Geo-location and recognition of electricity distribution assets by analysis of ground-based imagery

Andrea A. Mammoli
Professor, Mechanical Engineering, University of New Mexico

Thomas P. Caudell
Professor Emeritus, Electrical & Computer Engineering, University of New Mexico

John J. Simmins
Technical Executive, Electric Power Research Institute

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Outline

- Do we have a problem?
- Ground-based imagery
- Identifying distribution poles using virtual drive-by
- Geo-location of poles
- Geolocation accuracy
- What's on the poles?
- Related applications

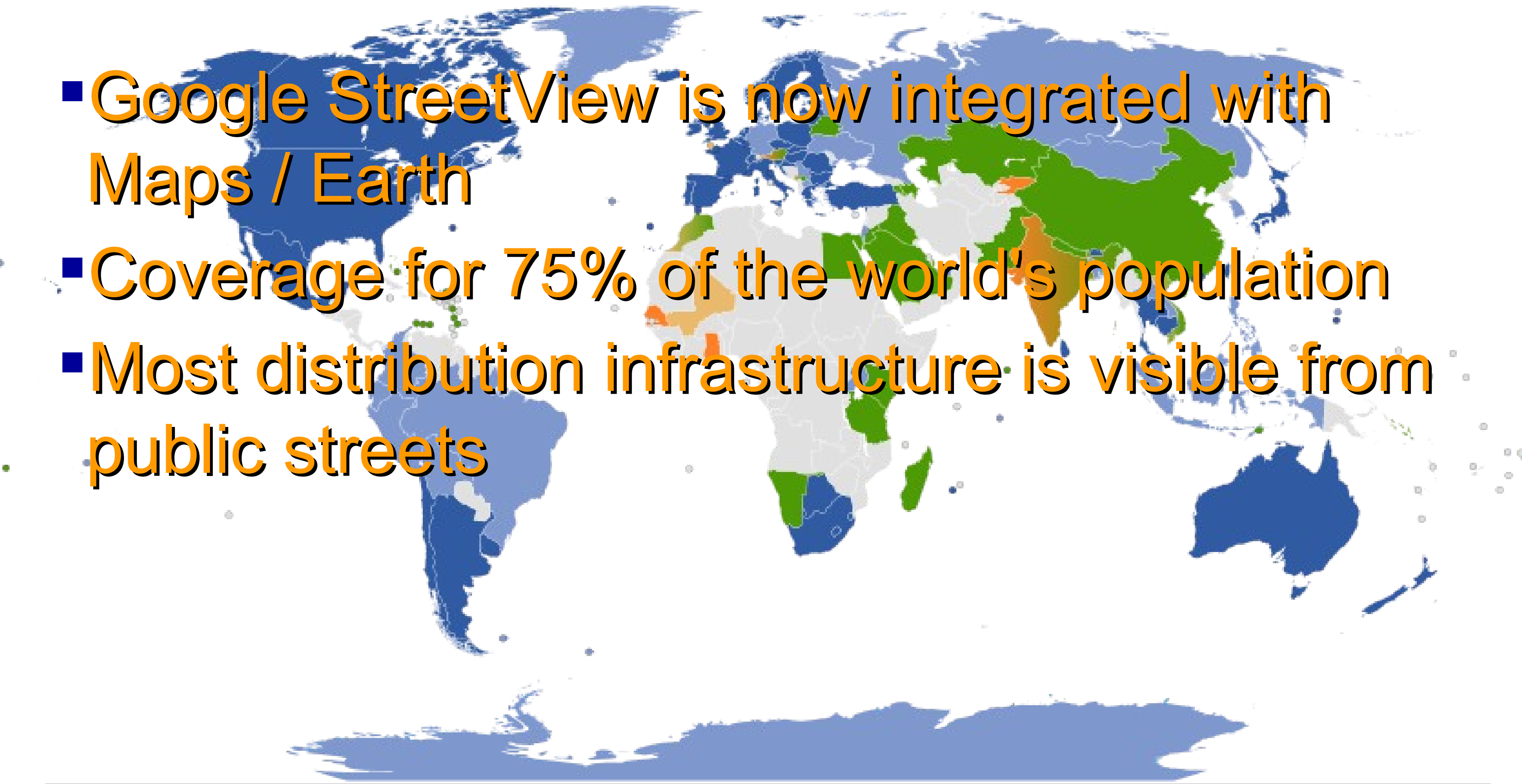
ESRI 2010 report on survey of 226 electric utilities

- Over 30% of respondents report incomplete model of primary distribution
- About 50% of respondents report incomplete model of secondary distribution
- GPS accuracy is one of the major problems
- GIS seen as critical by over 70%
- Large companies typically have worse GIS

Why do we care?

- The "smart grid" relies on geospatial data to track location of devices within an increasingly complex system
- Proper monitoring and maintenance of system critical in functioning of complex interconnected systems
- Poor data quality can lead to:
  - Inefficiency & re-work
  - Accidents
  - Loss of service
  - Financial loss and potentially loss of life
- Accurate data can be expensive! How do we balance cost of accuracy with cost of inaccuracy?

Public land-based imagery databases



- Google StreetView is now integrated with Maps / Earth
- Coverage for 75% of the world's population
- Most distribution infrastructure is visible from public streets

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Image acquisition and characteristics

- Cameras on cars, scooters, bikes, backpack, scuba
- R7 has 15 identical 5M low-flare lenses covering full range of directions
- Images are stitched to create a single panoramic image
- The panoramic viewer then distorts the image to simulate what the eye would see

