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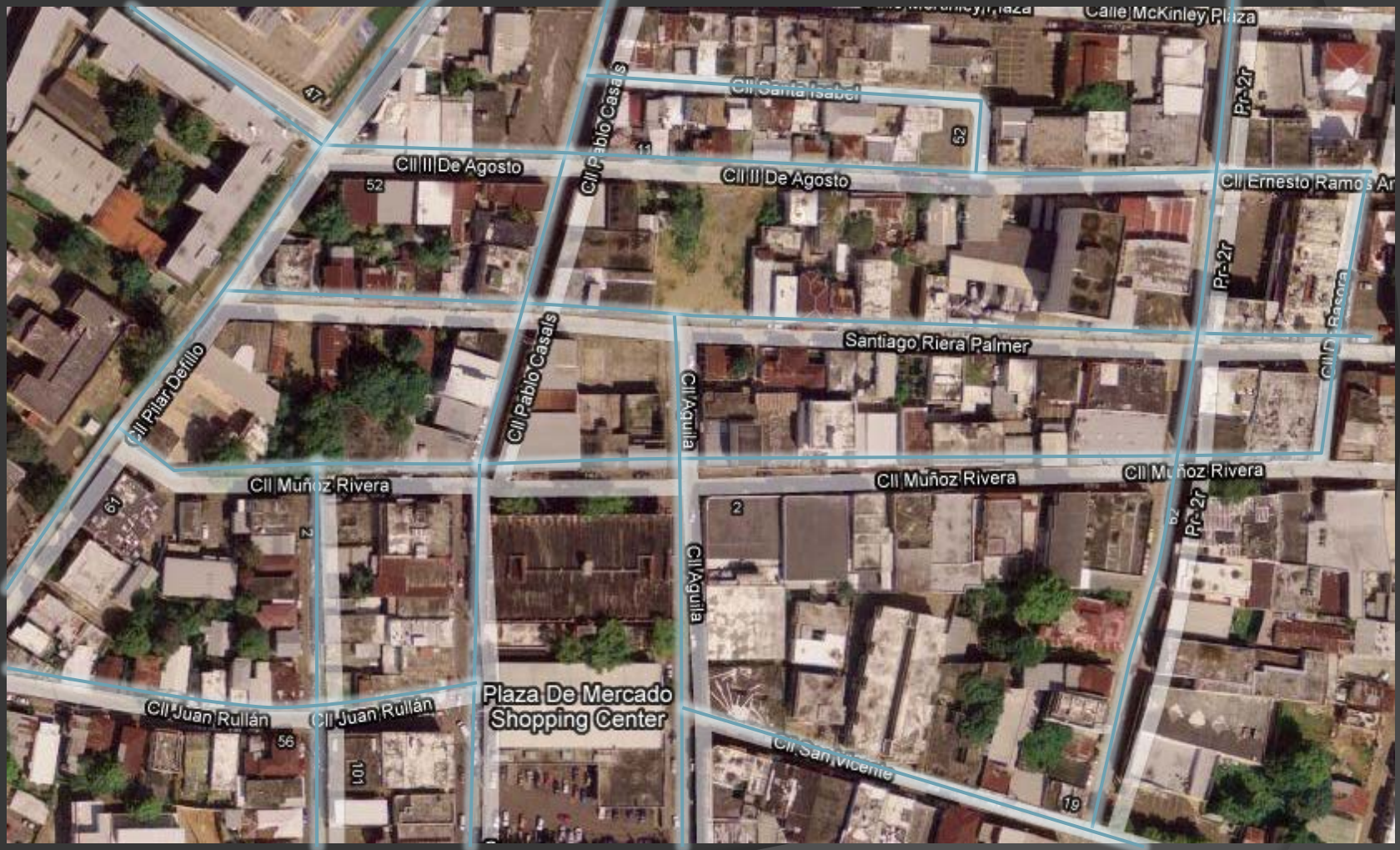
A STUDY ON REGISTRATION OF ROAD NETWORK TO IMAGERY

Problem

- One of the challenges for any Geographic Information System (GIS) application is to keep the spatial data up to date and accurate.
- With growing availability of more accurate satellite imagery from IKONOS, Quickbird, OrbView together with traditional aerial photographs, it is possible to keep tighter maintenance cycle than before.
- Traditionally this is a labor intensive operation that requires great resources from every department.
- To overcome this it is imperative to develop automatic or semi-automatic processes to detect required features in high resolution imagery.

Example


Calle McKinley Plaza
Cll Santa Isabel
Cll II De Agosto
Cll II De Agosto
Cll Ernesto Ramos
Cll Pablo Casals
Cll Pablo Casals
Pr-2r
Pr-2r
Santiago Riera Palmer
Cll Pilar Defillo
Cll Aguila
Cll Aguila
Cll Muñoz Rivera
Cll Muñoz Rivera
Cll Muñoz Rivera
Pr-2r
Plaza De Mercado
Shopping Center
Cll Juan Rullán
Cll Juan Rullán
Cll San Vicente

Common Approach

- Up to this point, must of the effort in the scientific community have concentrated in locating roads through various an automated approaches since roads are one of the most often changing urban features in a sustainable development society.
- There are other authors that concentrate their efforts in the location of road intersections. (Haverkamp 2002) follows a low-level pixel-based techniques with higher-level reasoning to extract the intersections.

