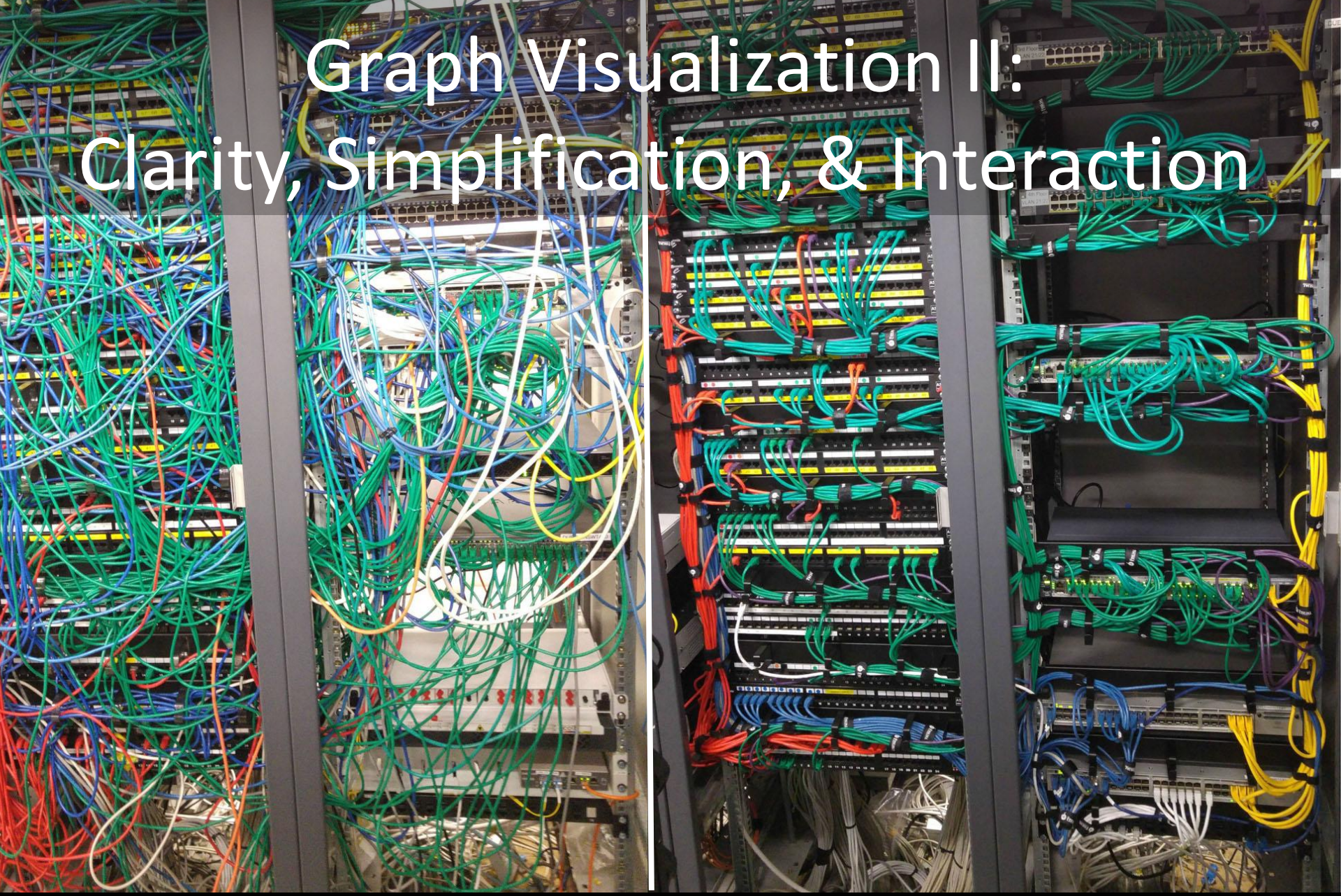
Graph Visualization II: Clarity, Simplification, & Interaction



http://i.imgur.com/cW19IBR.jpg
https://www.reddit.com/r/CableManagement/

Today's Worksheet: Graph Design

- Design a graph for the CSCI major template
- Visualize "Who teaches the CSCI courses"
- Crowdsourced data!
- Add something:

First Year

Fall 2019		Spring 2020	
CSCI 1100 Computer Science I[1]	4	CSCI 1200 Data Structures	4
MATH 1010 Calculus I	4	MATH 1020 Calculus II	4
PHYS 1100 Physics I[2]	4	BIOL 1010 Intro. to Biology[2]	3
HASS Elective	4	BIOL 1015 Intro. to Biology Lab[2]	1
		HASS Elective	4

Second Year

Fall 2020		Spring 2021	
CSCI 2200 Foundations of CS[3]	4	CSCI 2300 Intro. to Algorithms	4
CSCI 2500 Computer Organization[4]	4	CSCI 2600 Principles of Software	4
Mathematics Option I	4	Mathematics Option II	4
HASS Elective	4	HASS Elective	4

Third Year

Arch Summer 2021		Fall 2021 -or- Spring 2022	
CSCI 4210 Operating Systems[6]	4	CSCI 4430 Programming Languages[6] -or- CS Option/Capstone	4
CS Option/Capstone -or- Free Elective[5]	4	Science Option	4
HASS Elective	4	HASS Elective	4
Free Elective	4	Free Elective	4

Fourth Year

Fall 2022		Spring 2023	
CS Option/Capstone -or- CSCI 4430 Programming Languages[6]	4	CS Option/Capstone	4
CS Option/Capstone	4	Free Elective -or- CS Option/Capstone	4
Free Elective	4	Free Elective	4
Free Elective	4	Free Elective	4

https://tinyurl.com/crowdsourced-hw3

HW 3: Graphviz & RPI CSCI Course Data

- https://tinyurl.com/crowdsourced-hw3
- We'll work together to create a clean dataset
- Learn GraphViz: Open-source software automated graph drawing
- *an individual homework*

course code	name	prereq 1	prereq 2	prereq 3
CSCI 1100	Computer Science I			
CSCI 1200	Data Structures	CSCI 1100		
CSCI 2200	Foundations of Computer Science	CSCI 1200	MATH 1010	
CSCI 2500	Computer Organization	CSCI 1200		
CSCI 2300	Introduction to Algorithms	CSCI 1200	CSCI 2200	MATH 1010
CSCI 2600	Principles of Software	CSCI 1200	CSCI 2200	
CSCI 4210	Operating Systems	CSCI 2300	CSCI 2500	
CSCI 4430	Programming Languages	CSCI 2300	CSCI 2600	
CSCI 4530	Advanced Computer Graphics	CSCI 2300	CSCI 2600	
CSCI 4550	Interactive Visualization	CSCI 2300	CSCI 2600	

term	course code	name	instructor 1	instructor 2
Spring 2020	CSCI 1100	Computer Science I	Mushtaque	
Spring 2020	CSCI 1200	Data Structures	Holzbauer	
Spring 2020	CSCI 2200	Foundations of Computer Science	Gittens	
Spring 2020	CSCI 2500	Computer Organization		
Spring 2020	CSCI 2300	Introduction to Algorithms	Gao	Goldschmidt
Spring 2020	CSCI 2600	Principles of Software	Kuzmin	
Spring 2020	CSCI 4210	Operating Systems	Turner	
Spring 2020	CSCI 4550	Interactive Visualization	Cutler	
Fall 2019	CSCI 1100	Computer Science I	Turner	Mushtaque
Fall 2019	CSCI 1200	Data Structures	Cutler	
Fall 2019	CSCI 2200	Foundations of Computer Science	Magdon-Ismail	Kuzmin
Fall 2019	CSCI 2500	Computer Organization	Kuzmin	
Fall 2019	CSCI 2300	Introduction to Algorithms	Yener	
Fall 2019	CSCI 2600	Principles of Software	Thompson	
Fall 2019	CSCI 4430	Programming Languages	Varela	
Summer 2019	CSCI 1100	Computer Science I	Mushtaque	
Summer 2019	CSCI 2600	Principles of Software	Kuzmin	
Summer 2019	CSCI 4210	Operating Systems	Goldschmidt	Holzbauer
Spring 2019	CSCI 1100	Computer Science I	Mushtaque	
Spring 2019	CSCI 1200	Data Structures	Holzbauer	
Spring 2019	CSCI 2200	Foundations of Computer Science	Patterson	Mushtaque
Spring 2019	CSCI 2500	Computer Organization		
Spring 2019	CSCI 2300	Introduction to Algorithms		
Spring 2019	CSCI 2600	Principles of Software	Kuzmin	
Spring 2019	CSCI 4210	Operating Systems	Goldschmidt	
Spring 2019	CSCI 4530	Advanced Computer Graphics	Cutler	

Today

- Worksheet & HW 3: Course Data Graphs
- Reading: Lombardi Graphs
- Emergency Management Graph Visualization
  - Sean Kim's masters project
- Computational Geometry: Closest pair of points
- Readings for Next Week

Readings for Today *(pick one)*

- "Force-directed Lombardi-style graph drawing", Chernobelskiy et al., Graph Drawing 2011.