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A typical image

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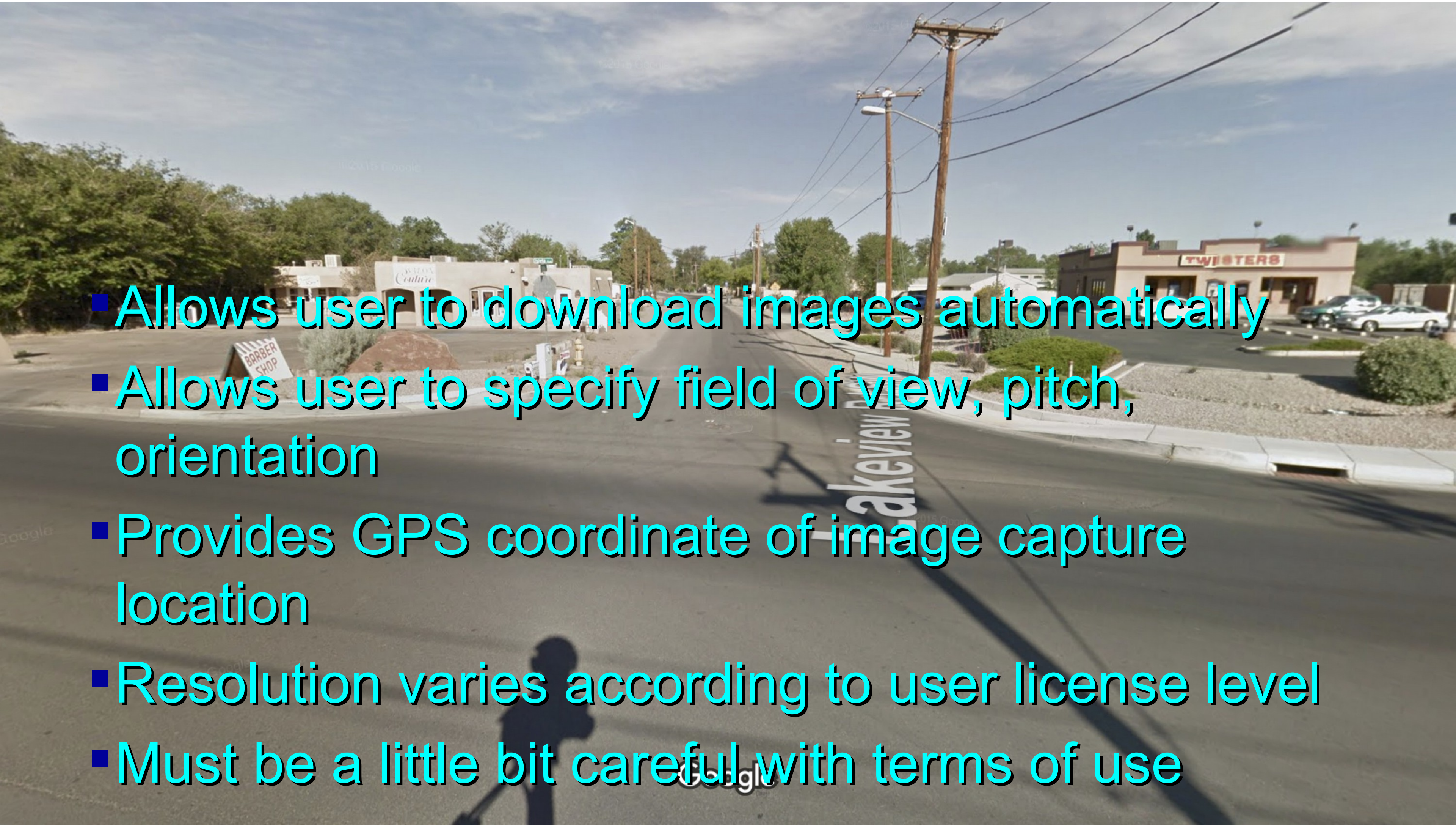
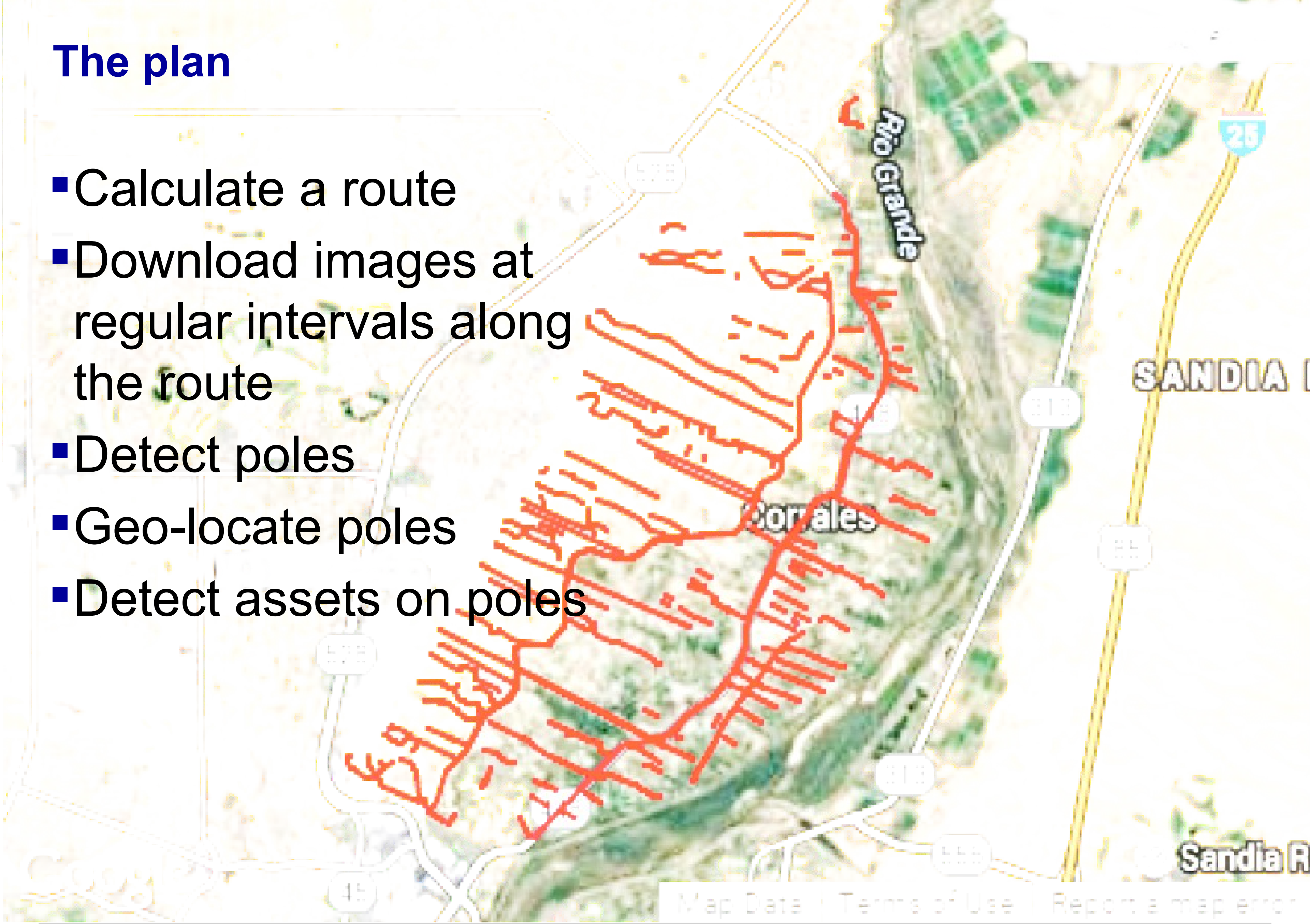
The StreetView API



- Allows user to download images automatically
- Allows user to specify field of view, pitch, orientation
- Provides GPS coordinate of image capture location
- Resolution varies according to user license level
- Must be a little bit careful with terms of use

The plan

- Calculate a route
- Download images at regular intervals along the route
- Detect poles
- Geo-locate poles
- Detect assets on poles



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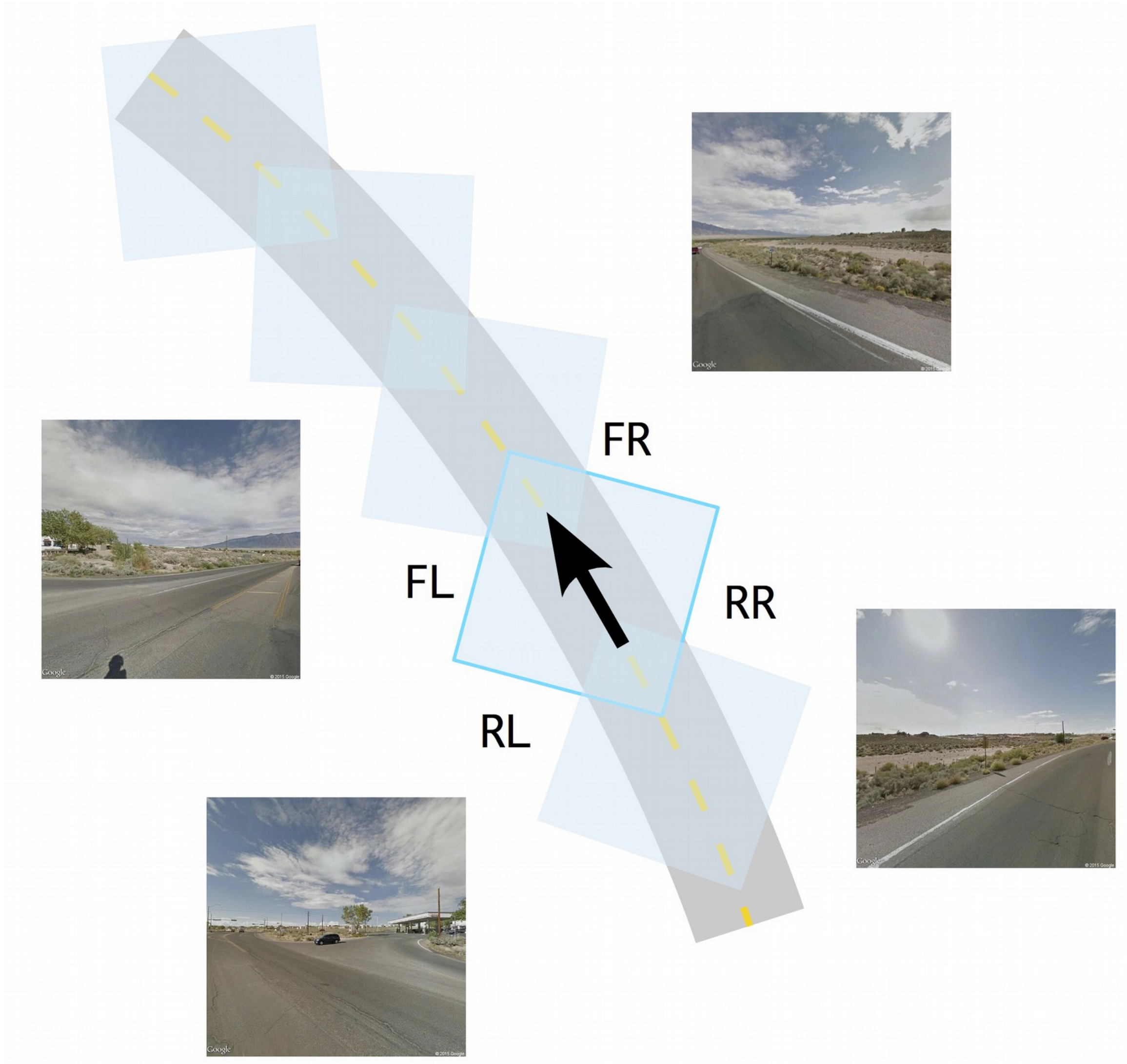
Planning a route

- Can be done by grabbing information from public databases on the web – e.g. real estate services
  - Obtain all street addresses in a given ZIP code
  - Group addresses by street
  - Obtain smallest, largest and some intermediate addresses
- Plan a route using Google maps for each street
- Travel virtually along route and collect images along that street

Image download format



Stitched composite image for analysis

- There are thousands of similar images
- For each, the angular location of power poles can be obtained by suitable image analysis means