Our Approach

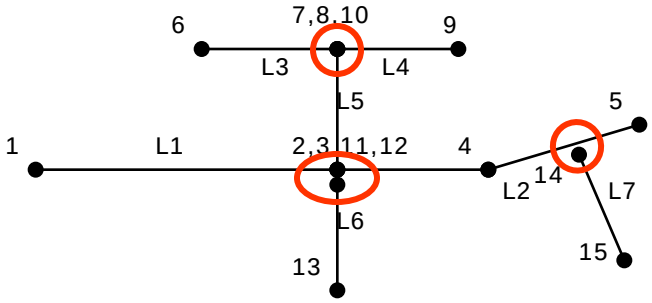
- In our approach we will use the existing road networks, their geometry, and relative location.
- However, it is not assumed that this information is complete, accurate; rather it is accurate enough to concentrate the extraction process in confined segments of the image located around intersection points in the road networks.
- The located intersection points in the image will guide the registration or re-registration process of the road network with reference to the image.

Steps

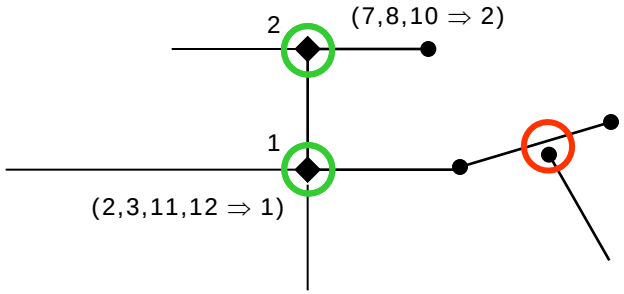
- Locate intersections on the vector road layers
- Preprocess image with common filters, like image smooth with edges enhance.
- Use Canny Edge Detector to find the road edges.
- Use the Hough Transform (HT) to parameterize the edges into lines.
- Use only the lines that fit a two lane road pattern, and calculate the center line of the road.
- Create a point representing an intersection where two center lines meet.
- Compare these intersection points with the vector layer intersection points to find the appropriate transformation parameters (4) that give the highest yield of matched points.
- Using the matched points on both points sets, find using least squares, higher order transformation parameters (6 – 8).

Locate Intersections from Road Network

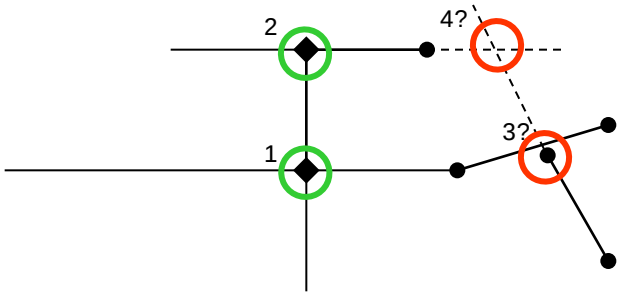
Find all vertices on a line (there is duplicity in the points generated)



Find all nodes in the intersections using all vertices within 1m of each other as criteria.



Find the intersecting points between specified lines that are at a distance less than 1m of point.



Select only the points that are within extent of the intersected line and 1m of the intersecting point.

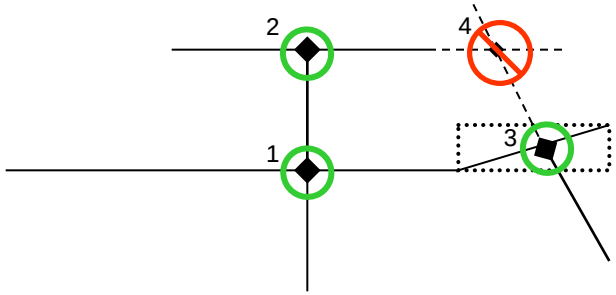
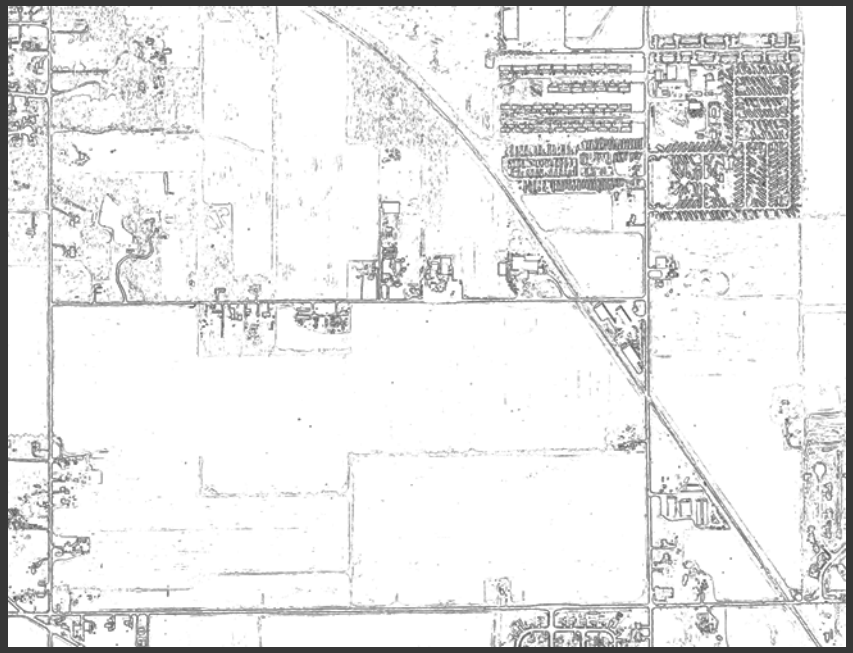