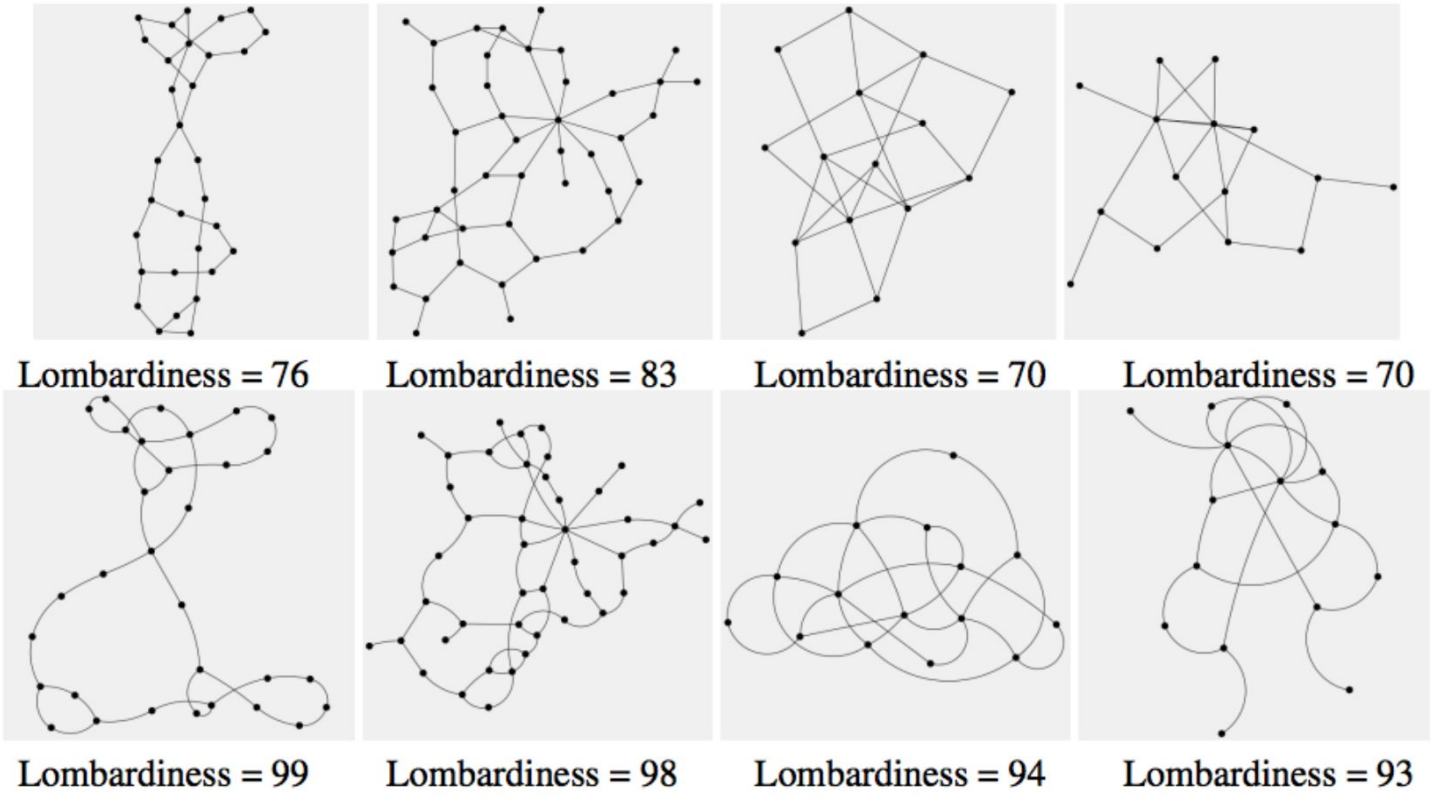
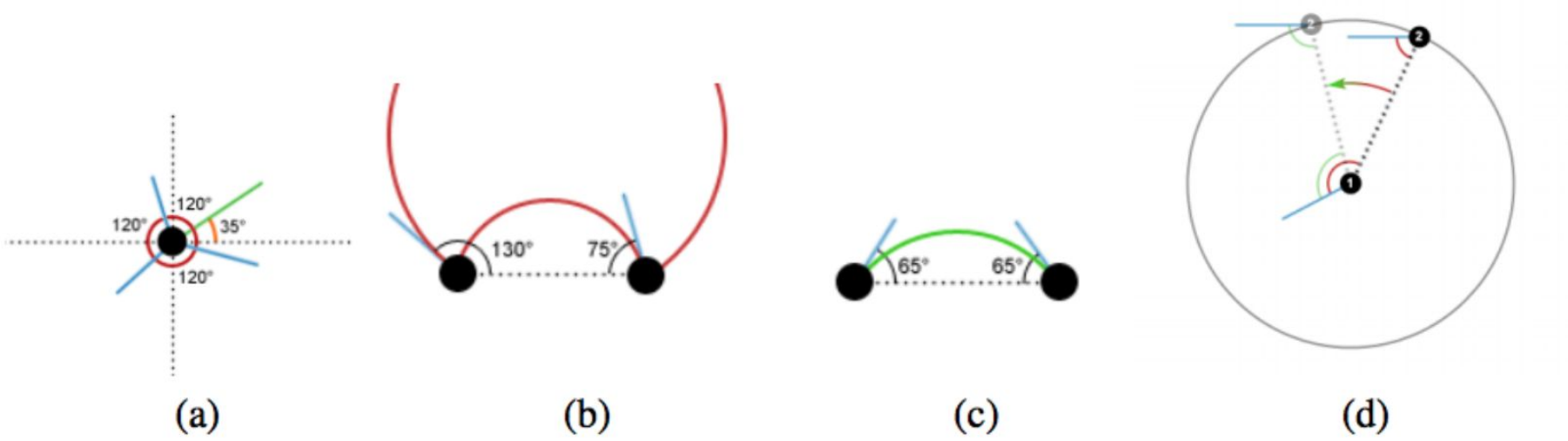


Fig. 5. Standard force-directed drawings (above) and near-Lombardi drawings (below).

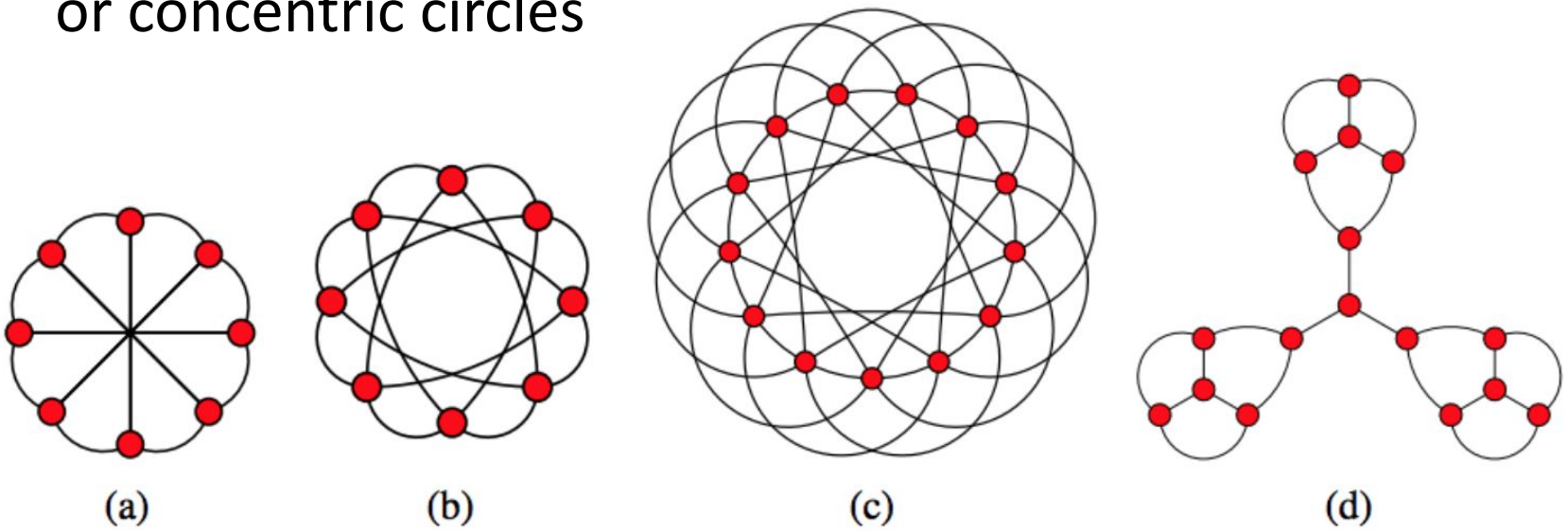
- Relaxation of the Lombardi Graph requirements (perfect angles)
- “straight-line segments rarely occur in nature ... it is not clear that humans prefer straight-line segments for the sake of graph readability”
- Forces on tangent angles as well as on vertex positions
- They use a cooling function
- Can compute the “Lombardi-ness” of a graph



"Lombardi drawings of graphs", Duncan, Eppstein, Goodrich, Kobourov, Nollenberg, Graph Drawing 2010