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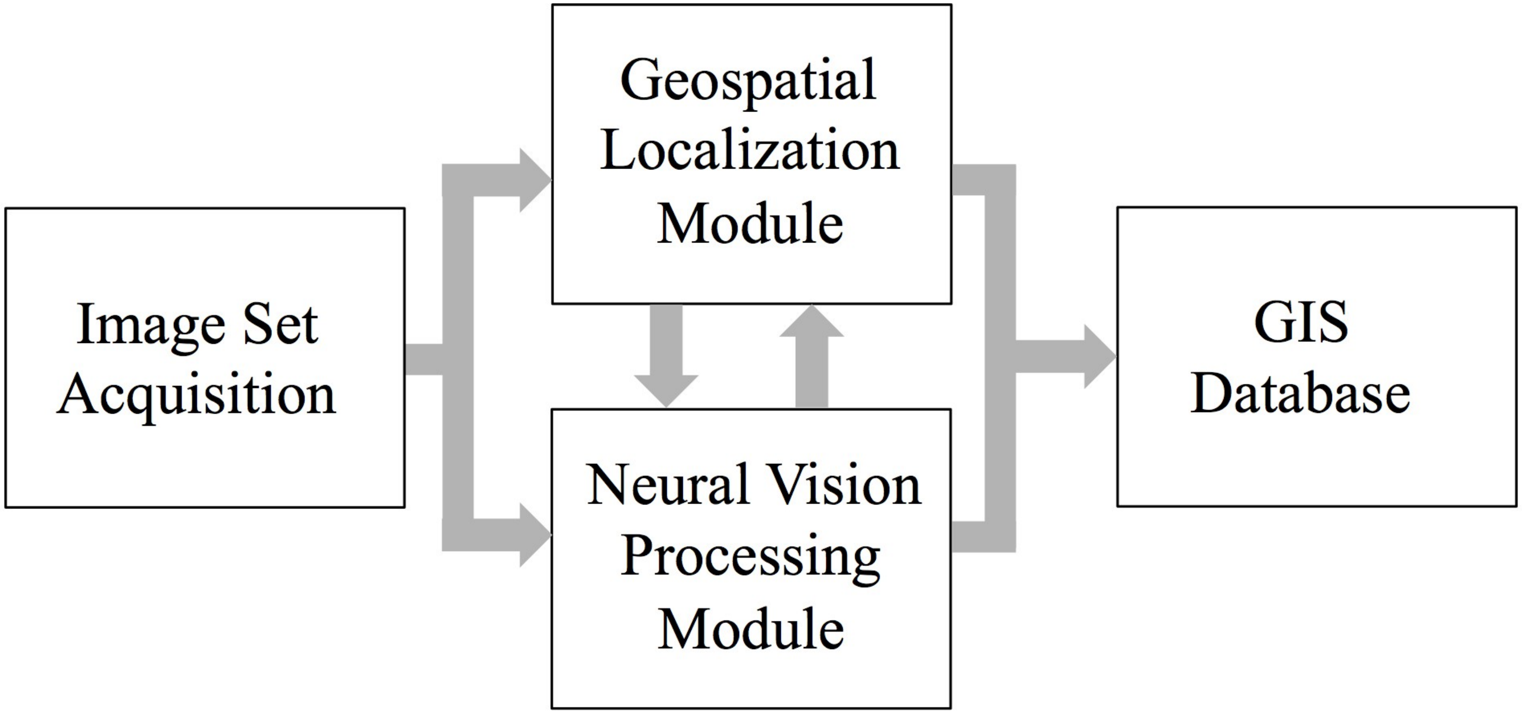
Structure of detection and location algorithms



How poles are detected – the "where" stream

- Convert to gray scale
- Convolve 2D Gaussian filter with the intensity image to reduce spatial noise
- intensity contrast gradient magnitude and direction at every image point using two orthogonal edge detector with derivative of Gaussian convolutional weights
- Suppress non-local maxima
- Compute and threshold gradient magnitudes in two opposite vertical directions
- Section image in horizontal swaths
- Compute horizontal image histograms in each direction
- Tabulate local maxima to find vertical substructures

Pole detection: the pitfalls

- Not all vertical structures are utility poles
- Sometimes poles are not vertical
- Sometimes poles are hidden or partially hidden
- Do we need / want to find *all* poles?

Some examples of badness in pole detection

TT 83.3%

TF 16.7%

FT 37.5%

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Some statistics – very preliminary

Tolerance	Nt	Nn	True-True	True-False	False-True
0	512	457	0	1	1
1	512	457	0.026120	0.973880	0.966384
2	512	457	0.076806	0.923194	0.912672
4	512	457	0.176291	0.823709	0.808245
6	512	457	0.253484	0.746516	0.720845
8	512	457	0.323878	0.676122	0.648137
10	512	457	0.371469	0.628531	0.603499

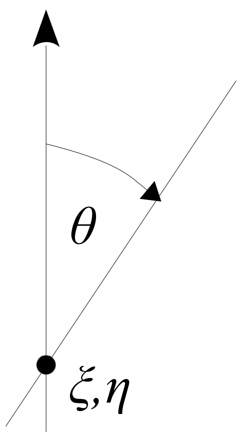
TT TF FT

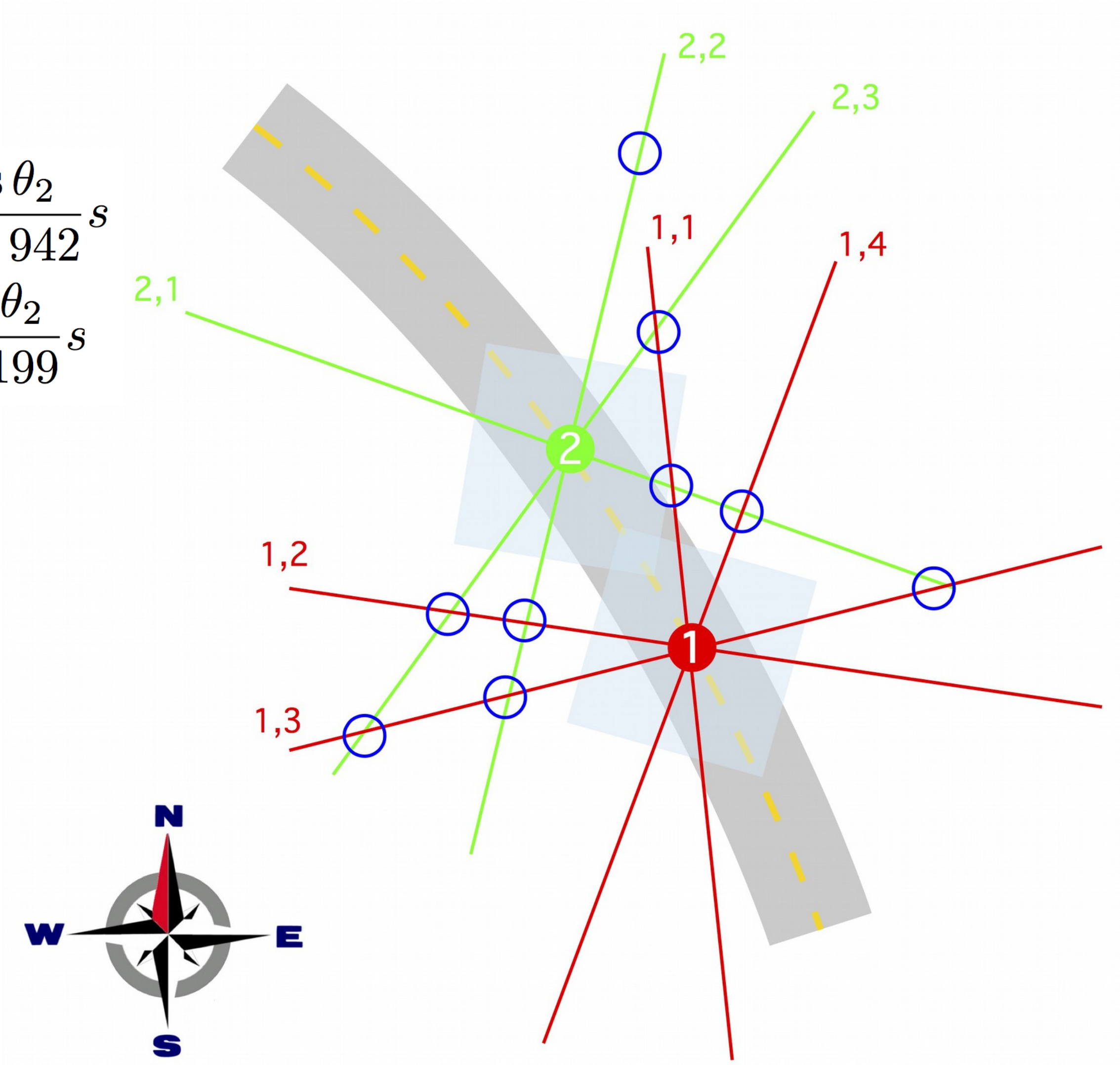
What we are doing to optimize the process

- Manual “ground truth” for thousands of images (this too has issues)
- Calibration of algorithm parameters to minimize false positives while retaining acceptable detection statistics
- Investigating “human” processes – e.g. correlation of vertical swaths, texture, color

The triangulation process

$$
\begin{aligned}
\xi_1 + \frac{\cos\theta_1}{110,942} r &= \xi_2 + \frac{\cos\theta_2}{110,942} s \\
\eta_1 + \frac{\sin\theta_1}{91,199} r &= \eta_2 + \frac{\sin\theta_2}{91,199} s
\end{aligned}
$$





