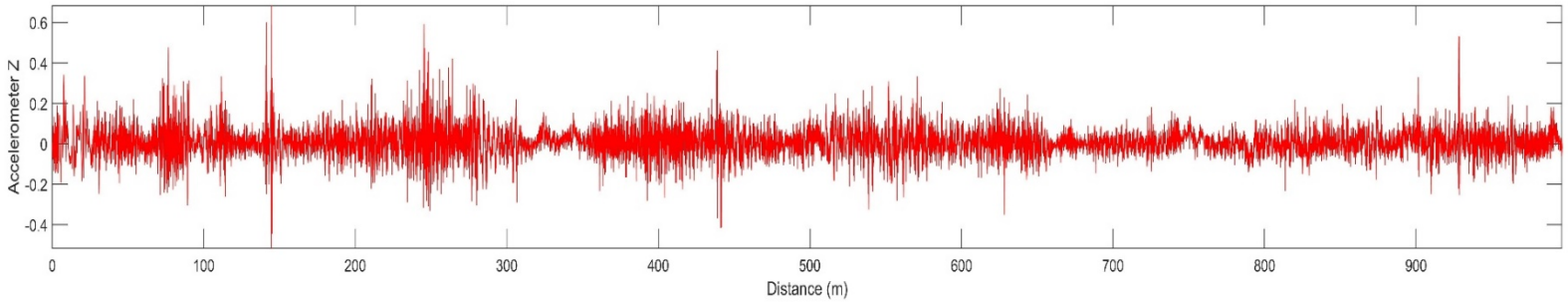
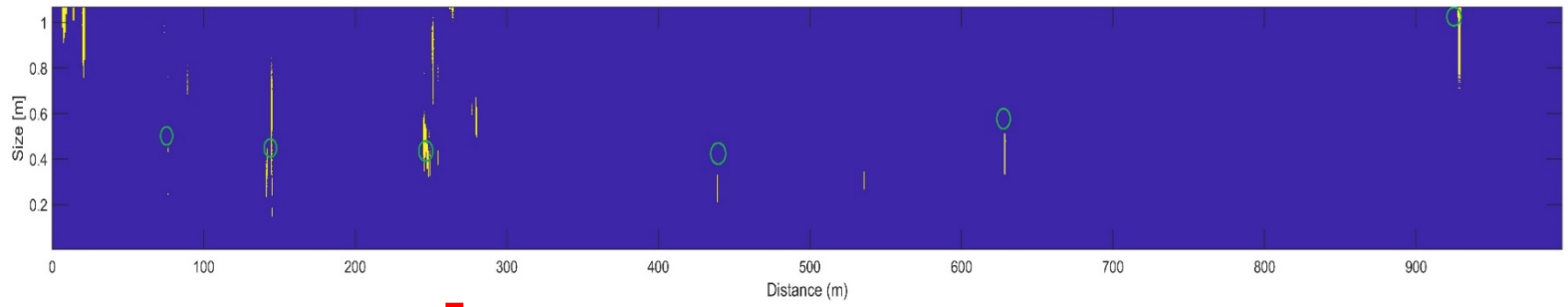



Wavelet coefficient image after thresholding

Continuous wavelet transform (CWT):

$$CWT(a,\tau) = \int_{-\infty}^{\infty} f(x) * \frac{1}{a}\psi^* \left(\frac{t-\tau}{a}\right) dt$$

Average Error: **9.615 cm**

Threshold = **17** x average coefficient value

## Z-PEAK


## Z – DIFF


## Z-STEDV


| Coverage Rate | | | | | | |
|---|---|---|---|---|---|---|
| | Positioning Accuracy 5 meters | | | Positioning Accuracy 10 meters | | |
| | 1 Time | 5 Times | 10 Times | 1 Time | 5 Time | 10 Times |
| D_PEAK | 12% | 21% | 26% | 29% | 40% | 42% |
| D_DIFF | 4% | 12% | 13% | 12% | 15% | 16% |
| D_STEDV | 9% | 29% | 40% | 24% | 44% | 46% |
| D_IMPROOVED | 25% | 40% | 47% | 35% | 56% | 66% |

| False Positive Rate | | | | | | |
|---|---|---|---|---|---|---|
| | Positioning Accuracy 5 meters | | | Positioning Accuracy 10 meters | | |
| | 1 Time | 5 Times | 10 Times | 1 Time | 5 Time | 10 Times |
| D_PEAK | 38% | 30% | 30.5% | 35% | 30.7% | 29% |
| D_DIFF | 50% | 37.5% | 36% | 34% | 31.5% | 31% |
| D_STEDV | 48% | 42.5% | 43% | 37% | 28% | 24% |
| D_IMPROOVED | 38% | 34.5% | 33% | 24% | 33% | 22.5% |