- Circular arcs
- Perfect angular resolution
  (edges for equal angles at vertices)
- Arcs only intersect 2 vertices (at endpoints)
- *(not required to be crossing free)*
- Vertices may be constrained to lie on circle
  or concentric circles

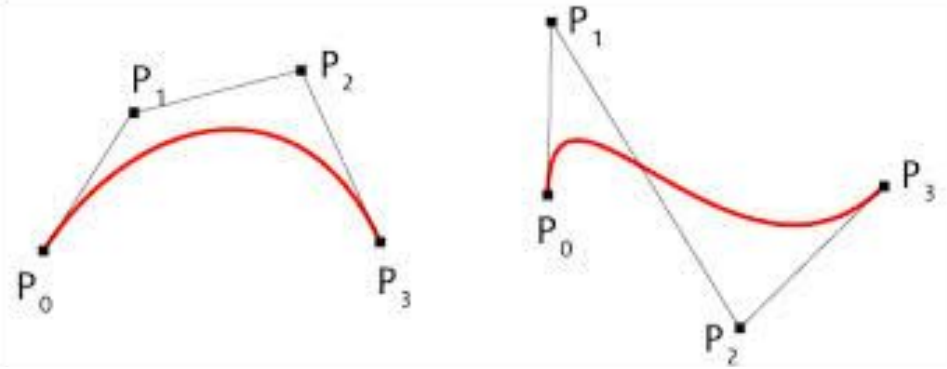
BONUS PAPER



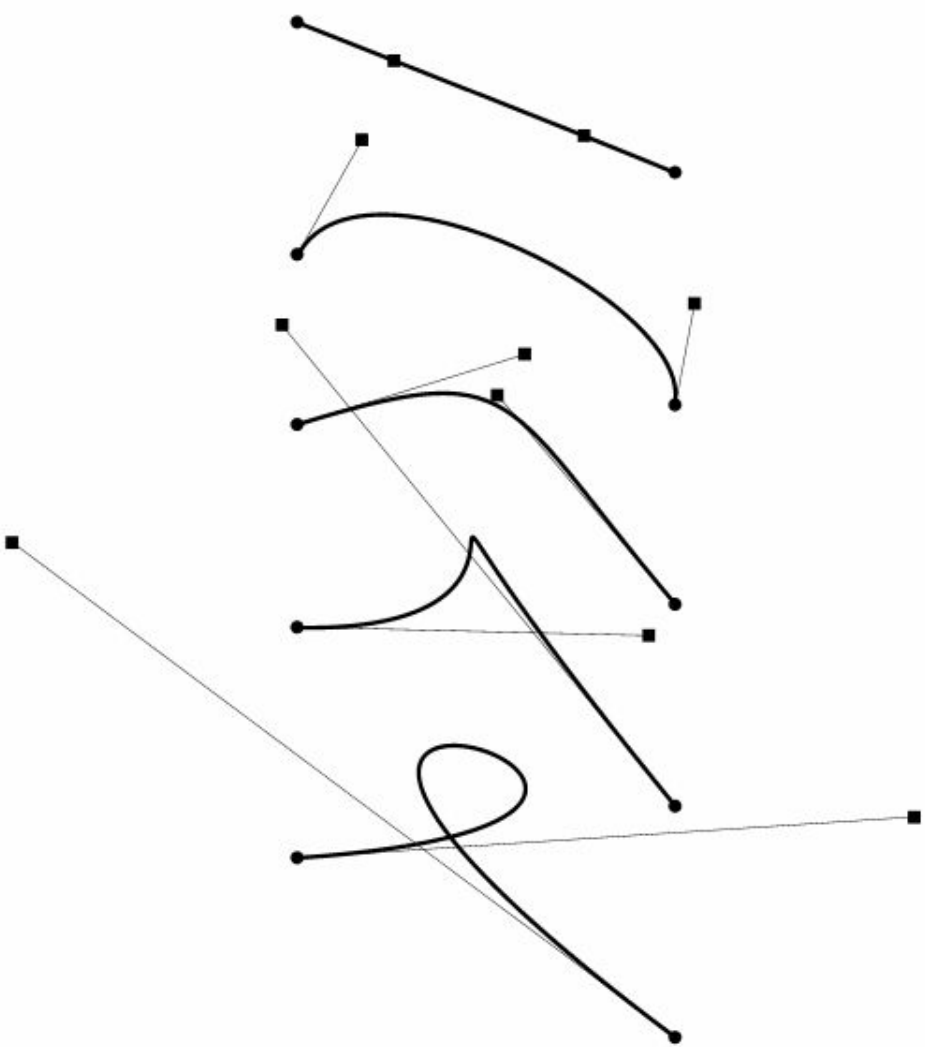
- People are more patient with aesthetically pleasing graphs (will spend longer studying to learn/draw conclusions)
- What about relaxing the circular arc requirement and allowing Bezier arcs?
- How does it scale to larger data?
- Long curved arcs can be much harder to follow
- Circular layout of nodes is often very good!
- Would like more pseudocode

Cubic Bézier Curve

- 4 control points
- Curve passes through first & last control point
- Curve is tangent at $\mathbf{P_0}$ to $(\mathbf{P_1}\text{-}\mathbf{P_0})$ and at $\mathbf{P_3}$ to $(\mathbf{P_3}\text{-}\mathbf{P_2})$



http://www.e-cartouche.ch/content_reg/cartouche/graphics/en/html/Curves_learningObject2.html