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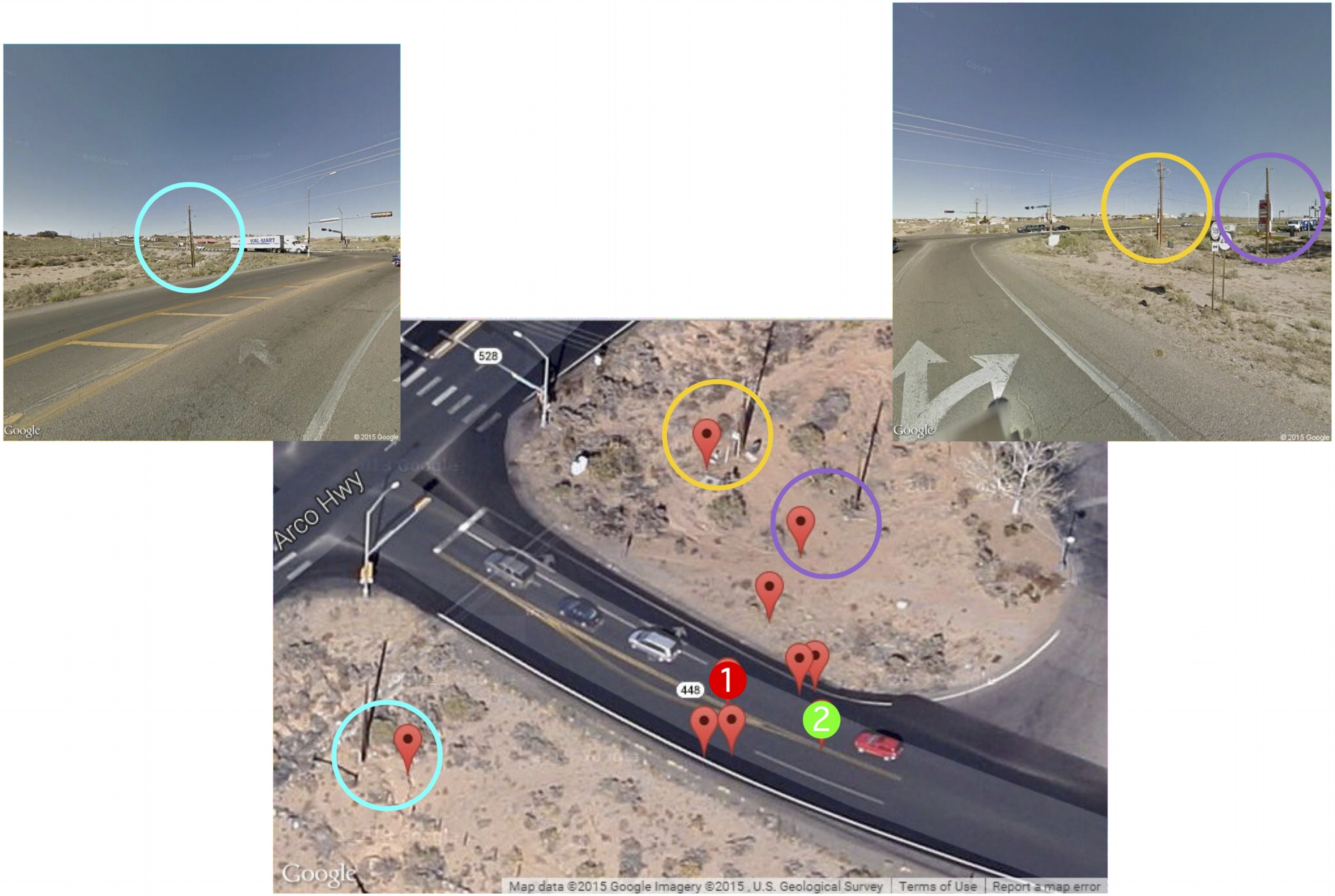
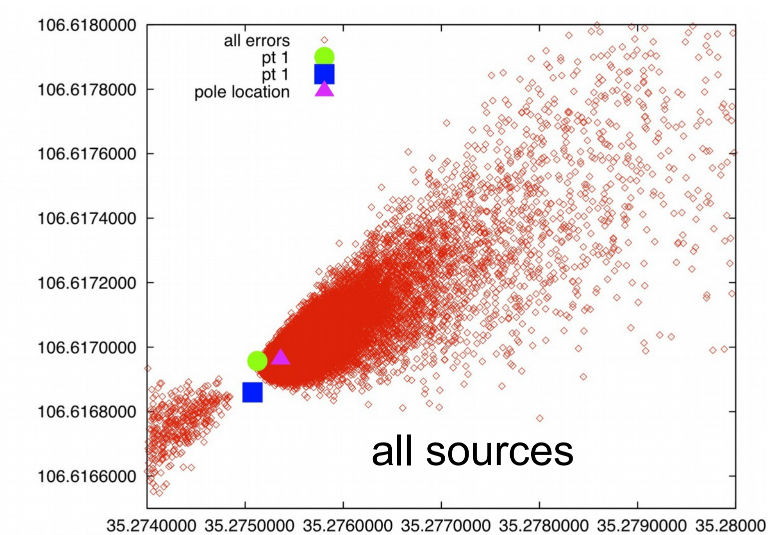
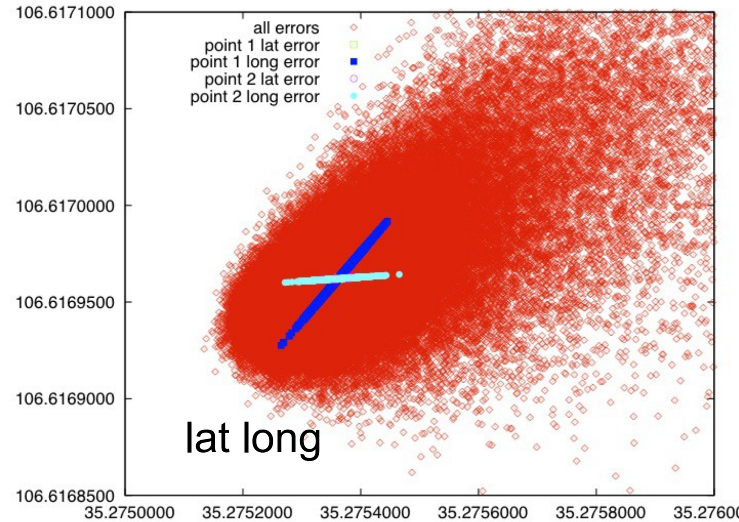
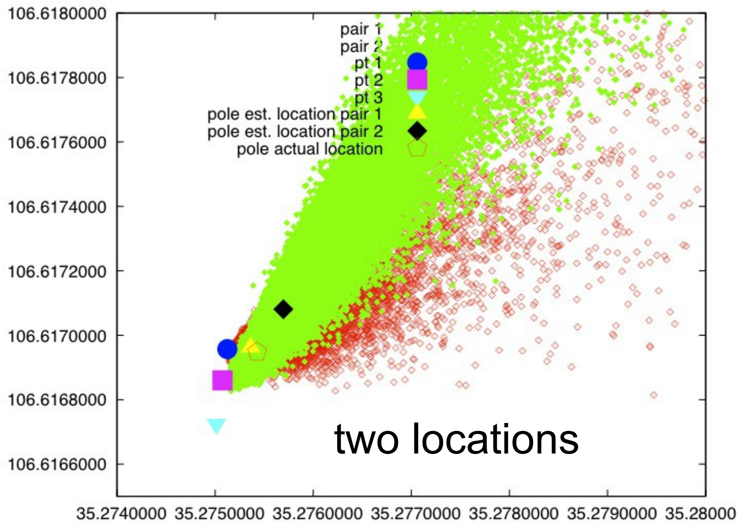
How well does this work?

