

A spatial optimization problem for determining optimal locations for Bluetooth beacon placement

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INDOOR NAVIGATION

One of the most requested applications of
SmartCampus

Network
Creation/Routing

Indoor
Positioning



Room:



Research Questions

Where are the optimal maximize coverage and minimize the number of beacons

How does RSSI relate to distance

- ▶ How many do we need?
- ▶ Where do we place them?

Basic experiment

- Could see beacon signal (stable) through walls at 20 meters.



1 beacon, 2 beacons, others state that you need to see 3+ (similar to GPS)

⌘ Specs:

- ⌘ BLE Location beacons
- ⌘ 200 meters distance
 - ⌘ Working about 70 meter
- ⌘ 2.4 GHz
- ⌘ 200ms Transmission interval
- ⌘ Estimote, Eddystone and iBeacon transmissions simultaneously

Lets do some math

Minimum beacons needed to cover floor:

- Square footage of floor/Area of 20 meter circle around beacon
 - = 5,020.676/1256.64
 - = 3.995 beacons



Double count to get decent overlap

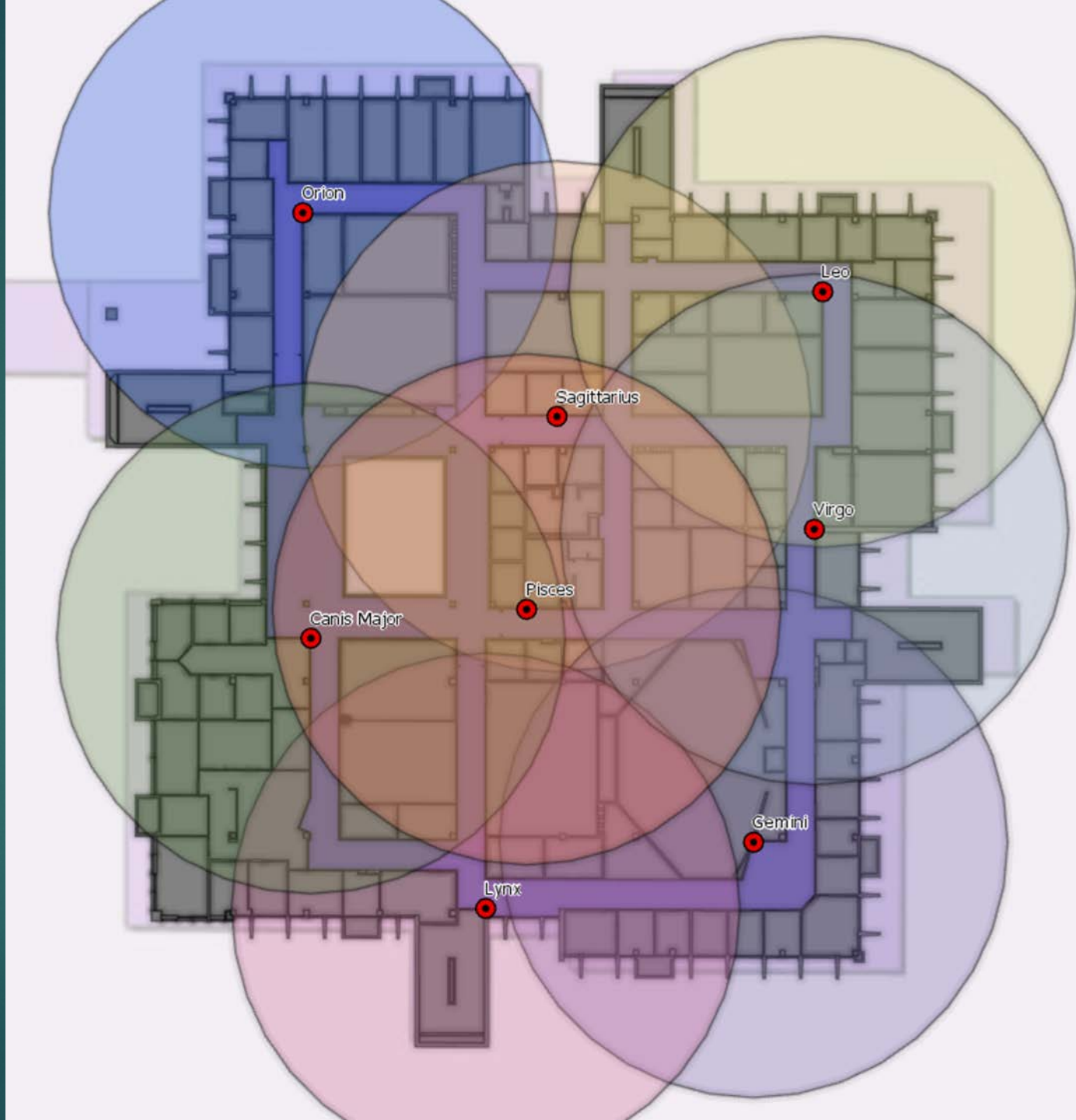
Set each to broadcast

- Eddystone UID
- +10 dBm Strength

Case Study

Cecil B.
Green Hall

UT-Dallas