Image Preprocessing

- In order to minimize false road edges in a image caused by shadows, vegetation, texture within an area the image should be preprocessed prior to using the Canny edge detector.
- Some recommended processing may include:
  - Eliminating preselected areas that may represent vegetation. This is possible using multispectral images.
  - Use of common image processing filters, like image smoothing, edge enhancers and even changing image contrast.

Comparison Preprocessing Image

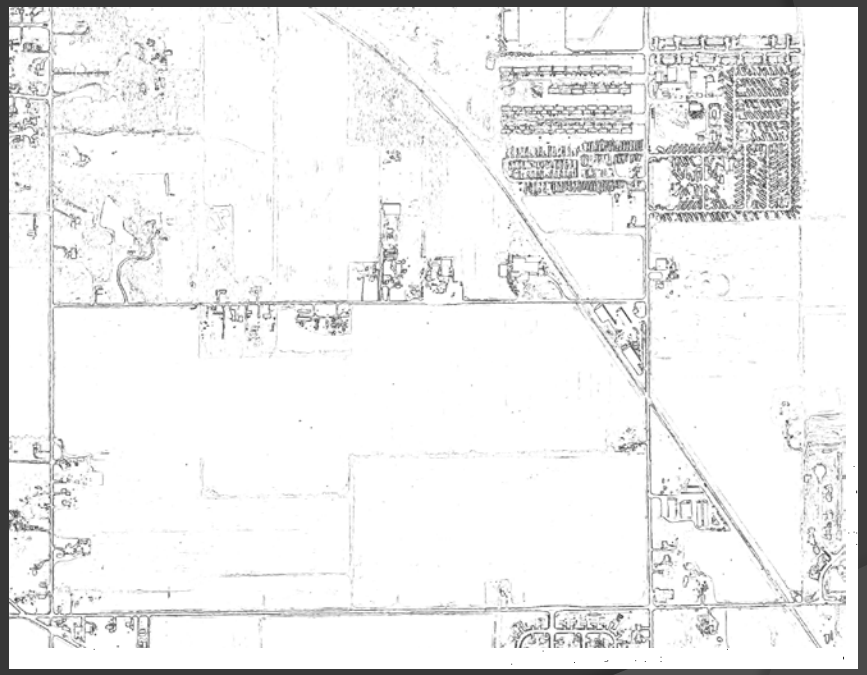
Canny edge prior image preprocessing



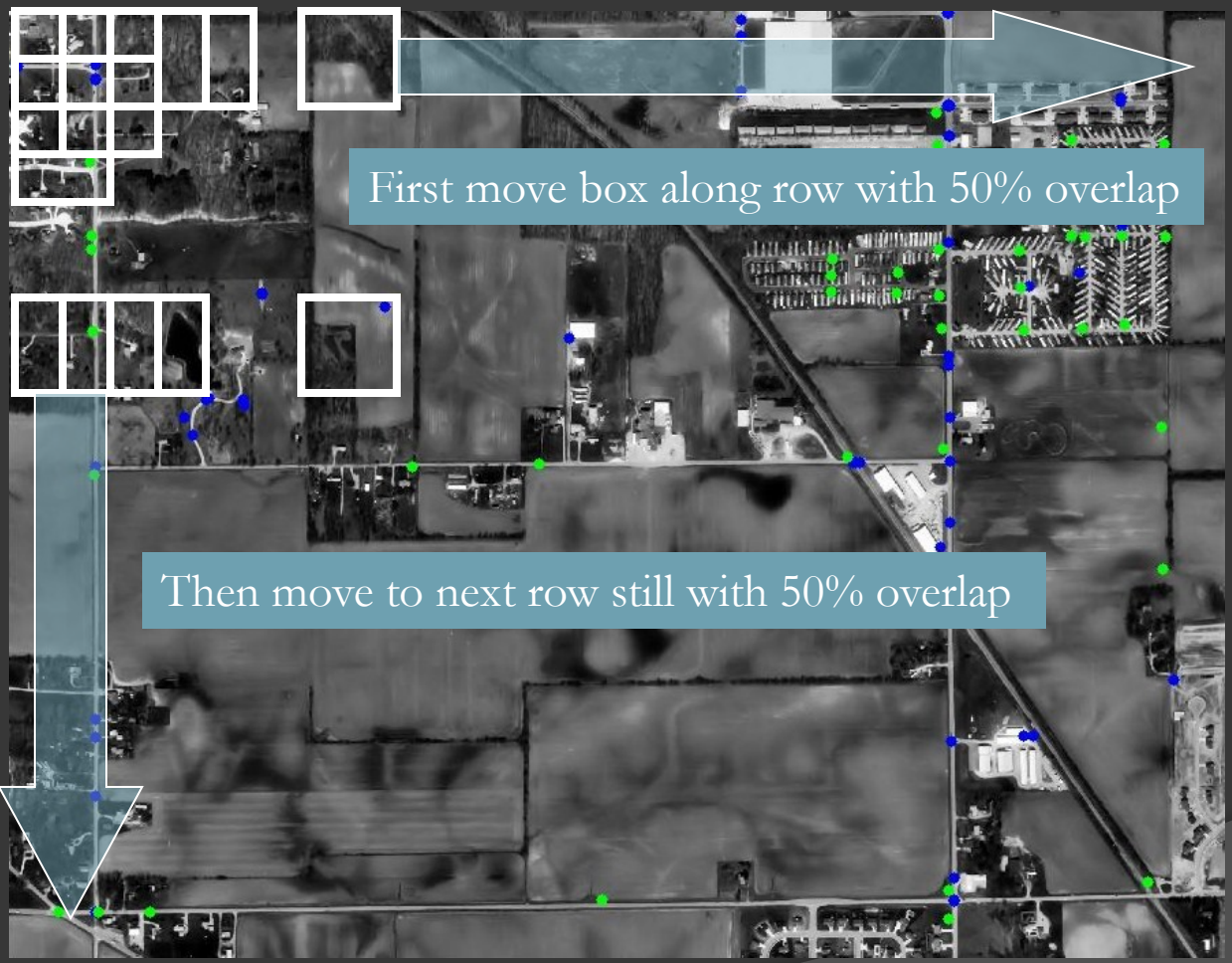
Canny edge post image processing

Edge detection from image

- Edge detection made by Canny edge detection algorithm (Canny, 1986)
- Canny filter was preferred because it is robust to noise, and more likely to detect true weak edges.