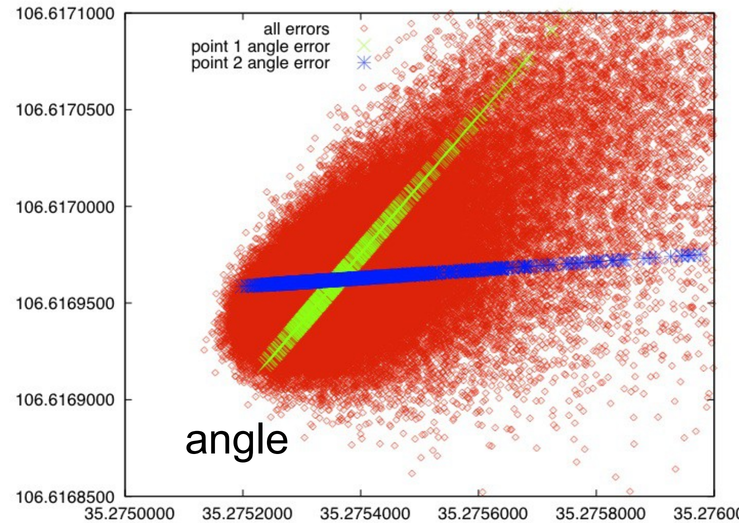


Sources of error

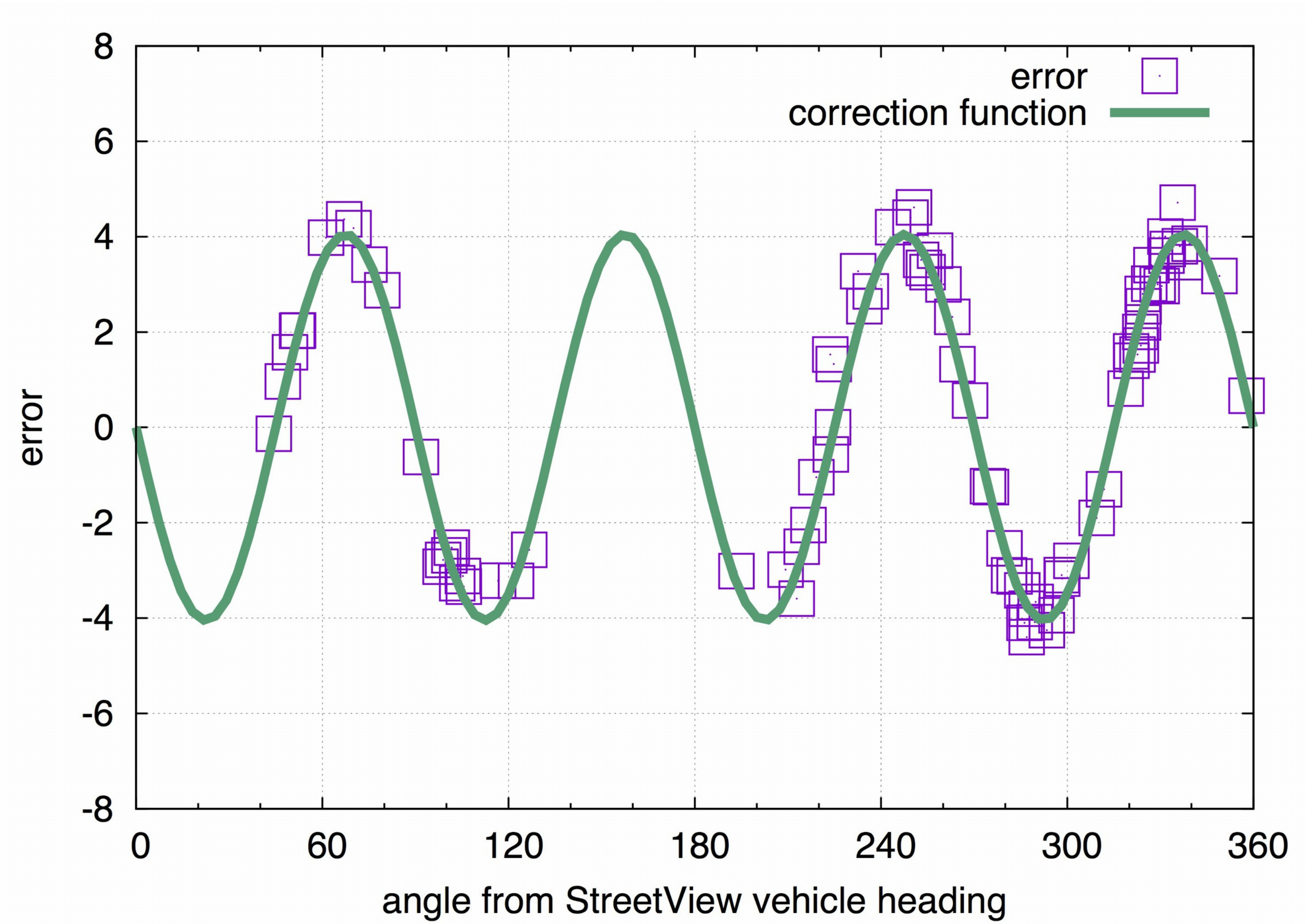








Could there be some optical distortion?



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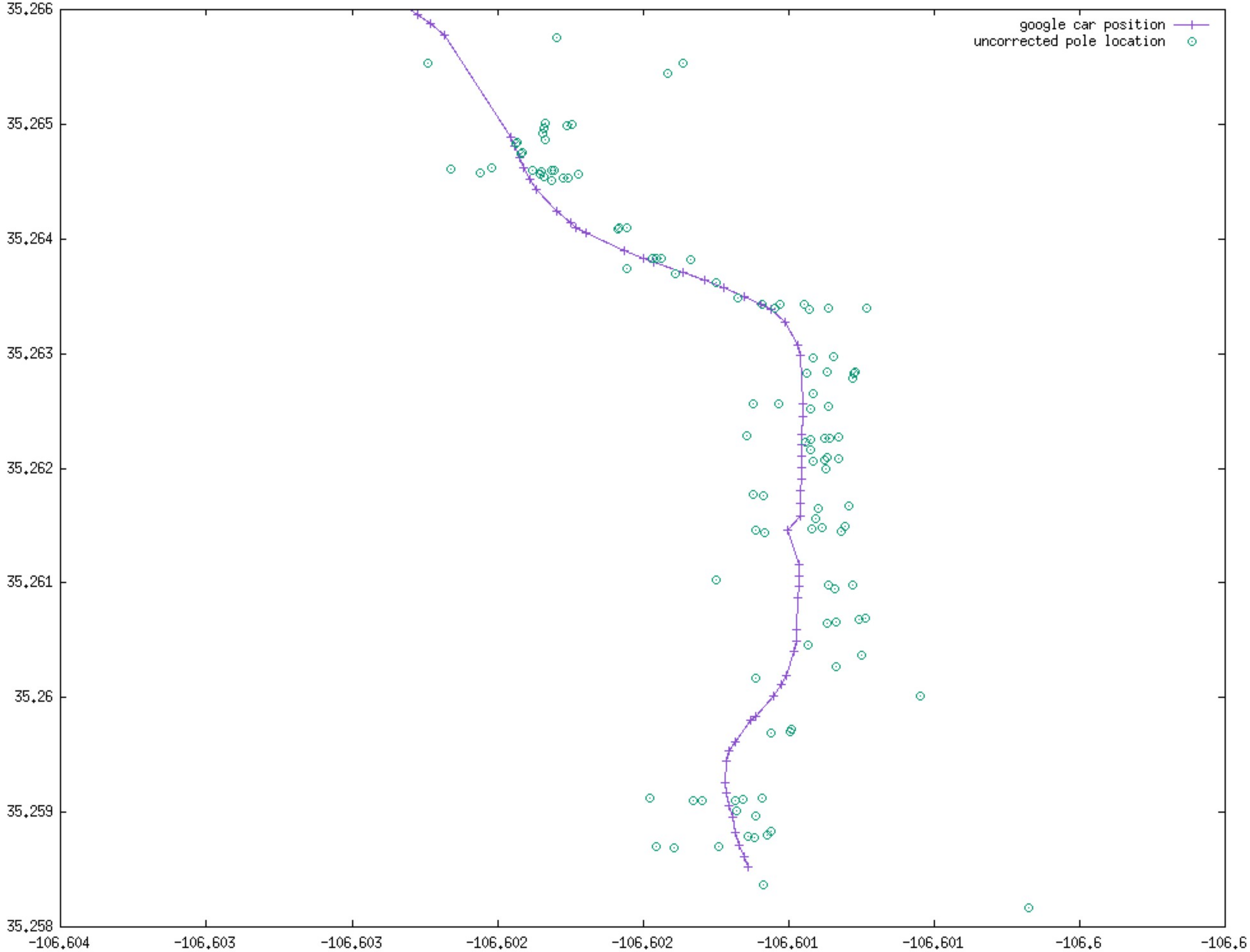
Pole locations before angle correction