http://www.webreference.com/dlab/9902/bezier.html

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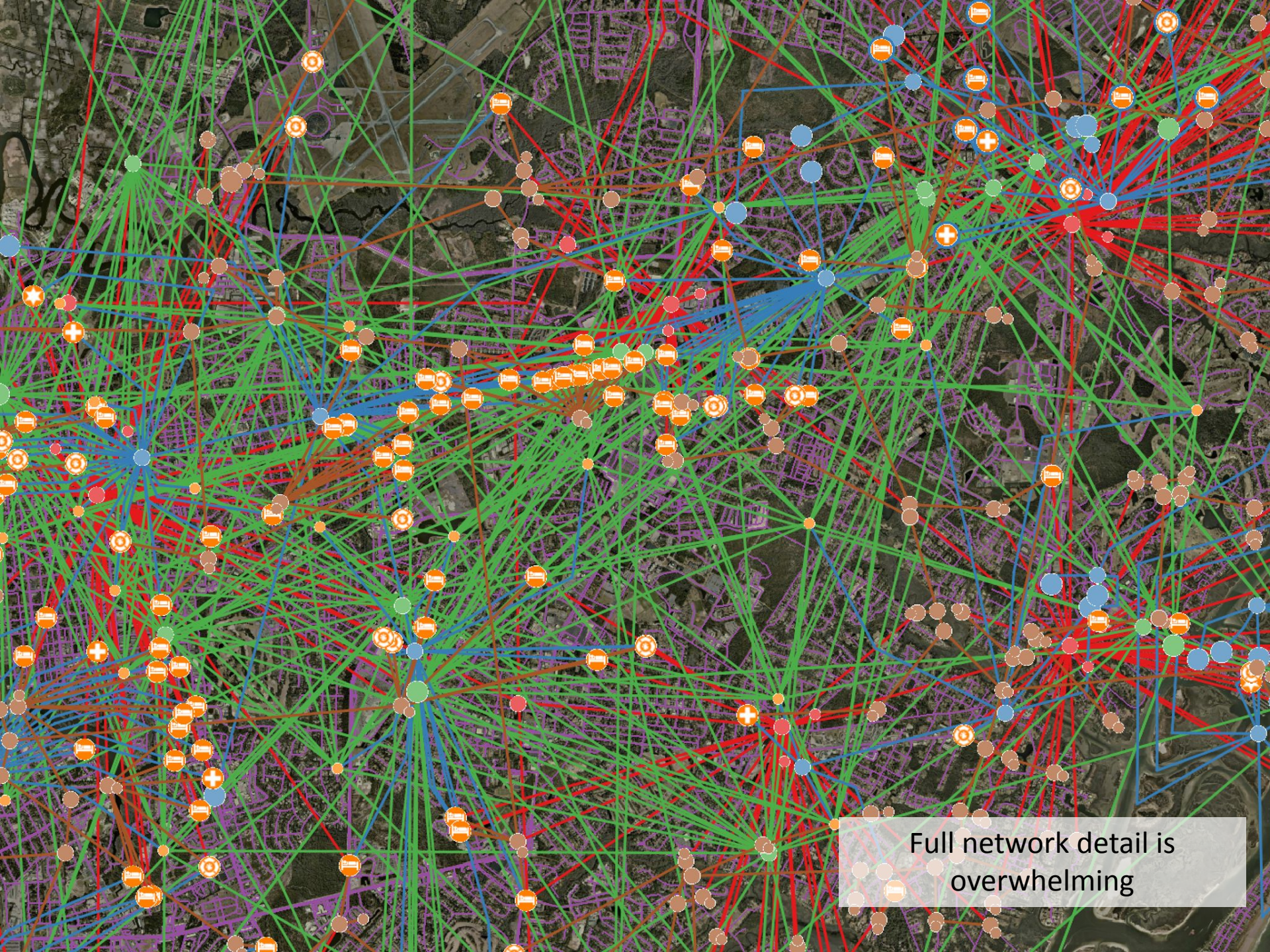
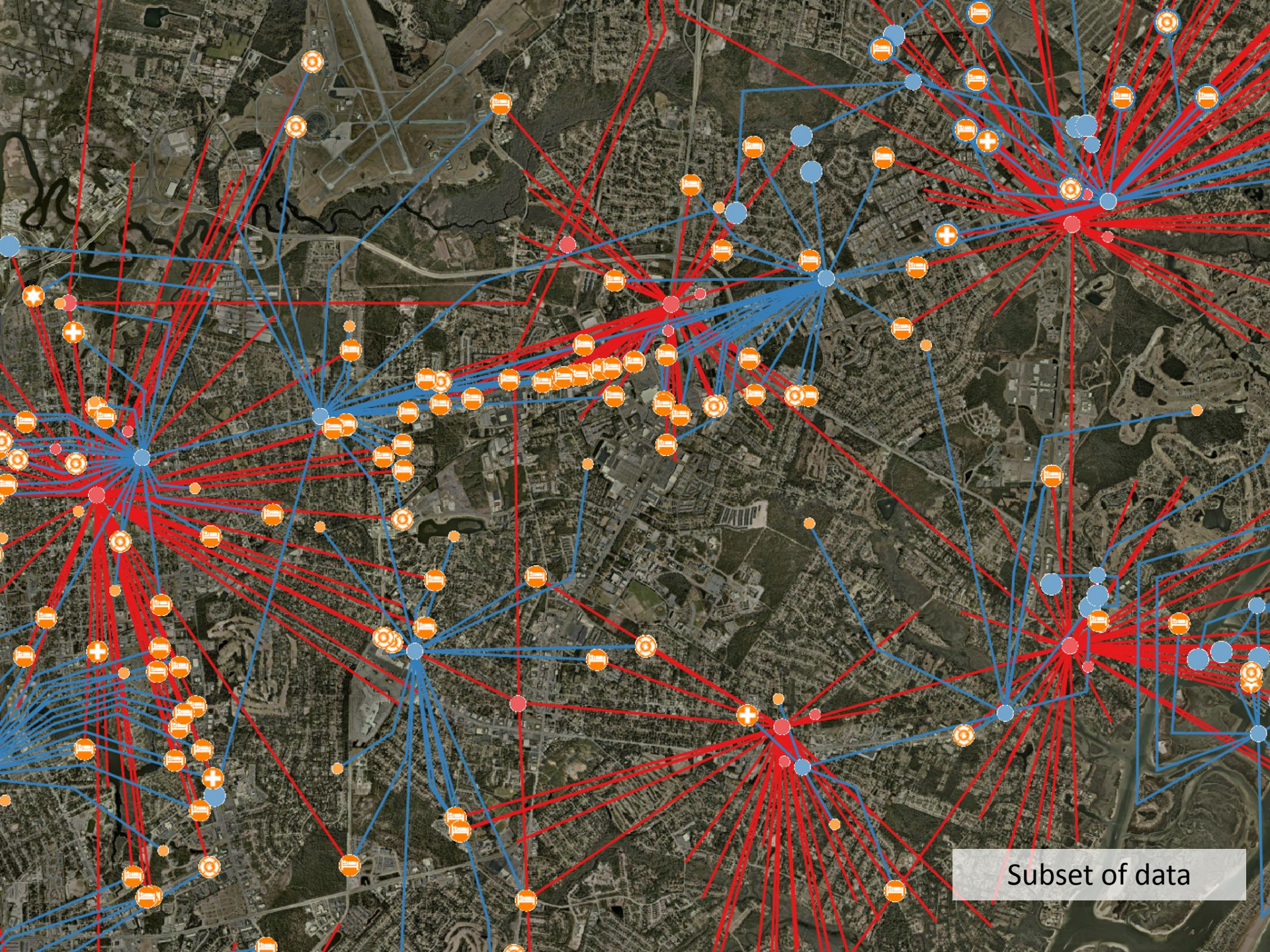
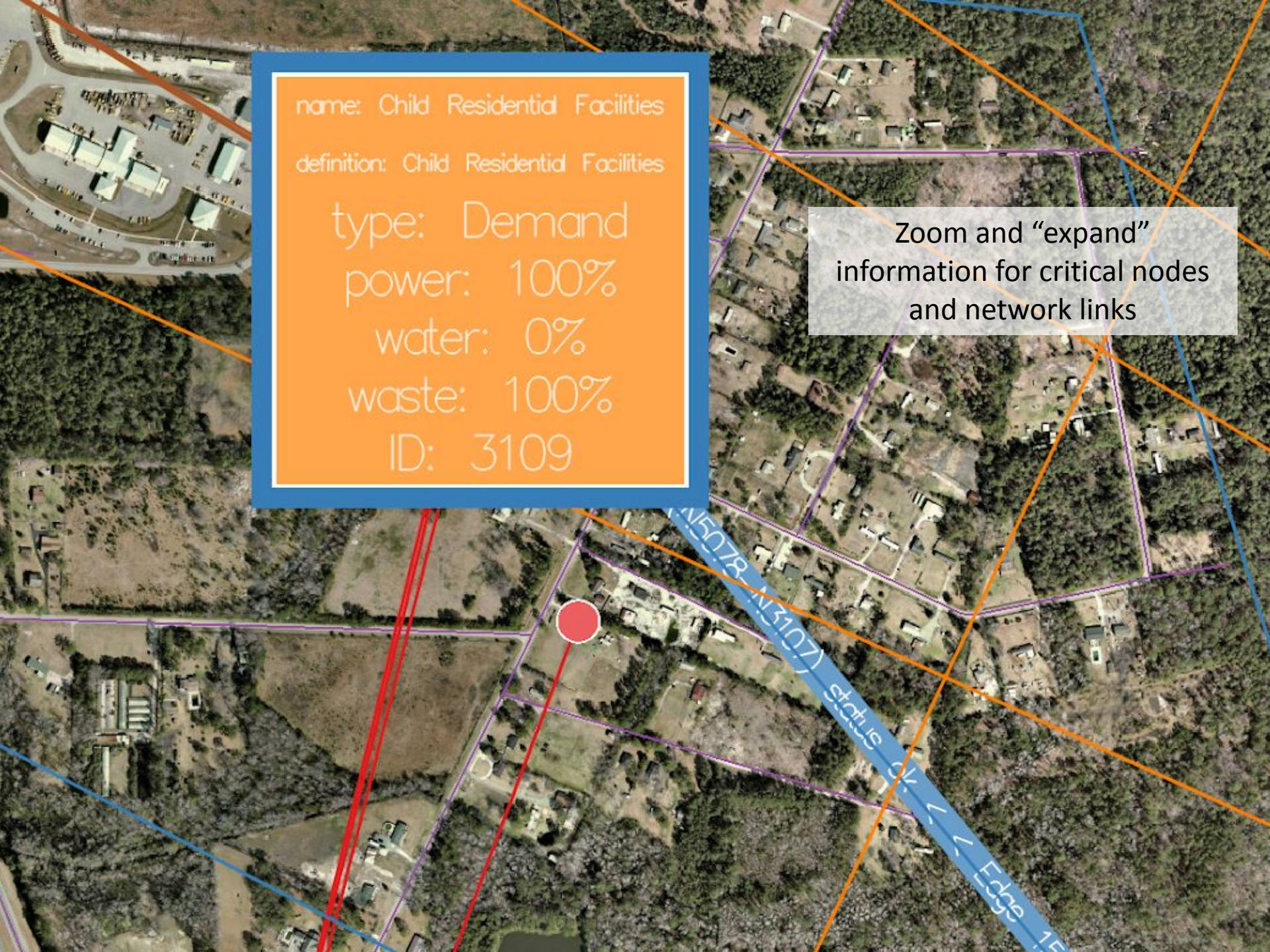
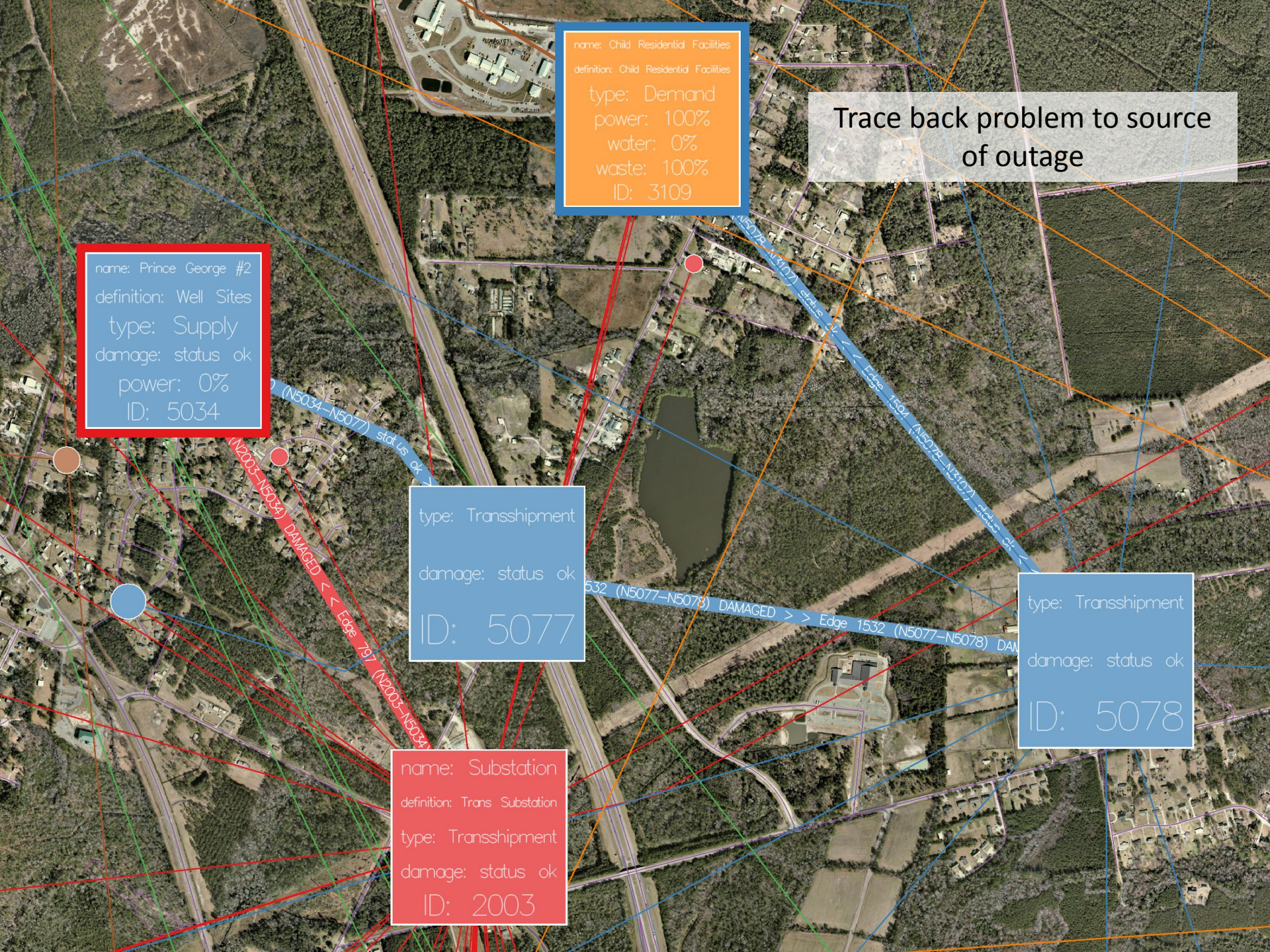
Emergency Response Decision Making