iBeacon Scanner



RSSI	TX	UUID	
-77 dBm	-58 dBm	999270eb234a	
Far	Distance	Major	Minor
	4.05 m	4	1

RSSI	TX	UUID	
-78 dBm	-58 dBm	000000000000	
Far	Distance	Major	Minor
	5.25 m	1	1

RSSI	TX	UUID	
-86 dBm	-58 dBm	999270eb234a	
Far	Distance	Major	Minor
	8.48 m	5	2



Considering Three Dimensions

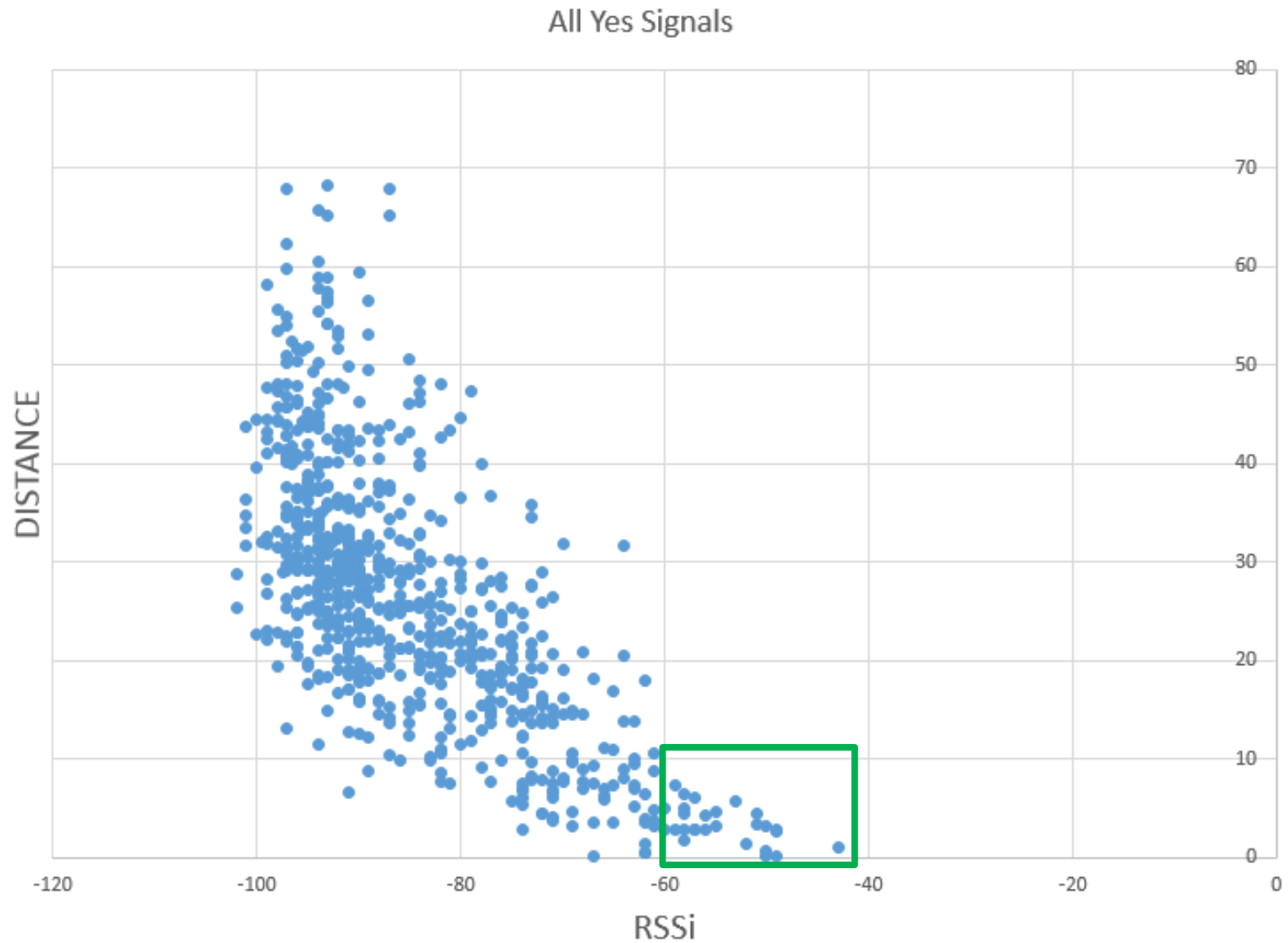
Problem becomes
much more
complicated

Signal can be seen
through floors,
Although it is
weaker

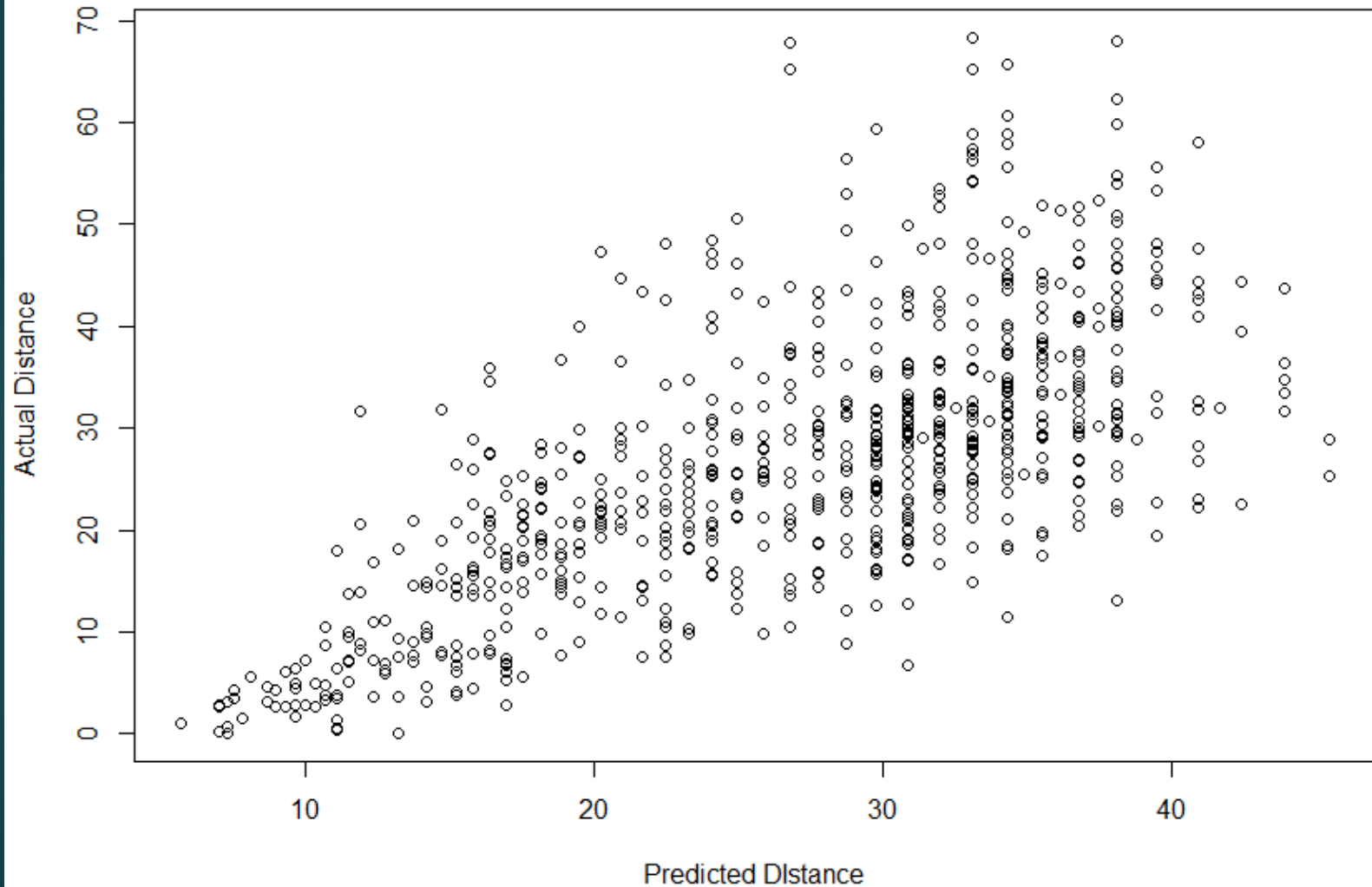
Beacons with
unstable signal
attenuate errors

Beacons have
unique IDs so
triangulation
algorithm can filter
out.