- This step does not provide parameters to define lines, so another step will needed.



The Moving Box for HT

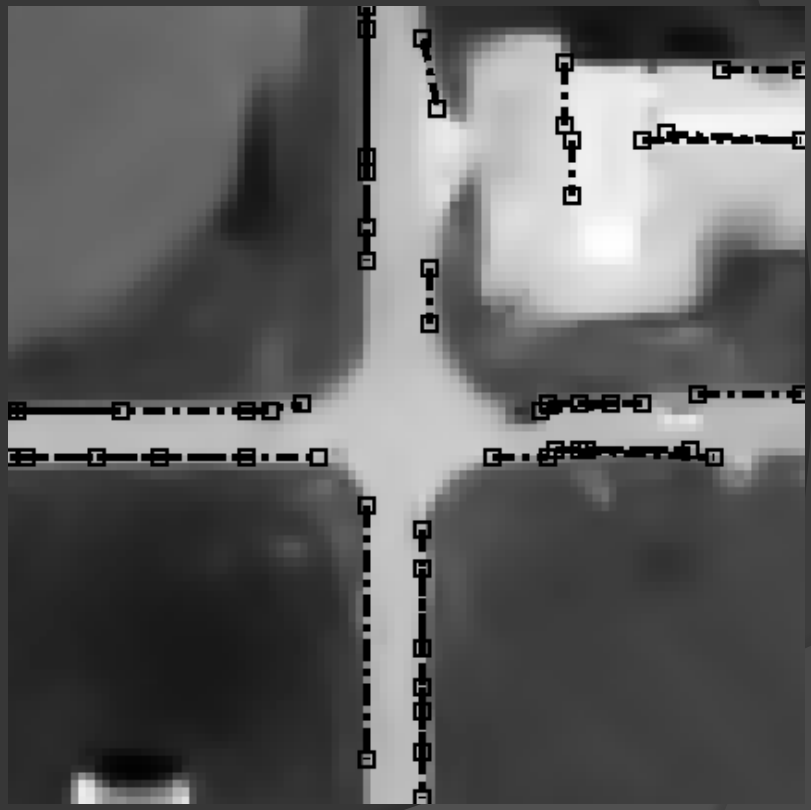


Facts of the Moving Box for HT

- Using the moving box methods guaranties searching all possible areas where there could an intersection.
- The size of the box is 100x100m.
- Moving the box with a 50% overlap, allows for the box to position itself to accommodate over an intersection without cropping an incoming road from either side of the mention intersection.
- However, it may provide a higher yield of intersection points within an image, it may also provide duplicate points representing an intersection that are not necessarily overlapping one over the other.
- This has little consequence given that one of the overlapping points will be ignored when the relative positions with other found intersections is compared with the vector intersection points.