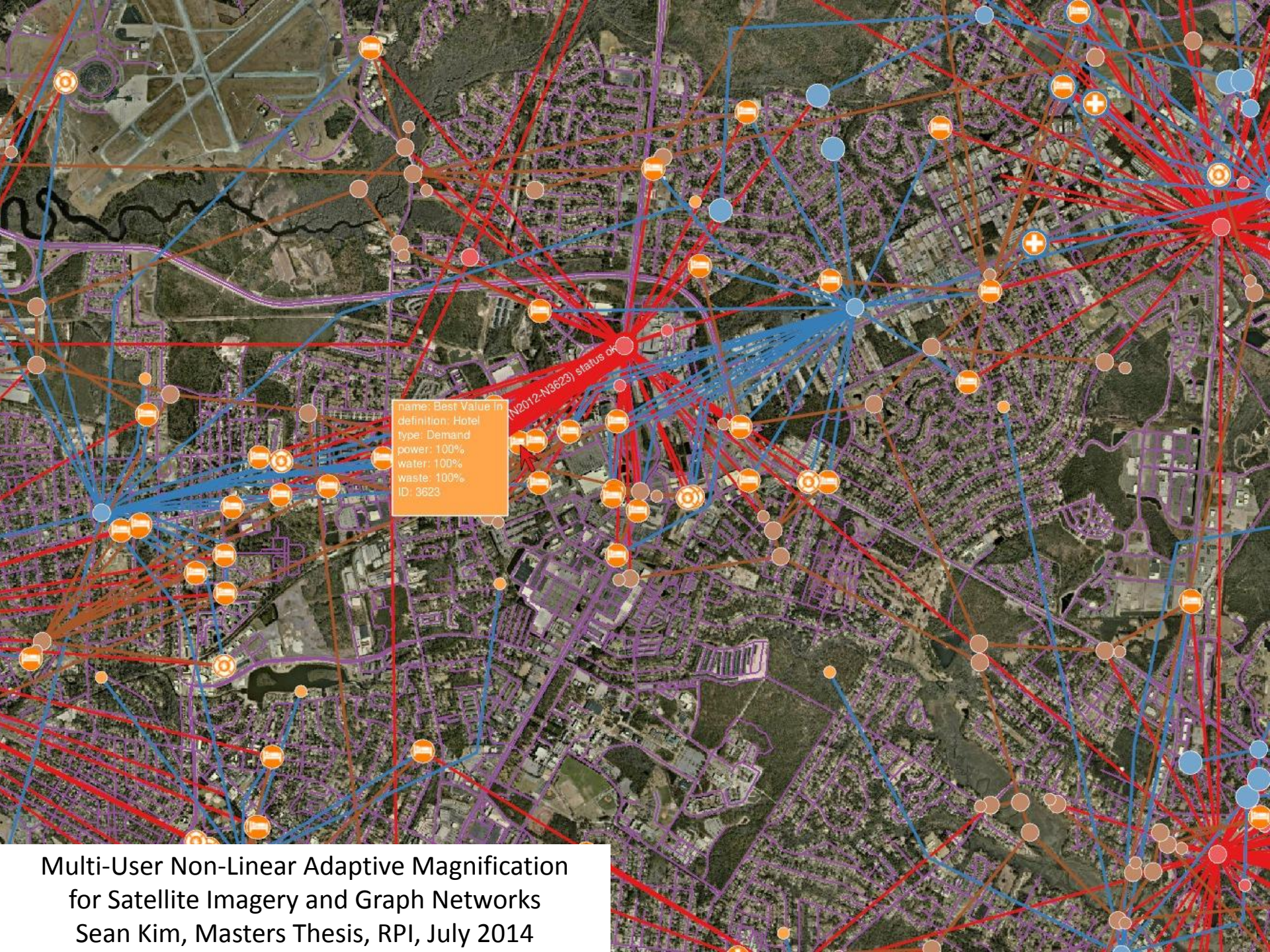

Full network detail is overwhelming


Subset of data


name: Child Residential Facilities
definition: Child Residential Facilities
type: Demand
power: 100%
water: 0%
waste: 100%
ID: 3109
Zoom and “expand” information for critical nodes and network links


name: Child Residential Facilities
definition: Child Residential Facilities
type: Demand
power: 100%
water: 0%
waste: 100%
ID: 3109
Trace back problem to source of outage
name: Prince George #2
definition: Well Sites
type: Supply
damage: status ok
power: 0%
ID: 5034
type: Transshipment
damage: status ok
ID: 5077
type: Transshipment
damage: status ok
ID: 5078
name: Substation
definition: Trans Substation
type: Transshipment
damage: status ok
ID: 2003


name: Prince George #2
definition: Well Sites
type: Supply
damage: status ok
power: 0%
ID: 5034
Prioritize crew assignments
(N5034–N5077) stat us ok
(N2003–N5034) DAMAGED < < Edge 797
type: Transshipment
damage: status ok
ID: 5077



Multi-User Non-Linear Adaptive Magnification
for Satellite Imagery and Graph Networks
Sean Kim, Masters Thesis, RPI, July 2014