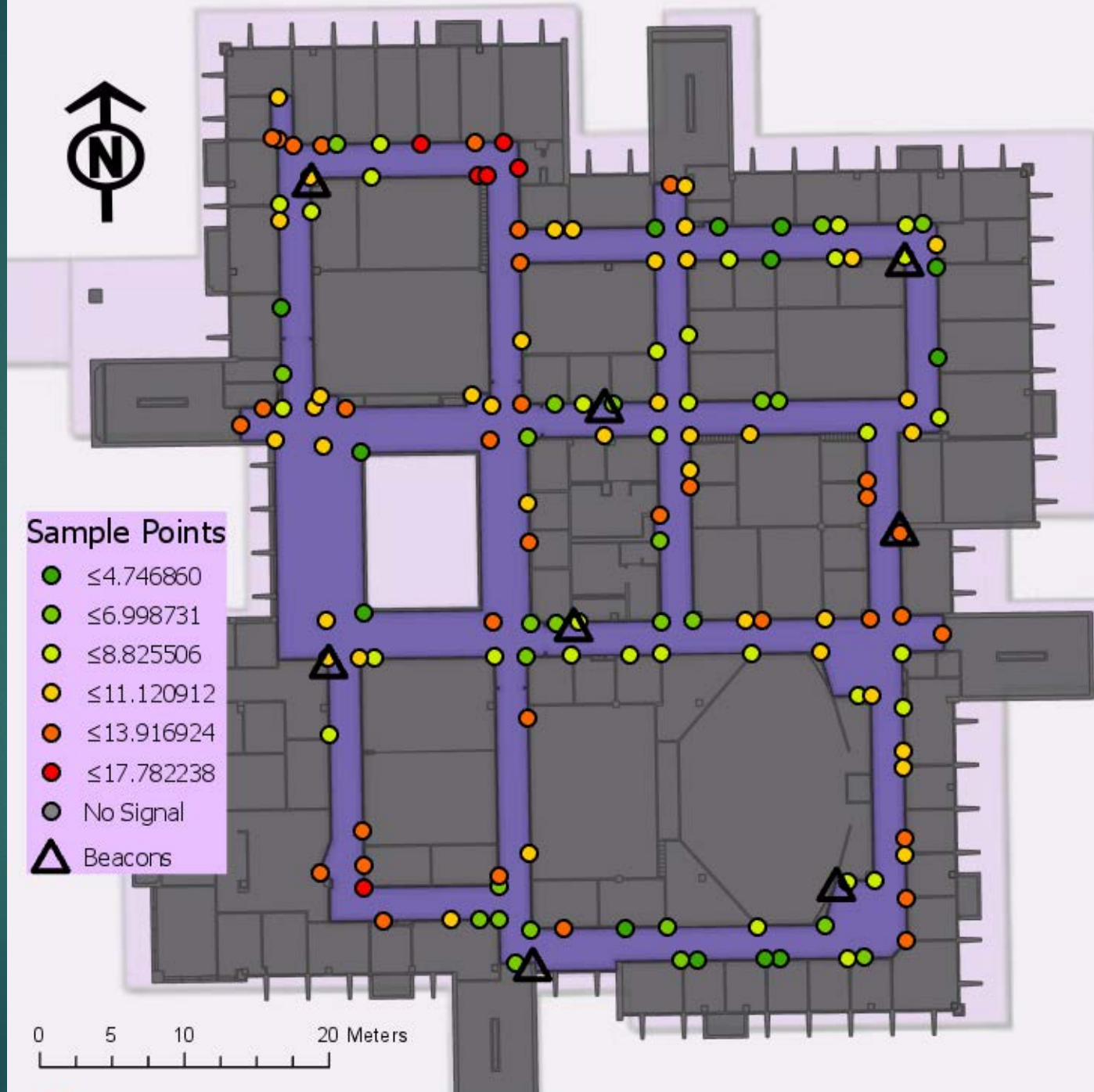
Compare RSSi & Distance



Predicted vs Actual Distance