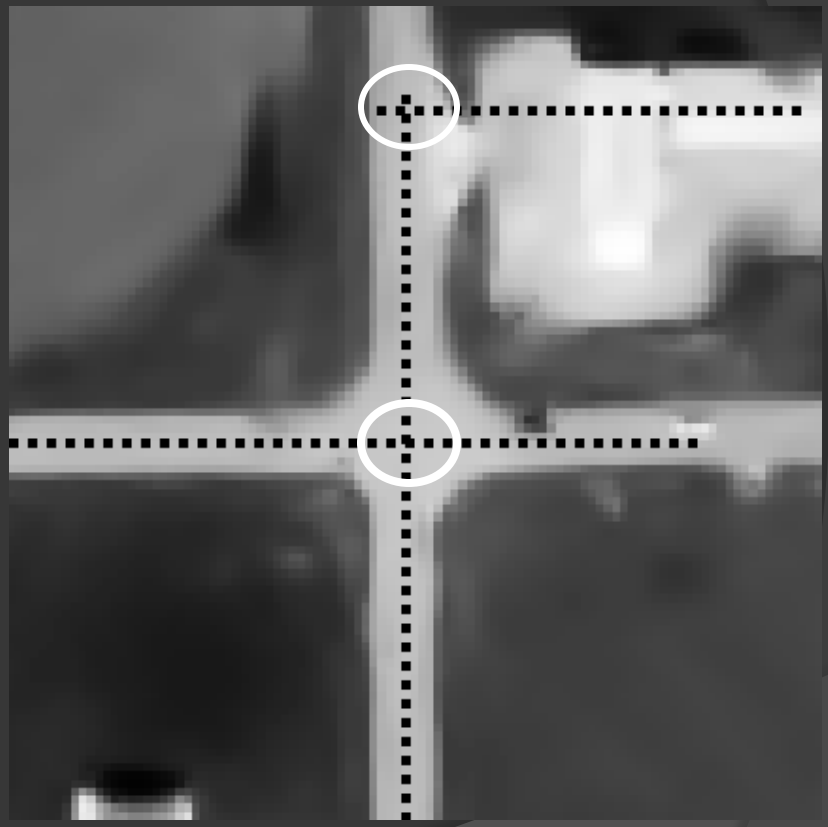
Hough Transform (HT)

- Using the Hough transform to search for edges that represent the border of a road, is more effective if made locally.
- HT prioritizes the edges from the longest set of pixels that may represent a line to the shortest.
- So it will provide with most likely set of lines that may represent an road end.
- However it will not discriminate between different cultural object like road, parking lots or buildings or even natural objects like tree lines.



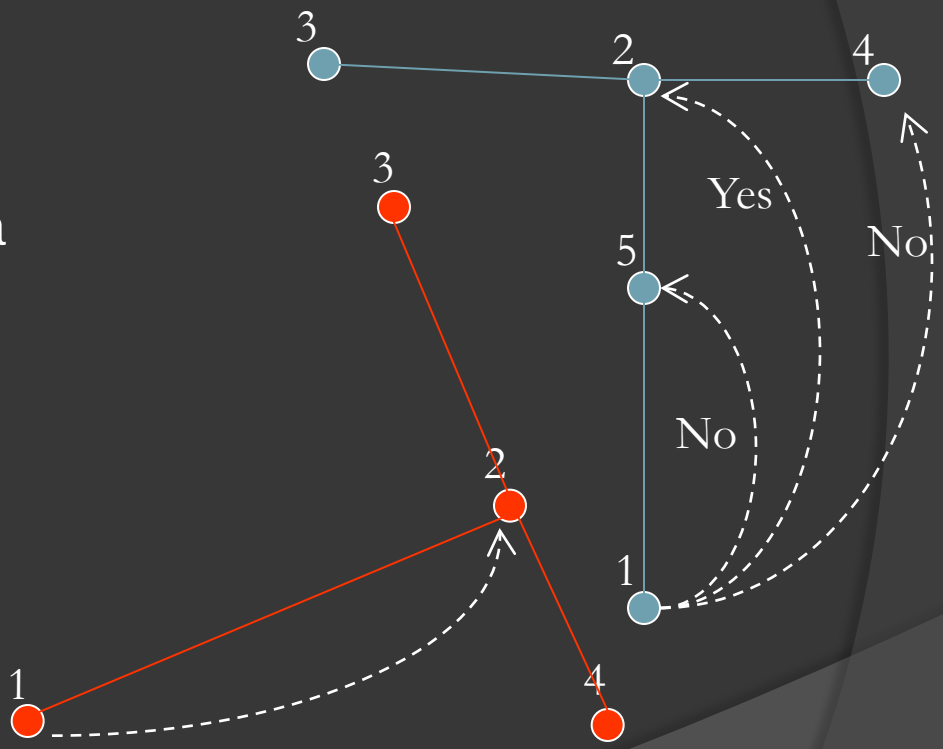
Finding Intersection from HT lines

- Using the HT lines to find pairs that best represent a two lane road (~7meters).
- Then calculate the center lines for each pair (dashed lines).
- Find each intersection between two center lines within the moving box.
- On the image on the right, the edges of a structure had the same dimension of a road and this provided a false intersection point.