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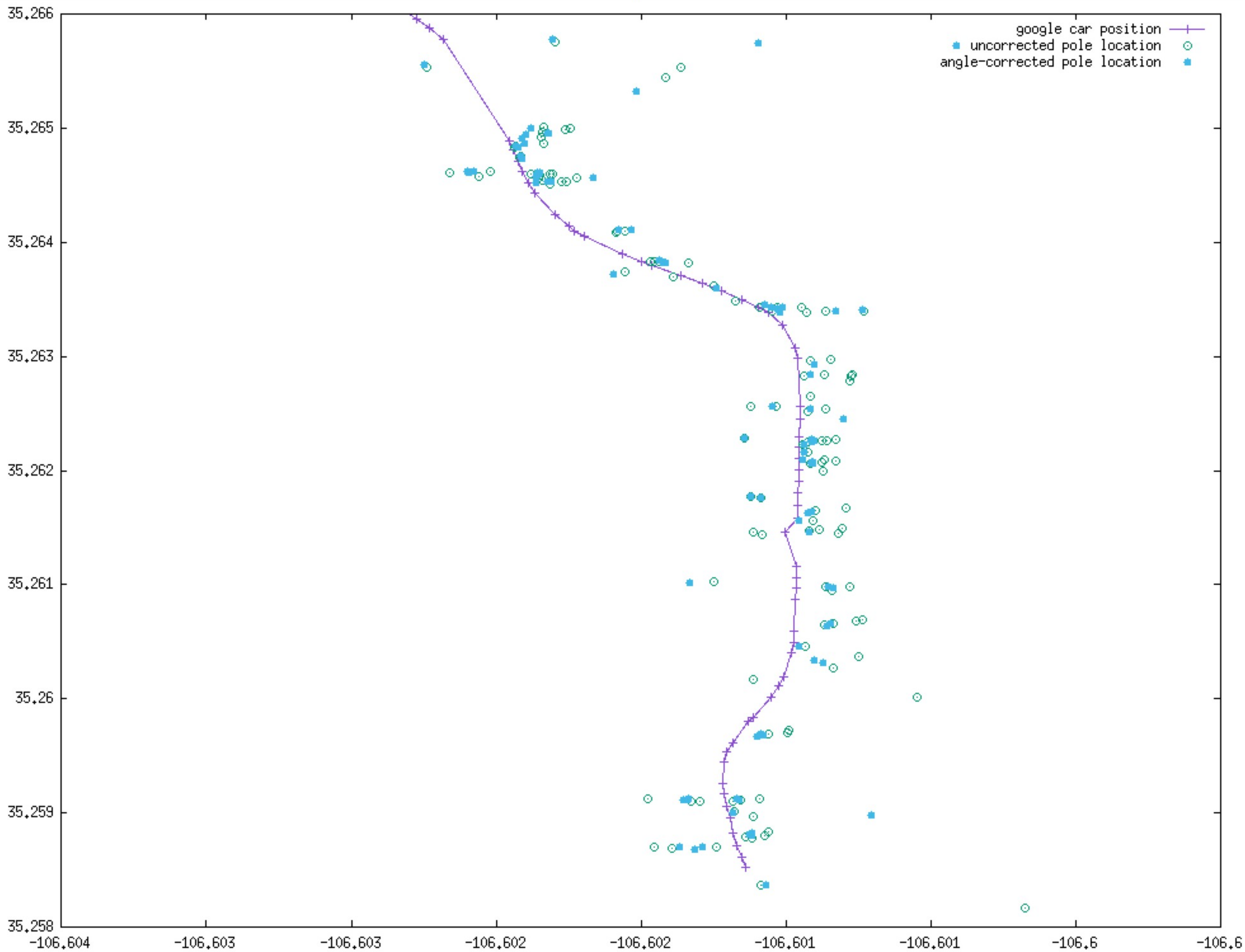
Pole locations after angle correction



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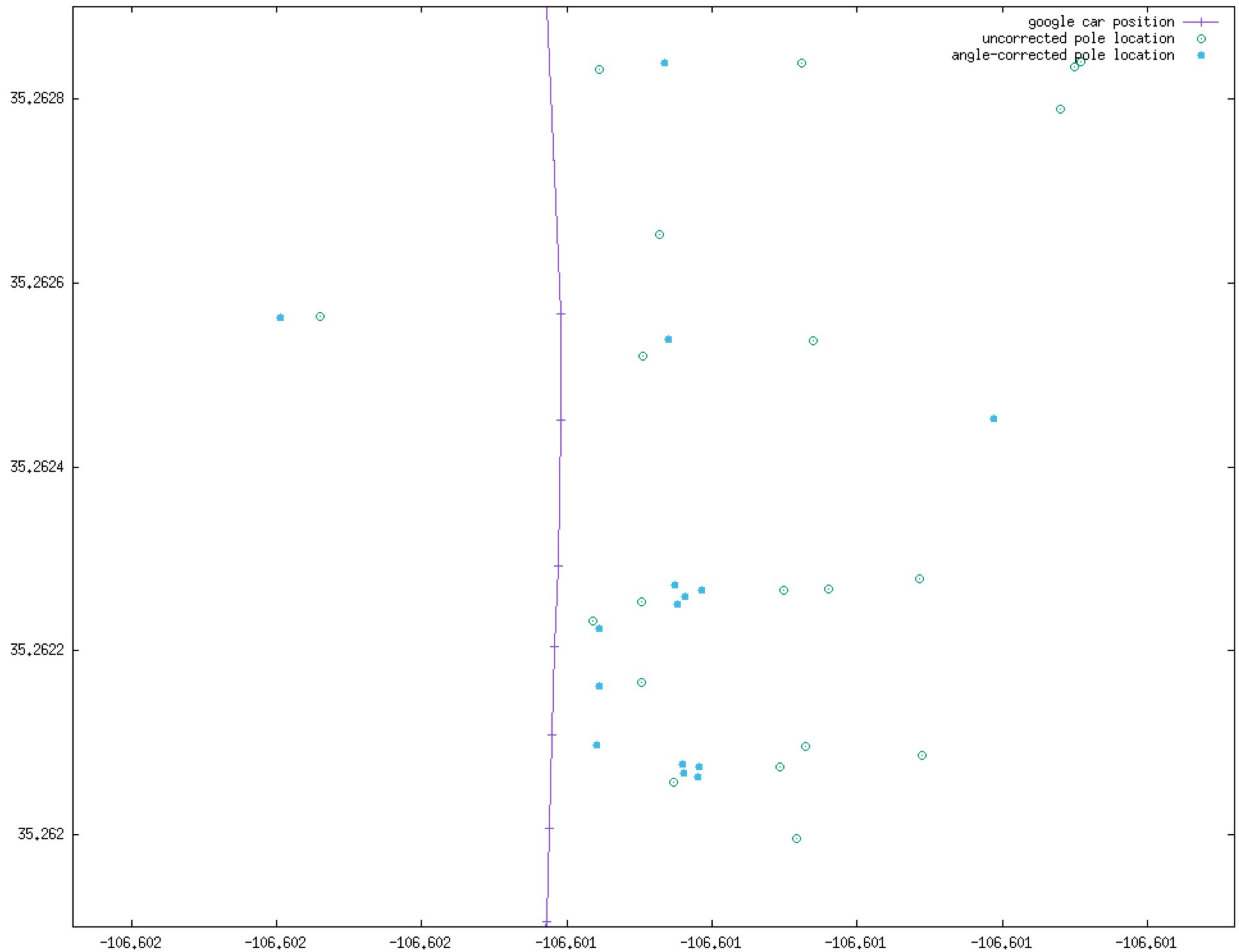
A closer look



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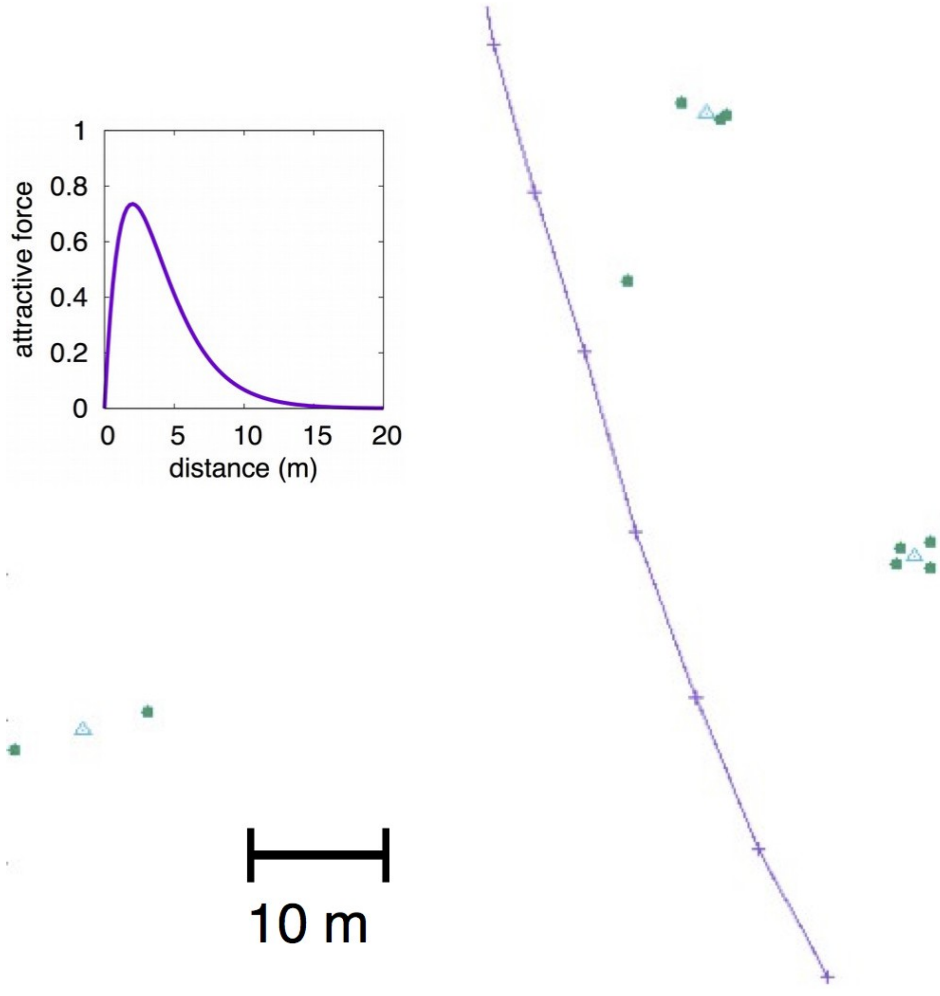
After clustering algorithms is applied