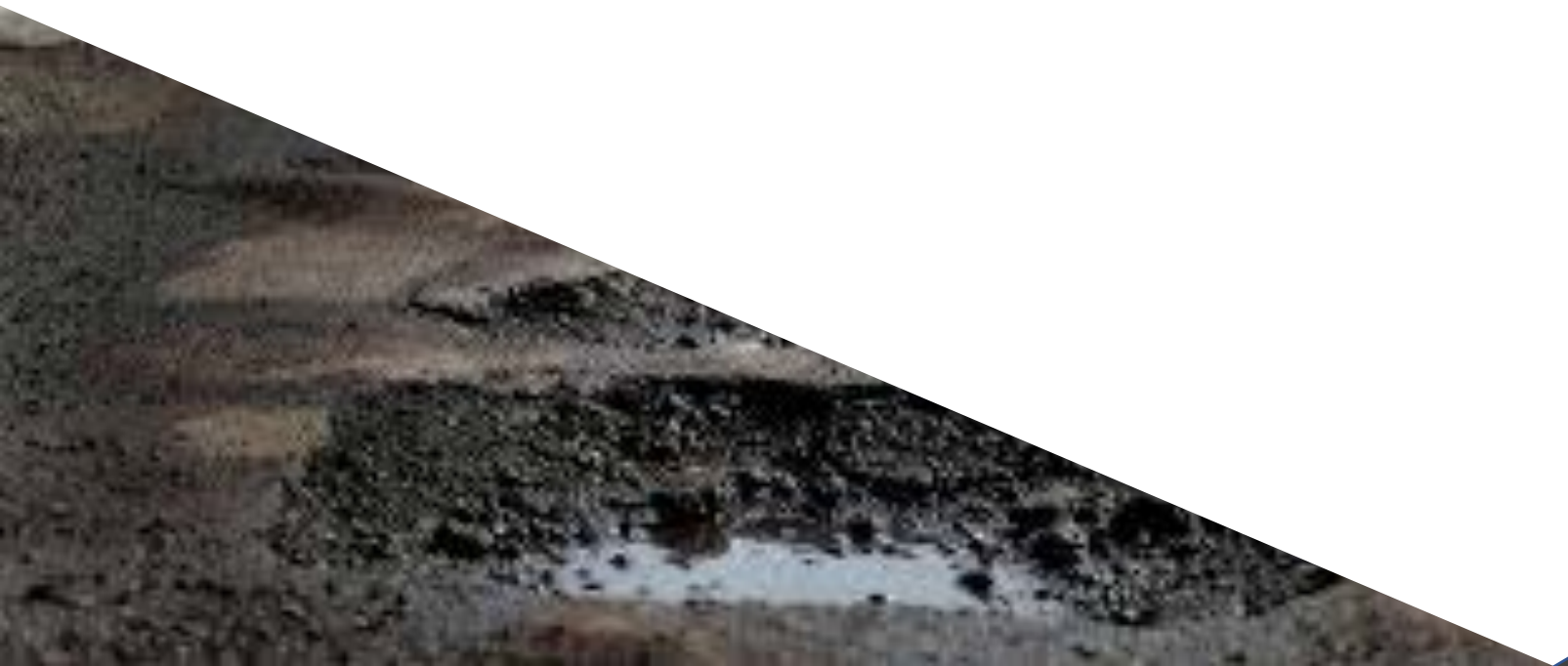
## IMPROVED

Built-in smartphone sensors can be used to detect potholes.

Damaging potholes can be identify using **Threshold + Wavelet.**

By mining crowd sensed data, a more accurate and reliable result can be achieved.

# Q & A




# Thank You