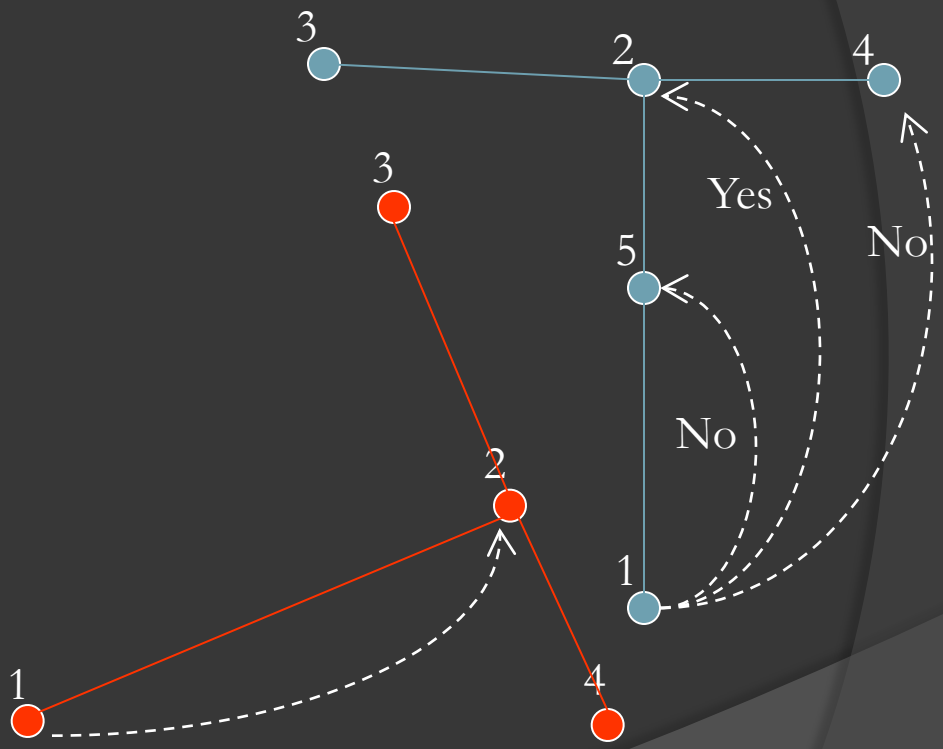
Pair Up Sets

- The procedure to pair up the vector point with the raster points is simple.
- It will pick the first point select the second and compared distances from sets. If distance match, it determine a set of four parameters for transformation.
- Then it will check how many points match, then repeat the process, and keep the set of parameters that provide the most match ups.
- For instance, it will take 1-2 red, compare to 1-5 blue, no match. The go with 1-2 blue, which will match, and get the parameters.



Pair Up Sets – RANSAC Approach

- With an approach similar the RANSAC (Fischler and Bolles 1981), to fit a model using both set of points, and obtain the most amounts of inliers.
- Using the relative position between any two points in both sets, a four parameter transformation is done, and counts the matched points in both sets.
- The points that were not matched are discarded and not used in any further transformation. The parameters that gives the most matched points are used.
- The paired up points are then used to perform a higher parameter transformation.



Pairing Raster & Vector Points

Green points represent the vector points after matching up with the raster points (blue points) using a four parameter transformation.

Registering the Road Layer

- Once the higher order parameters are obtained these parameters are used to transform the nodes and each vertices of the lines in the road layer.
- This will finish the process of registering or re-registering the road layer to the georeferenced image.

Roads Overlaid

- Original road layer.
- Roads after matching with raster points, using a 4 parameter transformation.
- Roads after applying a higher transformation using the matched points of the previous points.

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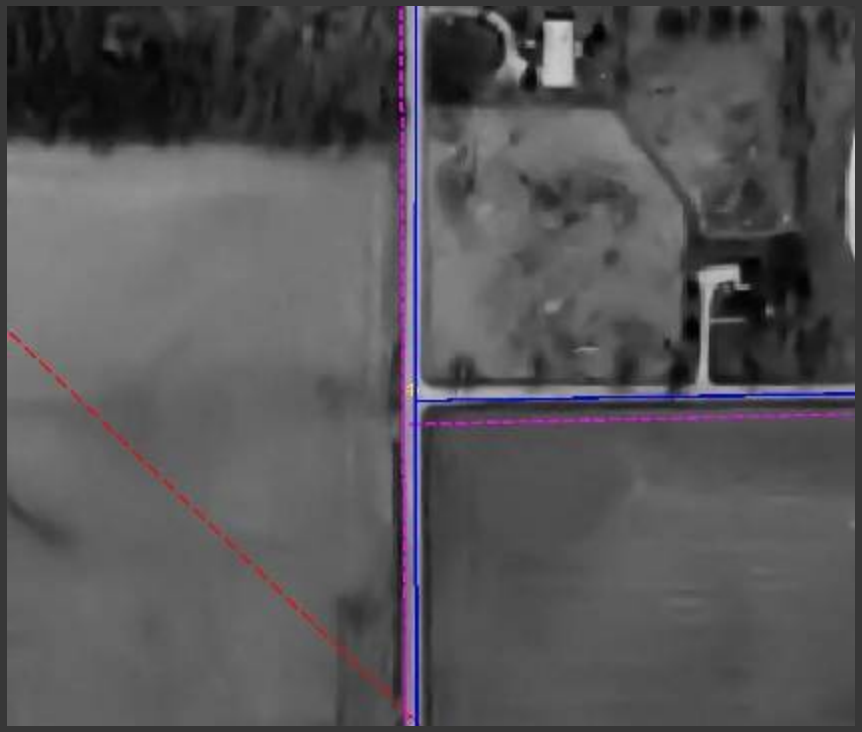
Closer look at Intersections