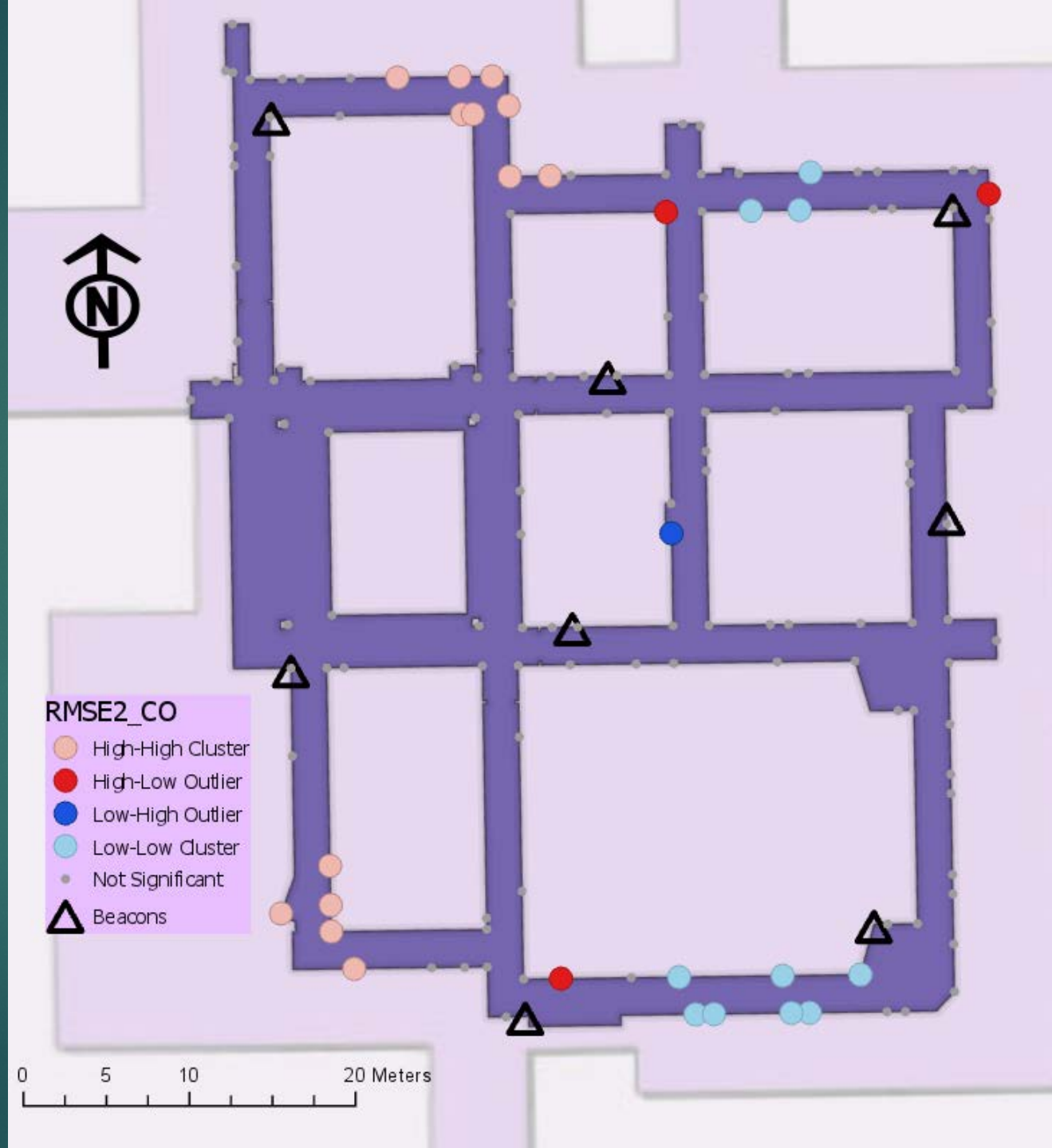
Mapping Errors



Determining Threshold

Examine RMSE clusters for impacts from beacons