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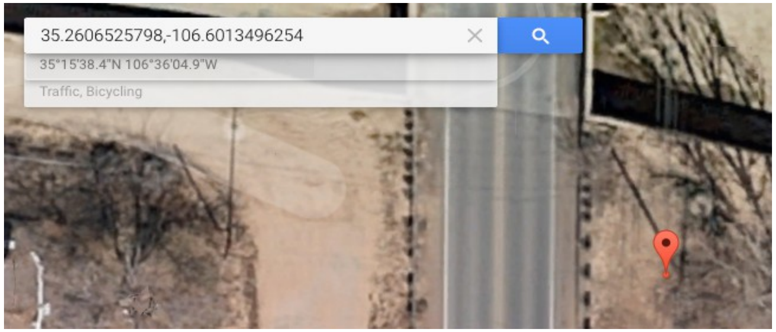
How did we do?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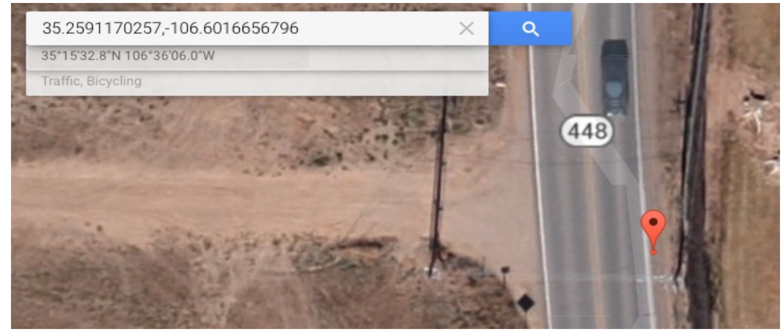
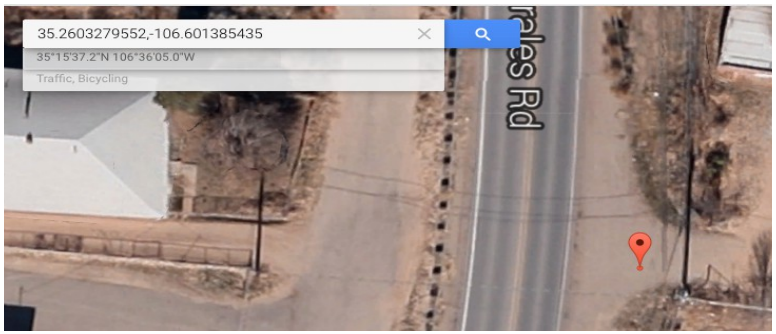
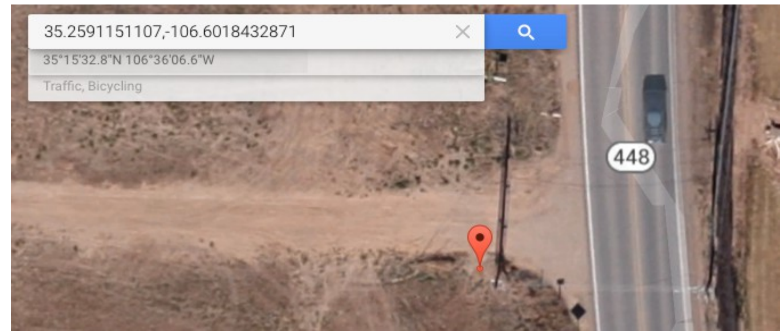
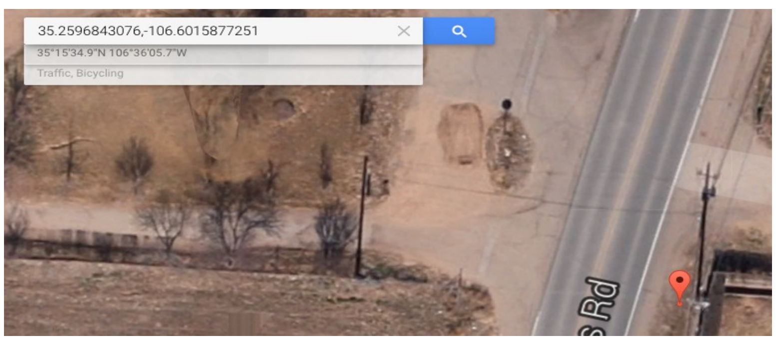
35°15'38.4"N 106°36'04.9"W
Traffic, Bicycling


35.2591170257,-106.6016656796
35°15'32.8"N 106°36'06.0"W
Traffic, Bicycling
448


35.2603279552,-106.601385435
35°15'37.2"N 106°36'05.0"W
Traffic, Bicycling


35.2591151107,-106.6018432871
35°15'32.8"N 106°36'06.6"W
Traffic, Bicycling
448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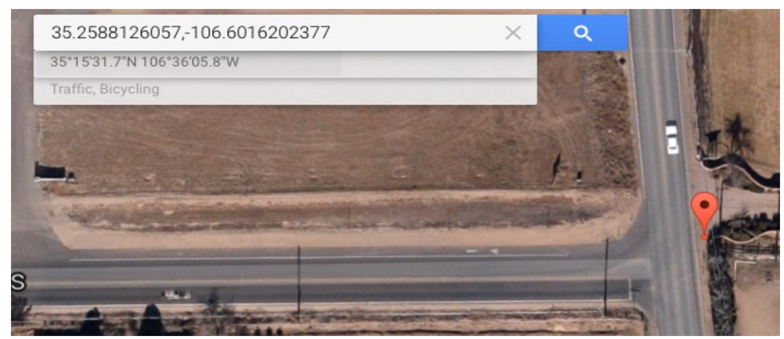
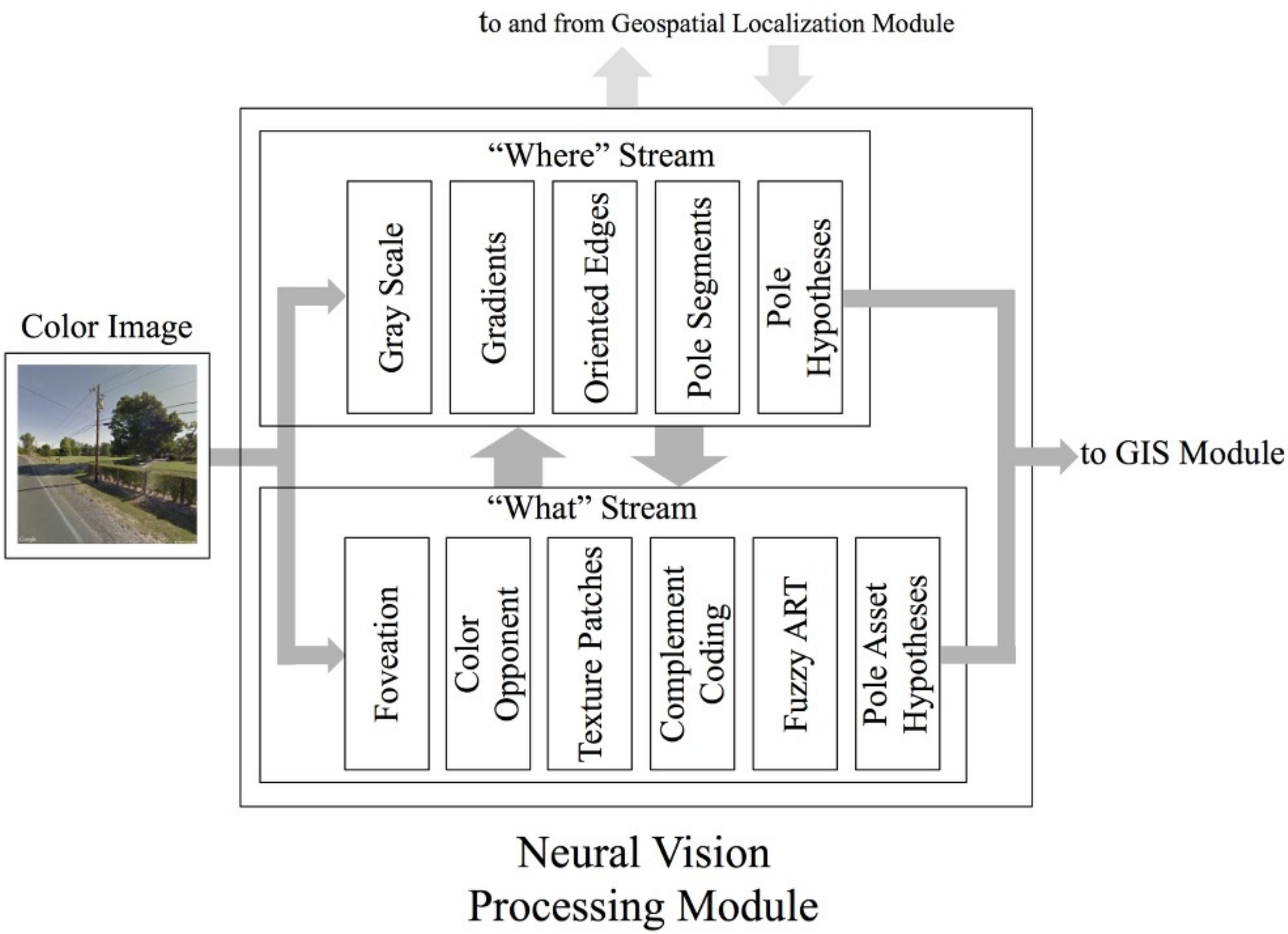
Traffic, Bicycling