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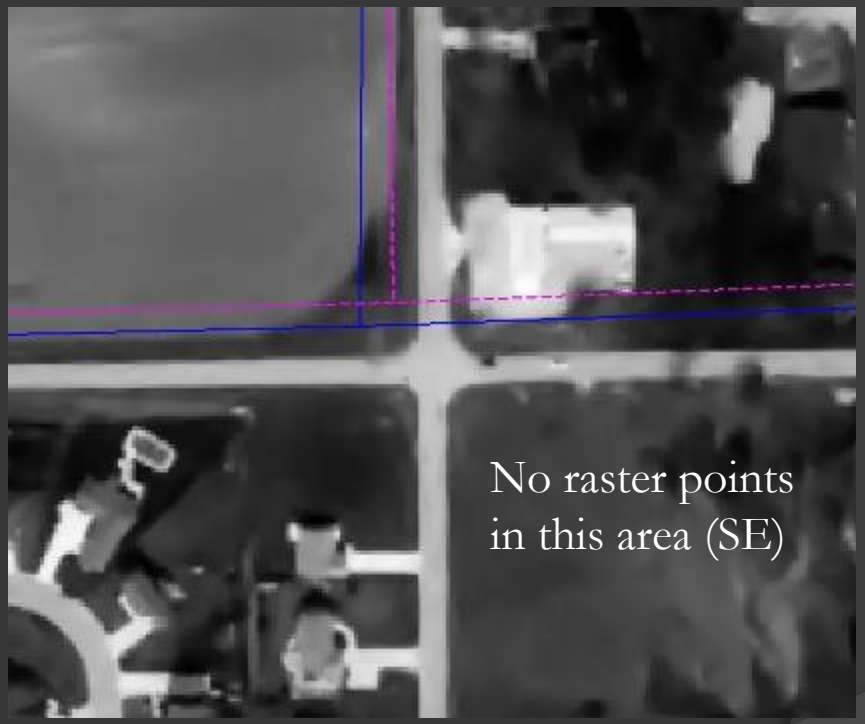

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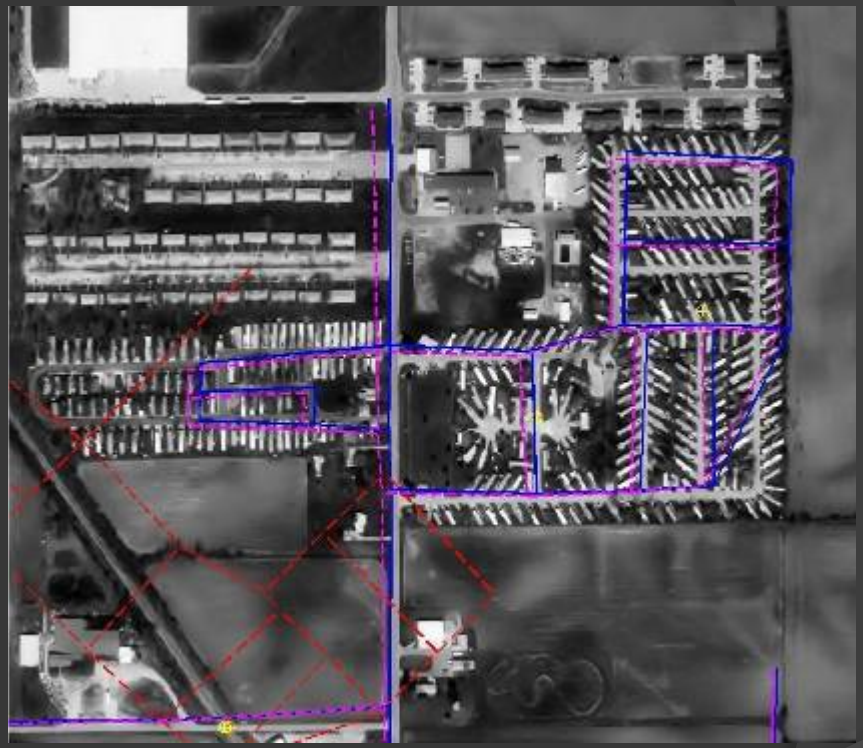