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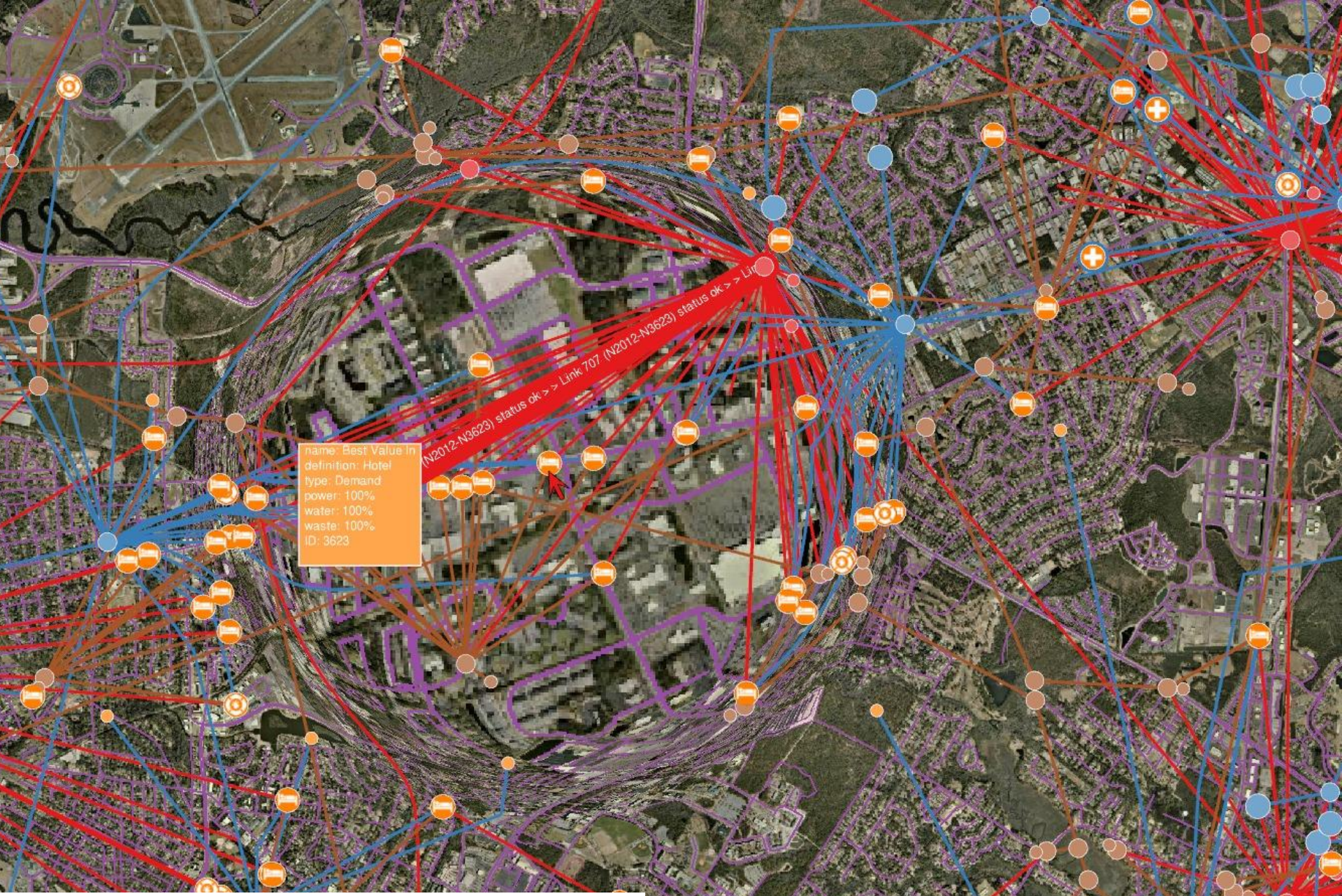

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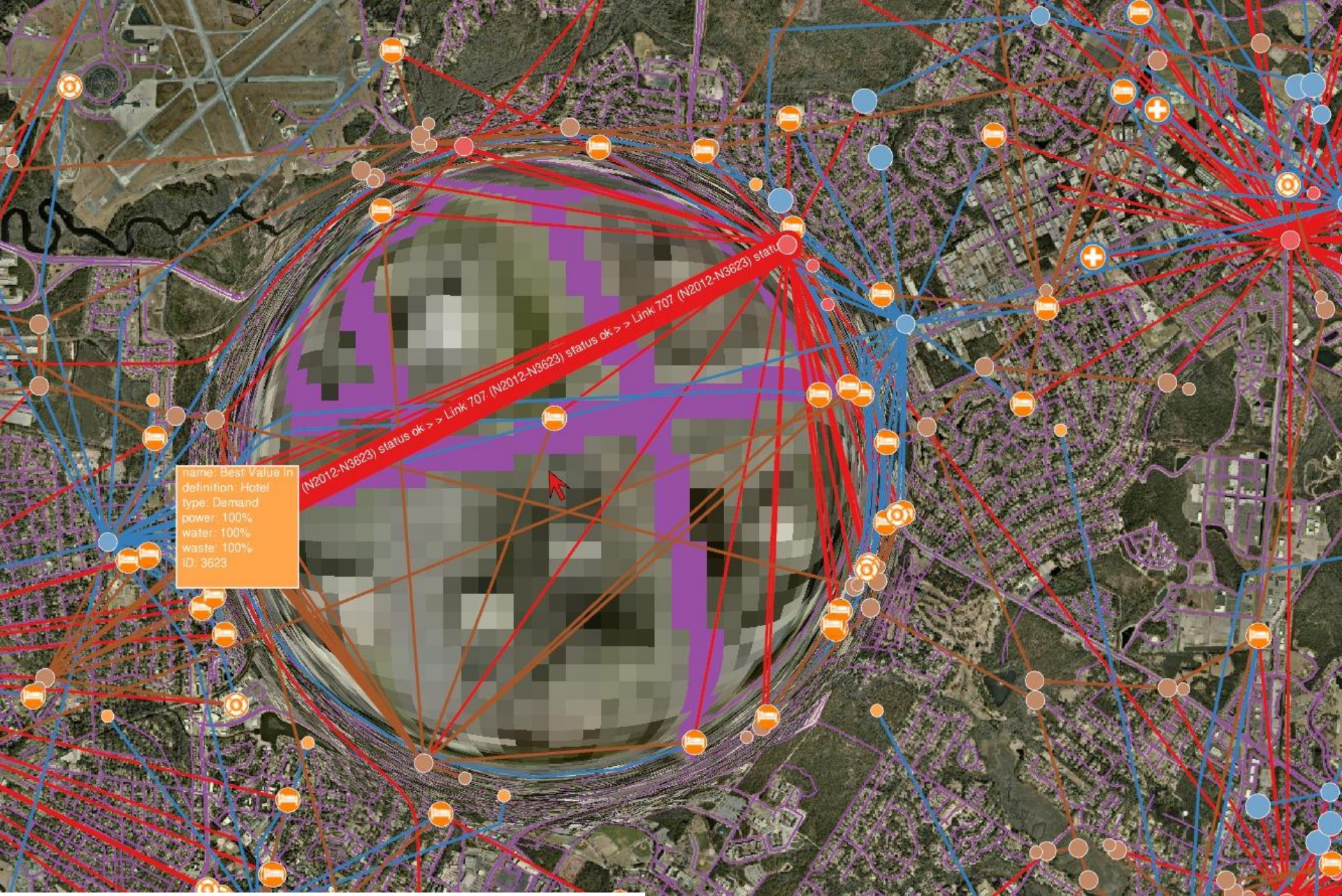

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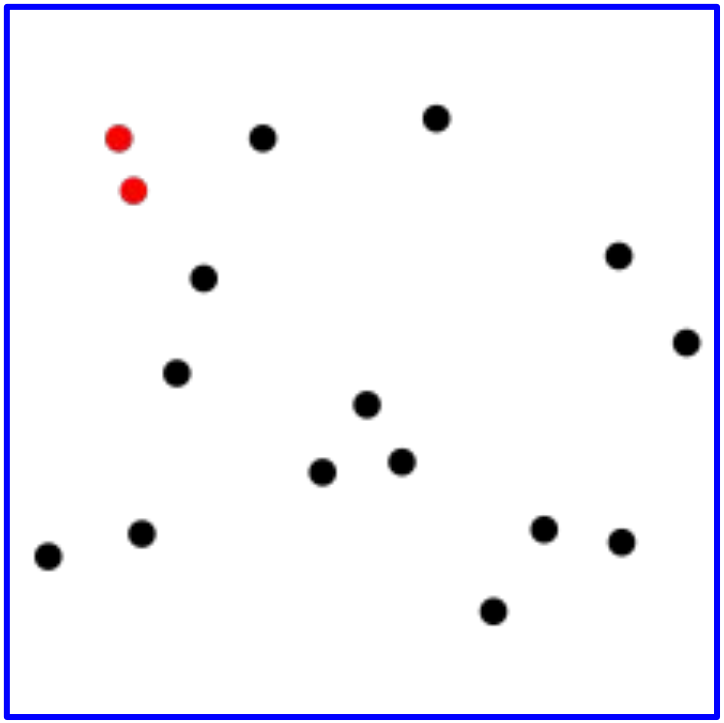
Closest Pair of Points Problem

- Given *n* points,
  find the two points that
  have the smallest distance
  between each other.

