SAND2014-17576D

Path Conditioning

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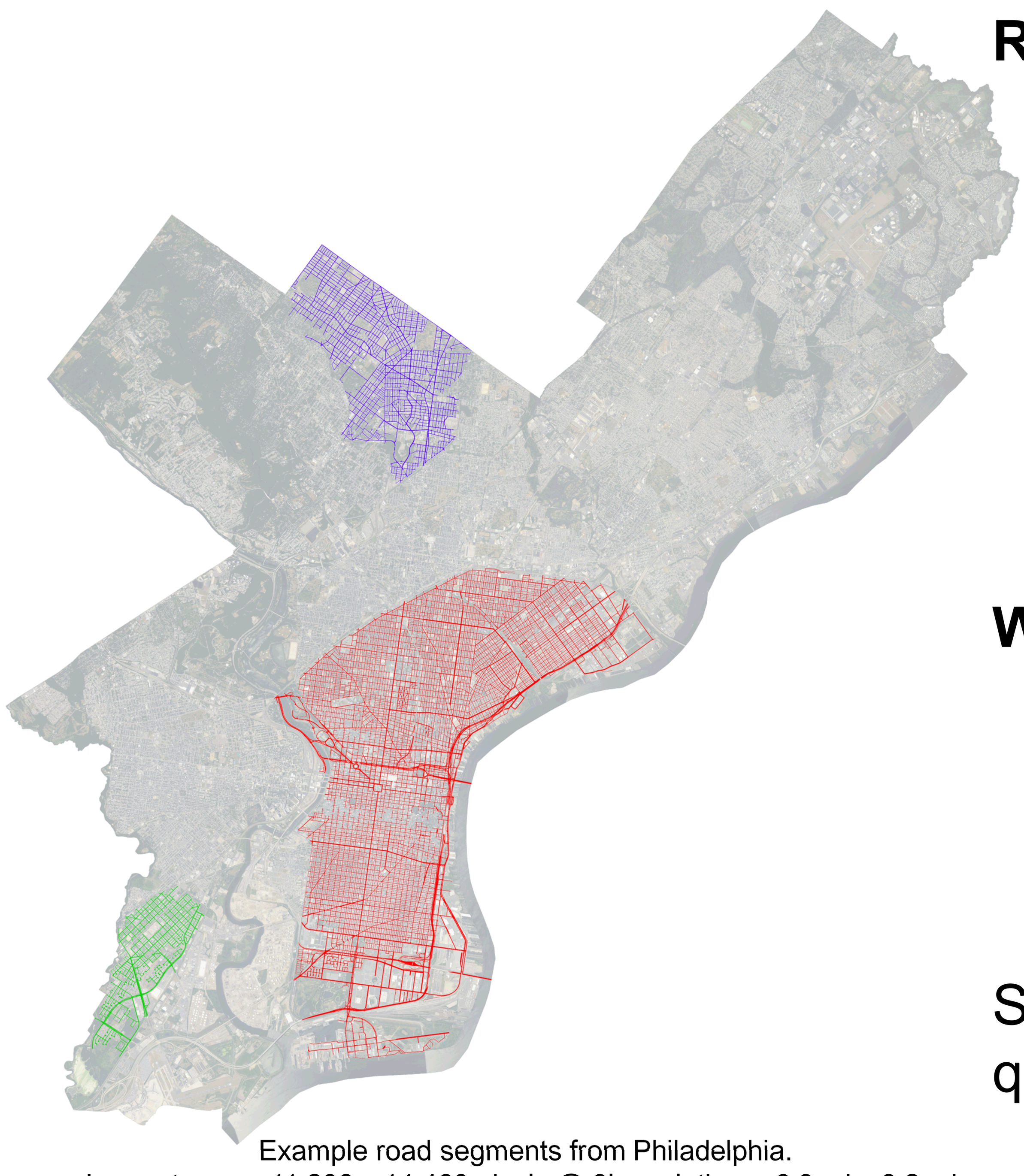
The Problem with Roads and Paths



Example road segments from Philadelphia.
Largest spans 11,206 x 14,460 pixels @ 3' resolution = 6.3 mi x 8.2 mi.