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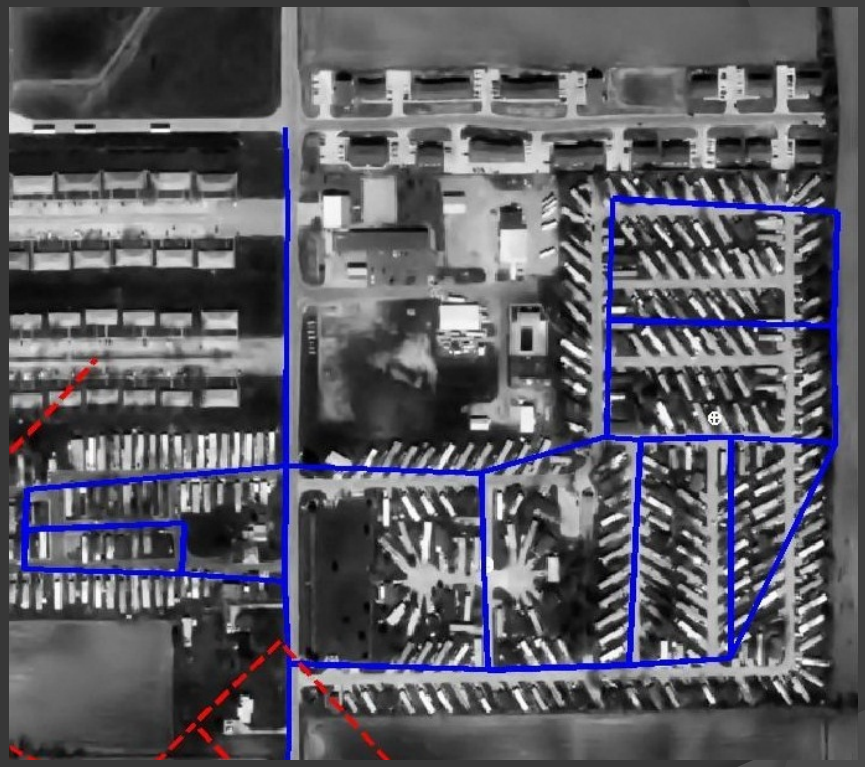

- Original road layer.
- Roads after applying a higher transformation using the matched points of the previous points.

Parameters Used

- Image is a 1 meter resolution panchromatic.
- The HT algorithm connected pixels into lines with a minimum of 7 pixels, and aloud gaps between pixels of 2 pixels.
- The maximum number of lines that the HT algorithm detected was 20.
- Lines to be considered parallel have to within 5 degrees from each other.
- For a pair of parallel lines be consider road edges they have to be 8(±3) meters apart. This is for a 2 lane rural road.
- To consider to points a match they should be lest that 20m apart.

Conclusions

- The use of canny edge detection y combination with the Hough Transform to model the edges of a road or street in an intersection has proven to be assertive. More so, they have proven to be independent of orientation of the roads.
- The use of the moving box to overcome the limit of the HT algorithm proved assertive in locating all possible intersections, even with the few drawbacks.
- However, the quality of the imagery has great relevance on how the edges would be determined. Preprocessing the imagery to eliminated objects data can be distracting, grass, trees, rivers, and other natural objects, would increase the accuracy of the detection of the road edges.
- If one or more of the edges are completely invisible, obscured by trees, or other tall objects, it will be impossible to detect the intersection. However, as long as some of the edge is visible, may specify the length of the edge to be accepted, the algorithm will go through and try to find a pair.
- The RANSAC approach to find matched pairs work extremely well with the data set used, even though there was no correspondence in the number of points used from both sets.
- Using an high order transformation proved little to adjust the roads and it's intersections with their corresponding location on the image, giving the randomness of distortion on the road, or street location.

References

- Canny, J. (1986). "A Computational Approach To Edge Detection." IEEE Transaction Pattern Analysis and Machine Intelligence **8**: 679-714.
- Fischler, M. A. and R. C. Bolles (1981). "Random sample consensus: a paradigm for model fitting with applications to image analysis and automated cartography." Communications of the ACM **24**(6): 381-395.
- Gautama, S. and W. Goeman (2004). Robust Detection of Road Junctions in VHR Images Using an Improved Ridge Detector. Proceedings ISPRS XXth Congress, Istanbul.
- Habib, A. F., R. I. Al-Ruzouq, et al. (2004). SEMI-AUTOMATIC REGISTRATION AND CHANGE DETECTION USING MULTISOURCE IMAGERY WITH VARYING GEOMETRIC AND RADIOMETRIC PROPERTIES. XXth ISPRS Congress, Istanbul, International Archives of Photogrammetry and Remote Sensing.
- Haverkamp, D. (2002). "Extracting Straight Road Structure in Urban Environments using IKONOS Satellite Imagery." Societyof Photo-Optical Instrumentation Engineers **41**(9): 2107-2110.
- Mena, J. B. (2003). "State of the art on automatic road extraction for GIS update: a novel classification." Pattern Recognition Letters **24**(16): 3037-3058.
- Tóth, Z. and A. Barsi (2005). Analyzing Road Junctions by Geometric Transformations. High-Resolution Earth Imaging for Geospatial Information, Hannover, ISPRS.

Roads