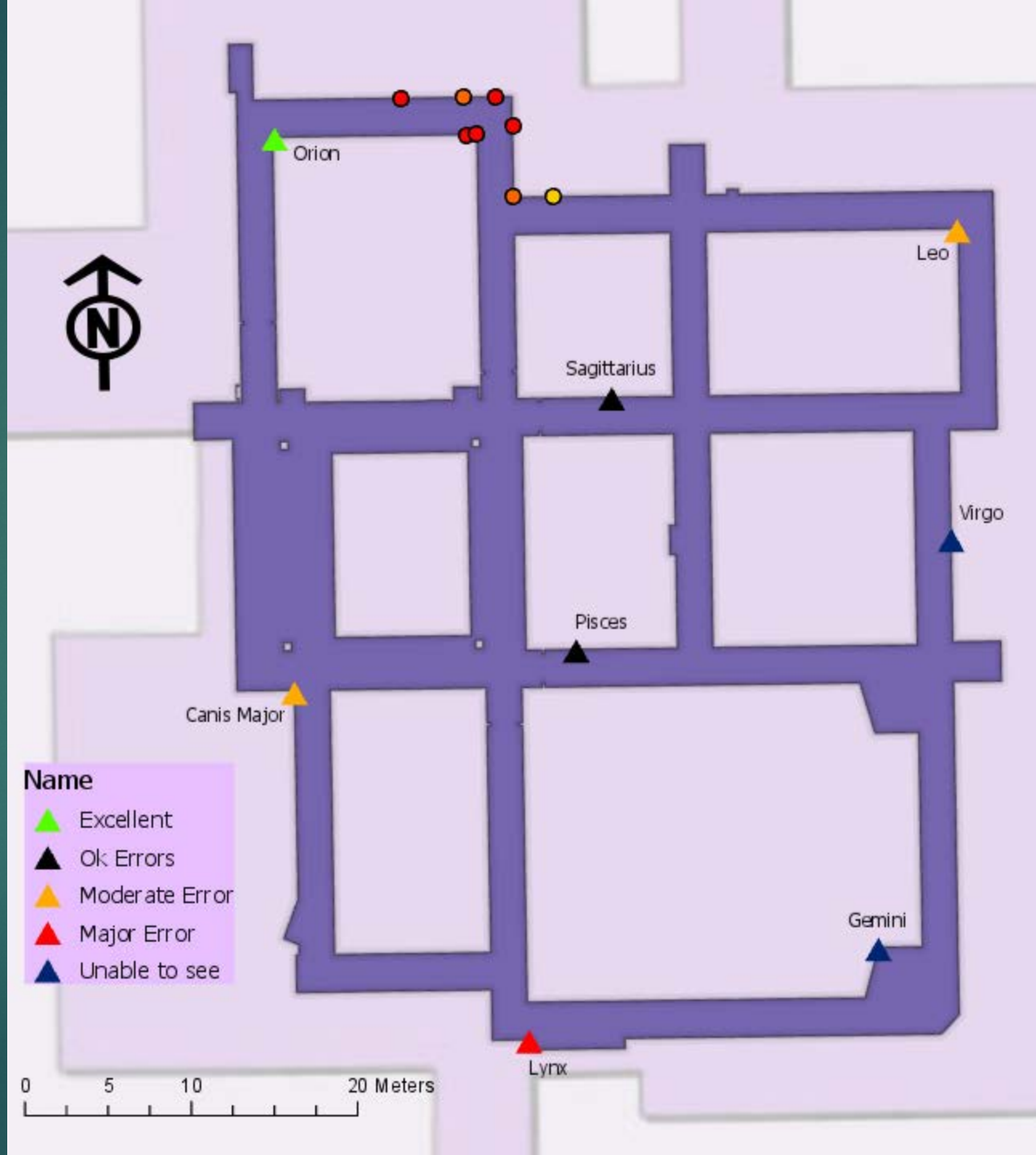
Local Moran's I
(Cluster and Outlier Analysis)