35.2588126057,-106.6016202377
35°15'31.7"N 106°36'05.8"W
Traffic, Bicycling

Now we can go further – by integrating the "what"



Our neural architecture

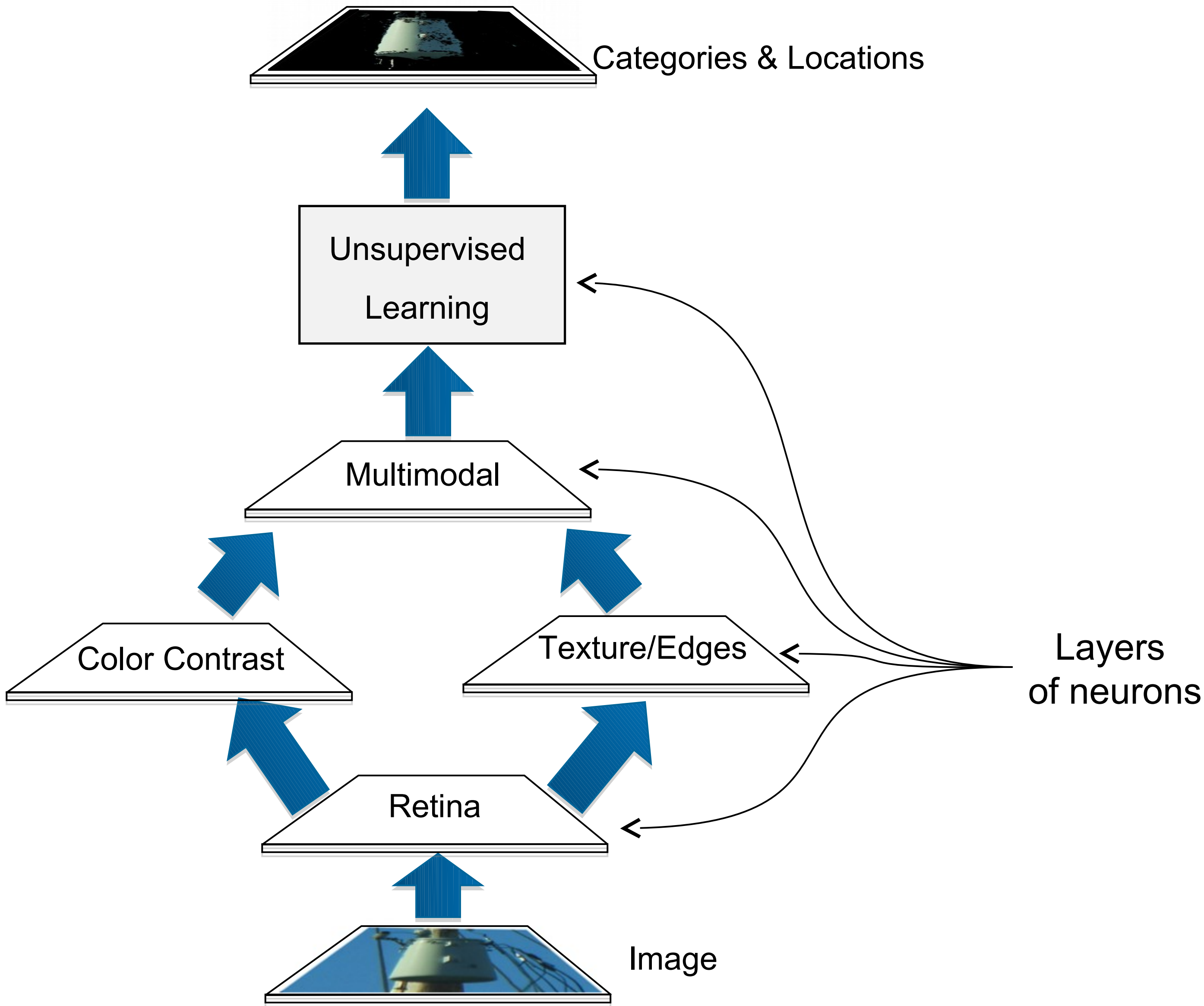


Image to edges and regions

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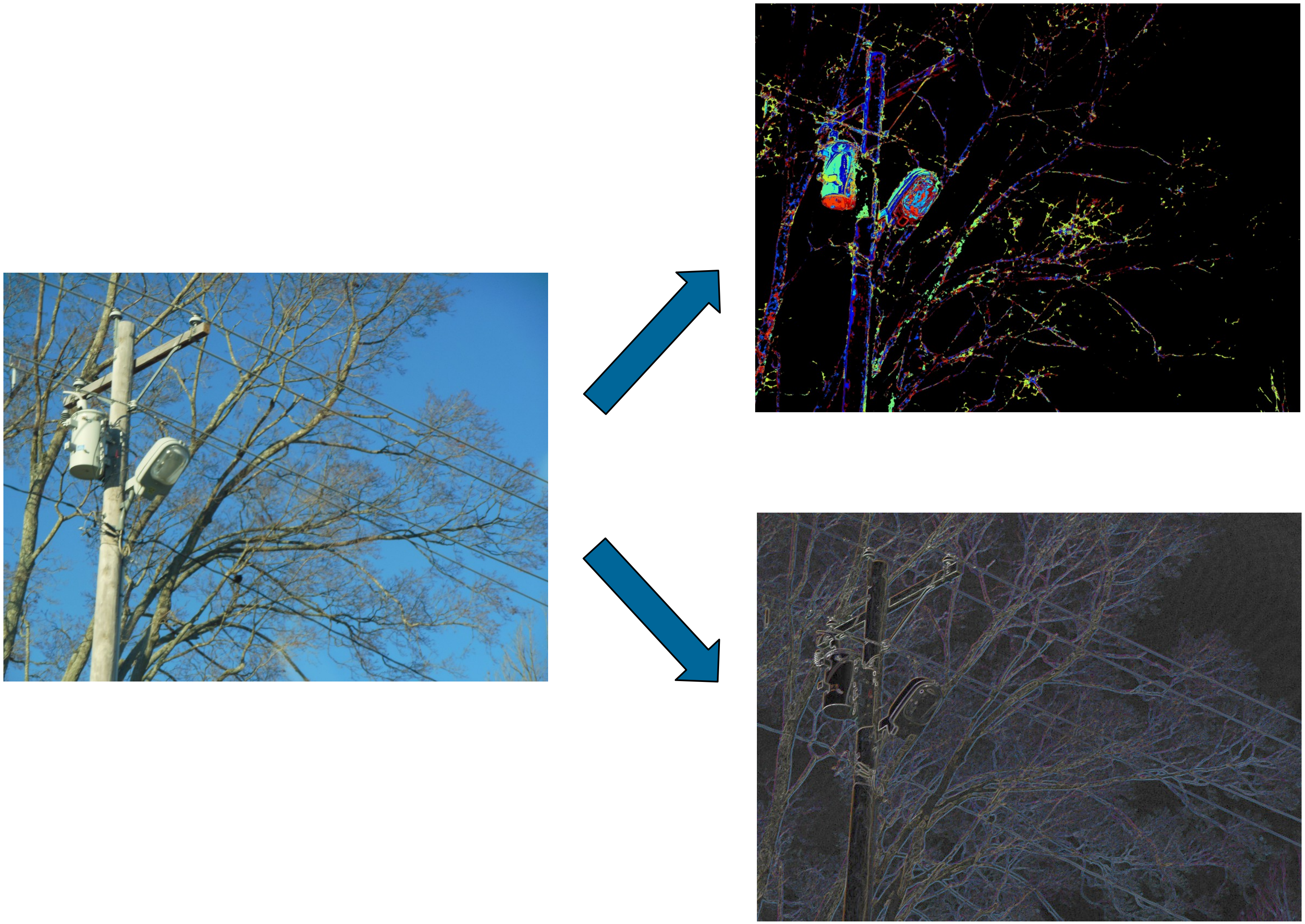
Image to categories and texture



Combined results

Outlook for the neural approach

- We have shown that we can simultaneously catalog and locate assets automatically
- Preliminary results show accurate geographic location from triangulation
- Need to optimize discrimination of vertical structures
- Artificial neural networks provide a technology that can mimic biological vision and recognition processes
- Limited preliminary results on transformers are very positive
- Future research should evaluate the robustness of this approach on large image data sets
- Image collection and computational resources should be addressed

Overall conclusions

- Triangulation from imagery can provide accurate location of poles
- We can detect poles automatically, but still need to optimize parameters and put in place filters to achieve full TT
- Neural approach can detect features successfully, given adequate training
- Rudimentary route-planning is in place for large-scale testing
- We now need to scale up and build statistics for an optimized system

Where to next?

- Expand recognition to more assets, e.g. padmounts, breakers
- Compare public domain with utility-owned imagery, determine overlaps and hierarchy
- Reverse-process: obtain imagery to determine damage, e.g. post-hurricane
- Compare with existing utility GIS

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