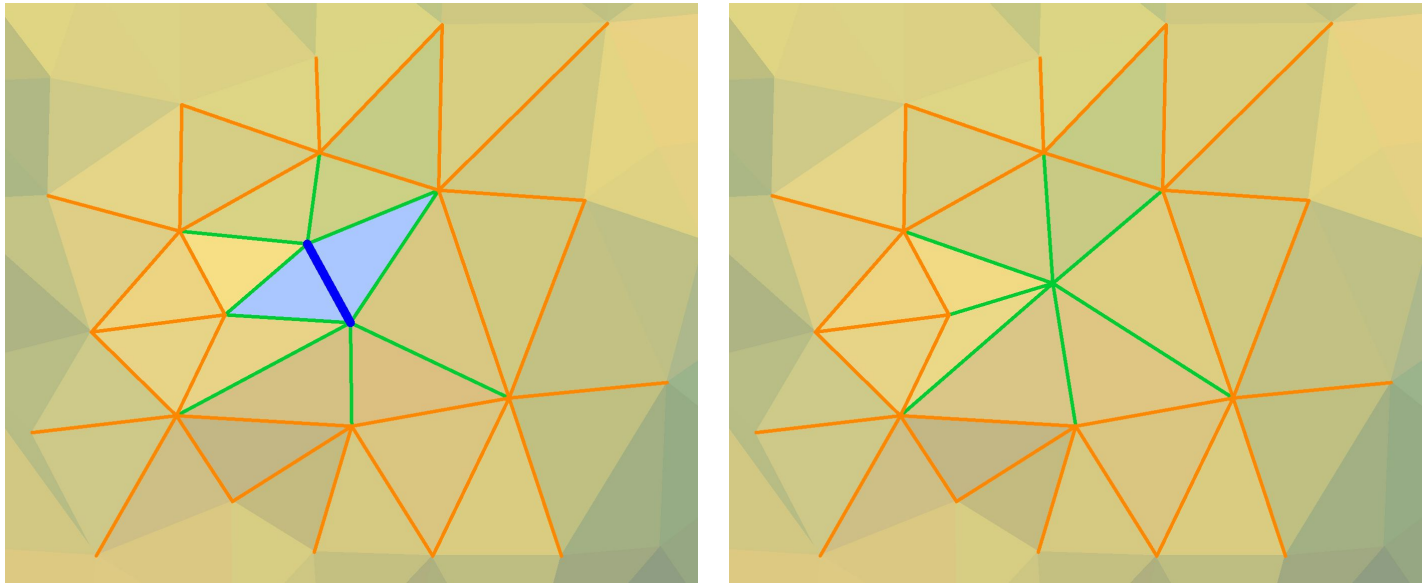


- Applications?
  - physical simulation
    collision detection
  - air traffic control
  - merging similar data points
    (data size reduction)
  - …

https://en.wikipedia.org/wiki/Closest_pair_of_points_problem

Edge Contraction / Edge Collapse

- Goal: Reduce number of vertices/edges while minimize shape/color/attribute loss
- Possible algorithm for 2D/3D meshes:
  Always collapse shortest edge



Brute Force Algorithm

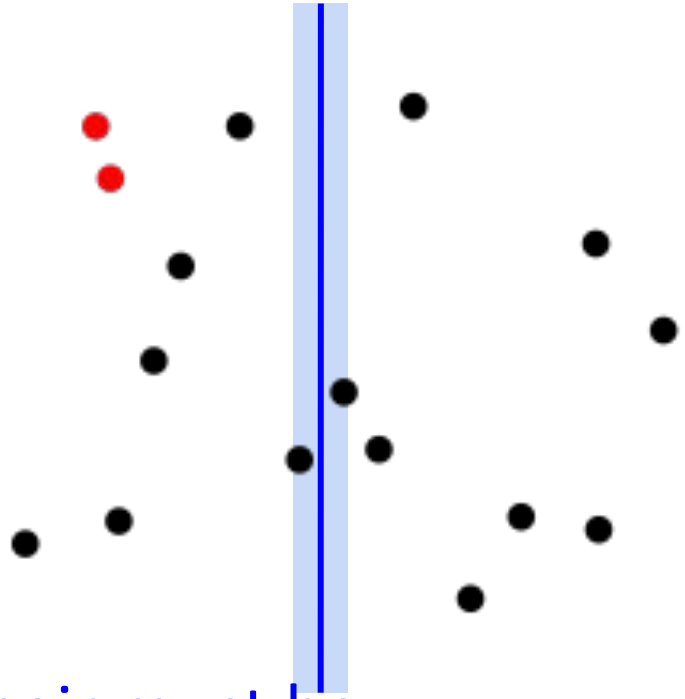
```
minDist = infinity
for i = 1 to length(P) - 1
 for j = i + 1 to length(P)
  let p = P[i], q = P[j]
  if dist(p, q) < minDist:
   minDist = dist(p, q)
   closestPair = (p, q)
return closestPair
```

Analysis? For n points? $O(n^2)$

https://en.wikipedia.org/wiki/Closest_pair_of_points_problem

Divide & Conquer

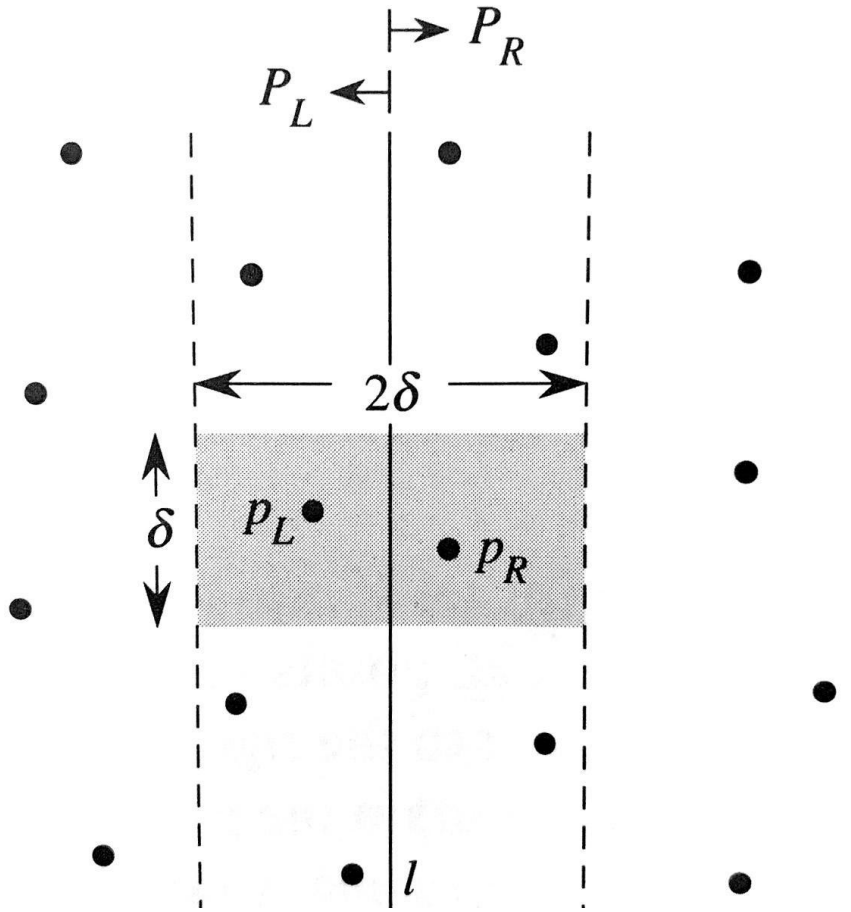
- Sort points by one of the axes
  - Find middle point,
  - Split points into two equal sized groups
  - & Recurse…



- Combine results: Overall closest pair must be:
  - Closest pair in left half (distance = δ_l), or
  - Closest pair in right half (distance = δ_r), or
  - A pair that spans the halve w/ distance < $\min(\delta_l,\delta_r)$

Divide & Conquer

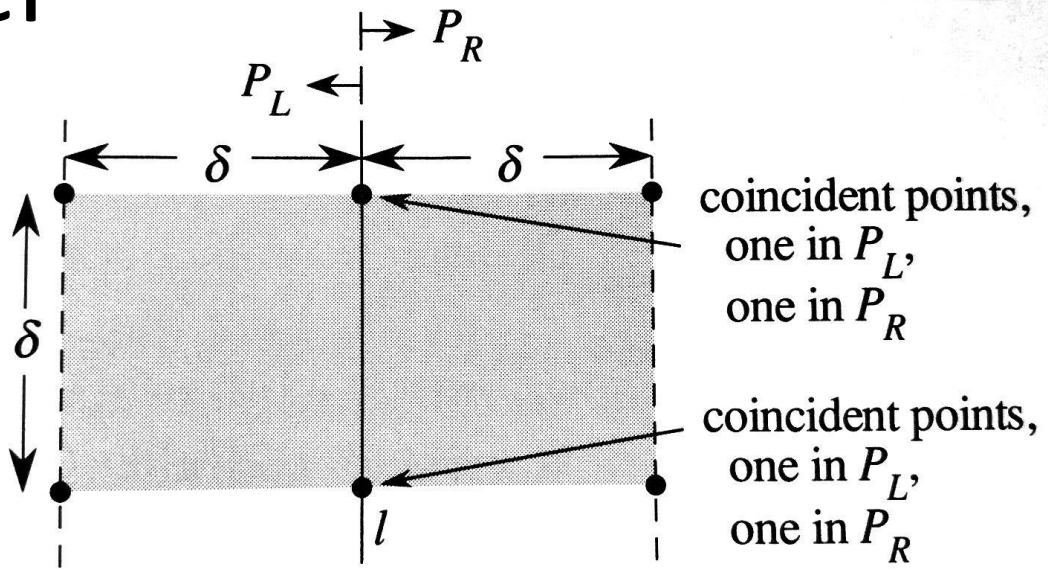
- How many pairs do we need to consider at the boundary?
  - In the worst case, all points are within δ of the split point!
    Note: $\delta = \min(\delta_l, \delta_r)$
  - Isn't this $O(n^2)$??