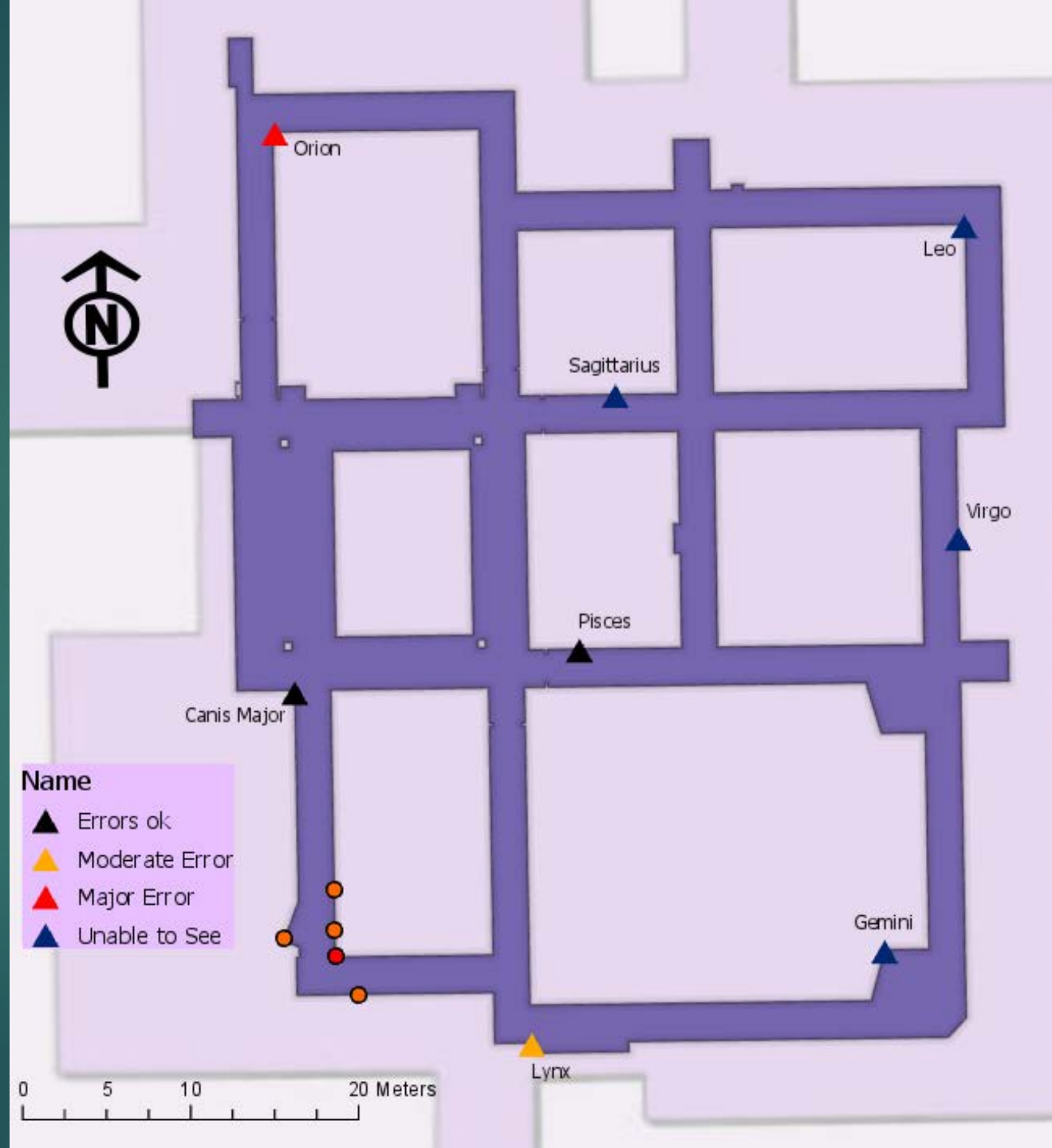
Cluster 1	Canis	Sag	Gem	Vir	Lynx	Leo	Pisces	Orion
Mean	9.95	4.7	n/a	n/a	33.46429	7.957142857	4.528333333	3.8
Std Dev	3.03	3.83	n/a	n/a	5.09	5.18	3.91	5.33
Sum	79.63	37.81	n/a	n/a	234.25	55.7	27.17	30.51
Count	8	8	n/a	n/a	7	7	6	8
Highest RSSi's	-89				-87	-70		

Cluster 2	Canis	Sag	Gem	Vir	Lynx	Leo	Pisces	Orion
Mean	5.23	n/a	n/a	n/a	13.03	n/a	5.05	23.8625
Std Dev	4.74	n/a	n/a	n/a	3.17	n/a	2.98	1.97
Sum	26.15	n/a	n/a	n/a	65.16	n/a	25.26	95.45
Count	5	n/a	n/a	n/a	5	n/a	5	4
Highest RSSi's	-74				-89		-88	-93

Cluster 1



Cluster 2



Beacon Location Estimator

Set
threshold
to -60
(10
meters)

Create
Buffers
(10m
radius)