Road and Path regions cause problems

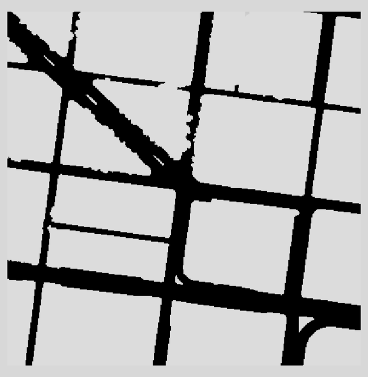
- Show up as a single *node* in the graph
- But it's not a *meaningful* node because so much information is lost in the abstraction.
- Highly-connected graph node has undesirable properties for our graph.
- Example
  - Search for two features within 10m of the *same road*.
  - Result could contain features separated by miles! Probably not what we mean by same road.

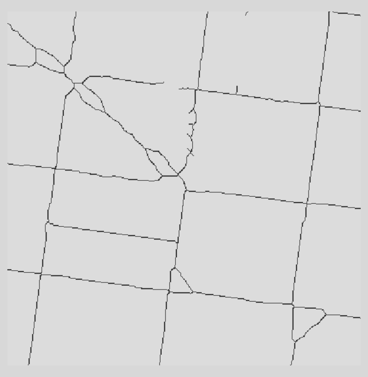
What do we do?

- Break them up into smaller segments
- Intersections are logical places to cut
- Segments can then be inserted into the graph with each node containing a single segment.

Solves the earlier problem and enables additional path and reachability queries to be asked that one could not ask before.

Partitioning the Segments





Skeletonization simplifies the shape into something we can use to find *intersections*.

Used a thinning algorithm
- Produces a *clean* skeleton with few 'spurs'
- Parallelizable

Algorithm

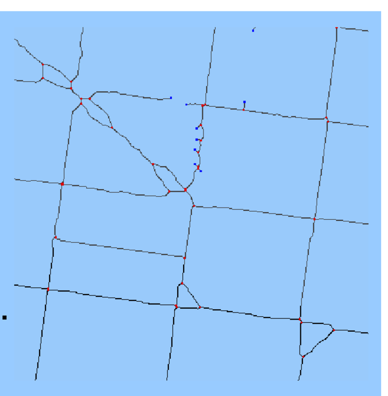
```
WHILE points are deleted DO:
    FOR all pixels p(i,j) DO:
        A = # of 0 to 1 transitions in CW direction:
        B = # of nonzero neighbors of p1.
        C = p2 x p4 x p6 ( odd iterations)
            p2 x p4 x p8 (even iterations)
        D = p4 x p6 x p8 ( odd iterations)
            p2 x p6 x p8 (even iterations)
        IF A==1 and (2 ≤ B ≤ 6) and C==0 and D==0:
            delete pixel p1.
        ENDIF
    ENDFOR
ENDWHILE
```

p_9	p_2	p_3
p_8	p_1	p_4
p_7	p_6	p_5

Reference: T. Y. Zhang and C. Y. Suen. 1984. *A fast parallel algorithm for thinning digital patterns*. Communications of the ACM 27, 3 (March 1984), 236-239.

Skeletonization → Find Critical Points → Break Intersections → Connected Components → Shape Fill

Finding Intersections and Endpoints



Use the 3x3 pixel grid to find the # of paths leaving a given skeleton pixel.

Classify pixels by the # of 0 to 1 transitions computed the same way as in skeletonization.

{0,1}	→	pixel is endpoint
2	→	pixel is a segment
≥ 3	→	pixel is an intersection

Break Skeleton at Intersections

Once the intersections are located we can break the skeleton by removing the intersection and its adjacent neighbors.

Reclassify endpoints and singleton pixels.

Connected Components

Compute the connected components of all the line segments and label them from 1..N

The general procedure is straight-forward, we use the end-points as the starting points to grow each CC.

Once computed, remove any CC that is smaller (fewer pixels) than a minimum set threshold. In practice, 20 has worked well.

Fill in the Original Shape

After skeleton segments are classified we use a brush-fire algorithm to grow the skeleton fragments back into the original shape.

Pixel labels are the same as the nearest skeleton segment.

Grows only into the four adjacent neighbors (above, below, left, and right) each round.

Results

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