Introduction to Algorithms, Cormen, Leiserson, & Rivest

Divide & Conquer

- Let's also sort the points by the y-axis
- Walk from top to bottom and compare each point to all points within δ vertical distance (grey box).
- Worst case, how many other points are in this rectangle?
  - No more than 7 other points!

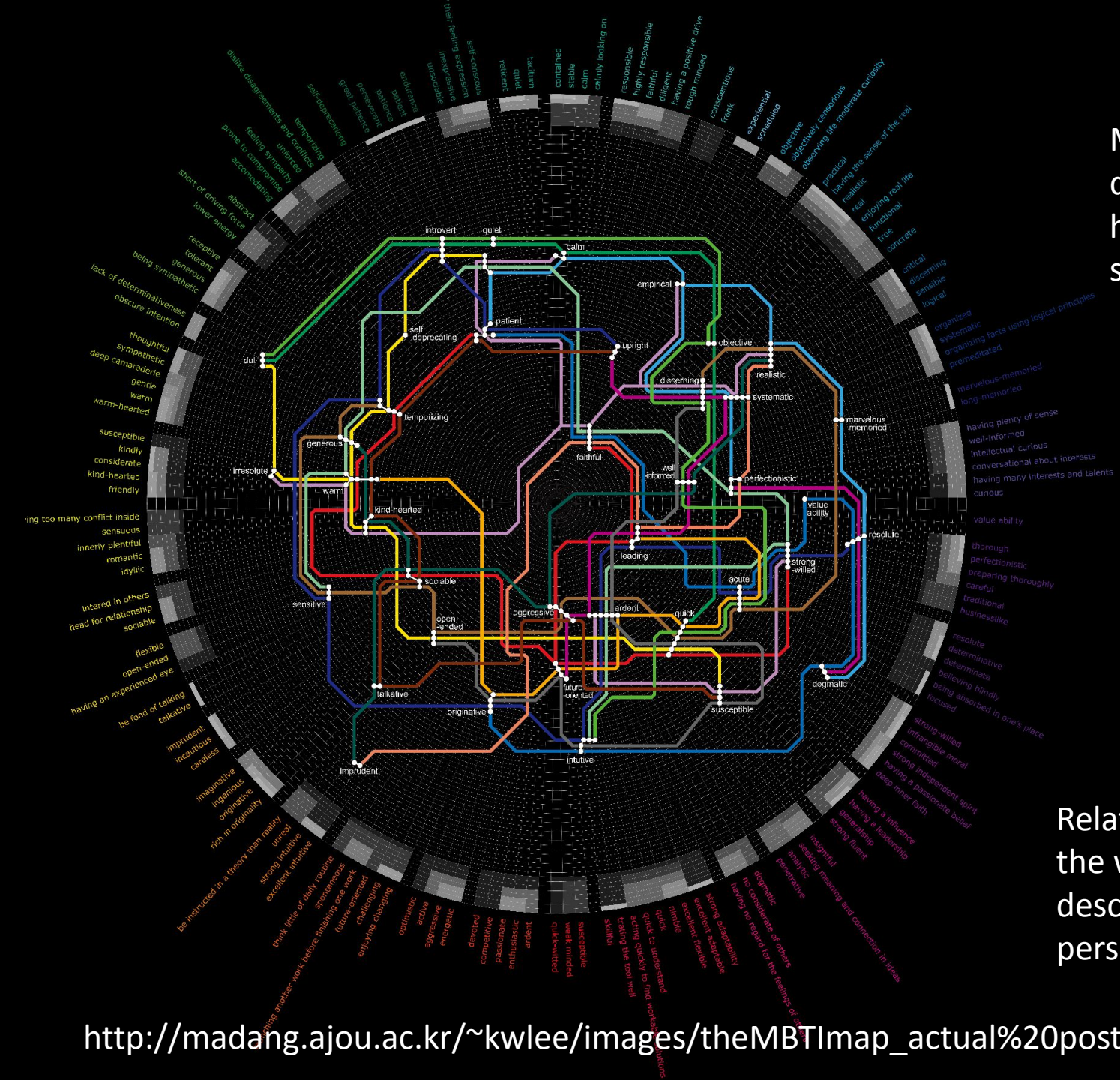


Introduction to Algorithms, Cormen, Leiserson, & Rivest

Divide & Conquer

- Analysis:
  - Store the points twice, sorted by x & y axes
    - Sort once at the start, not in each recursion
  - Per recursion
    - Max of *O(7n)* pairwise comparisons
  - Overall: *O (n log n)*

- Does it work in 3D? Or higher dimensions?
- Can we do better?
- What about dynamic data? What applications?



Many datasets don't (initially) have coordinate systems!

Relationship among the words that describe people's personalities

http://madang.ajou.ac.kr/~kwlee/images/theMBTImap_actual%20poster%20image.pdf

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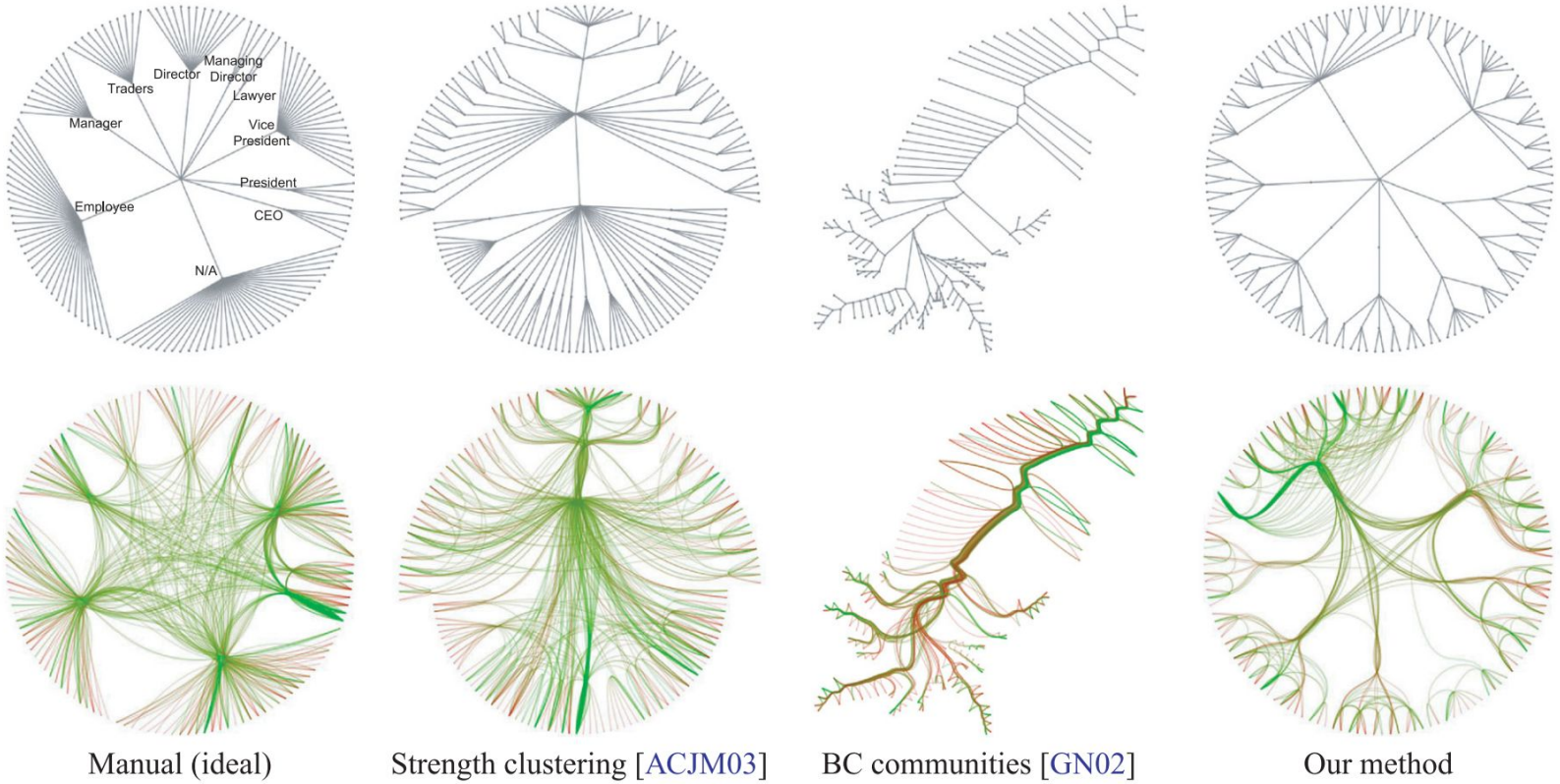
Readings for Next Tuesday *(pick one)*

- "Social Network Clustering and Visualization using Hierarchical Edge Bundles", Jia, Garland, & Hart, Computer Graphics Forum, 2011.



Readings for Next Tuesday *(pick one)*

"Angular Brushing of Extended Parallel Coordinates", Hauser, Ledermann, and Doleisch, InfoVis 2002