Calculate
under-
served
areas

Apply
basic
geometric
principles

Add
beacons
to fill gaps

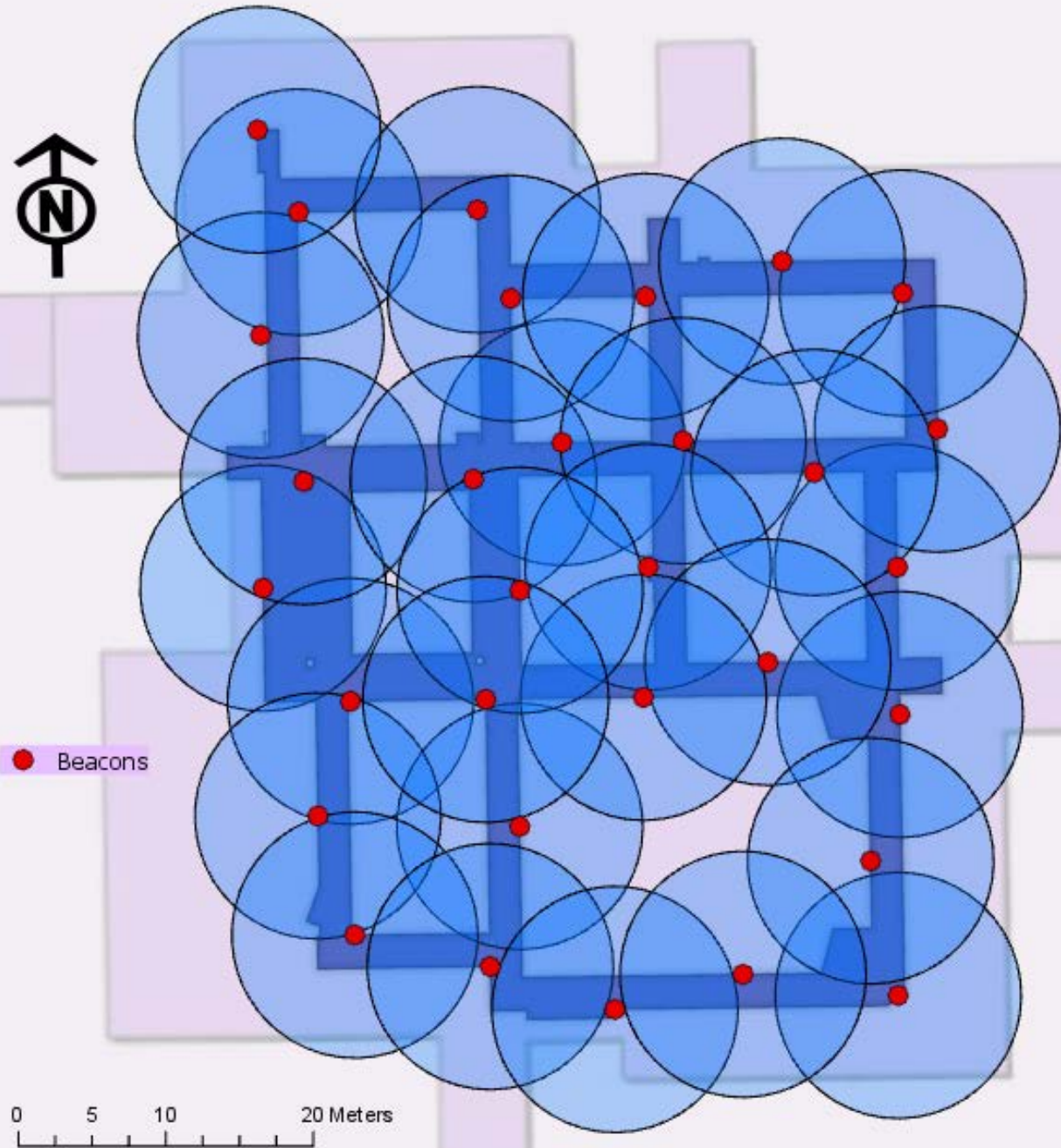
Estimated
number of
beacons



10 Meter Buffer
(-60 RSSI
threshold)

31 Beacons Total

All locations can
see at least two
beacons,
sometimes three.



Key Takeaways

There is a complex relationship between distance and RSSi, including some environment factors that may not be fully understood

We determine -60 as optimal RSSi for indoor positioning.

In a 3D environment, separate floor triangulation is preferred

Future & Concurrent Research

Estimate signal reflection in hallways

CISCO CMX
Wireless Tracking

Photo based location matching

Thanks for listening

For more information on progress as well as other projects, please visit:

<https://gaia.utdallas.edu>



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Application Research Lab