

Spatial Statistics: What's New

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What are
Spatial Statistics?

Spatial statistics are a set of exploratory techniques for describing and modeling **spatial distributions, patterns, processes, and relationships**

They aren't just traditional statistics that *happen* to be applied to spatial data.

They use geography in their calculations.

Proximity, coincidence, connectivity, shape, direction...

That's all true.

But it's actually a lot more exciting than it seems!

And a lot more **important**.



Spatial statistics **extend** what our eyes and our minds do naturally whenever we look at a map

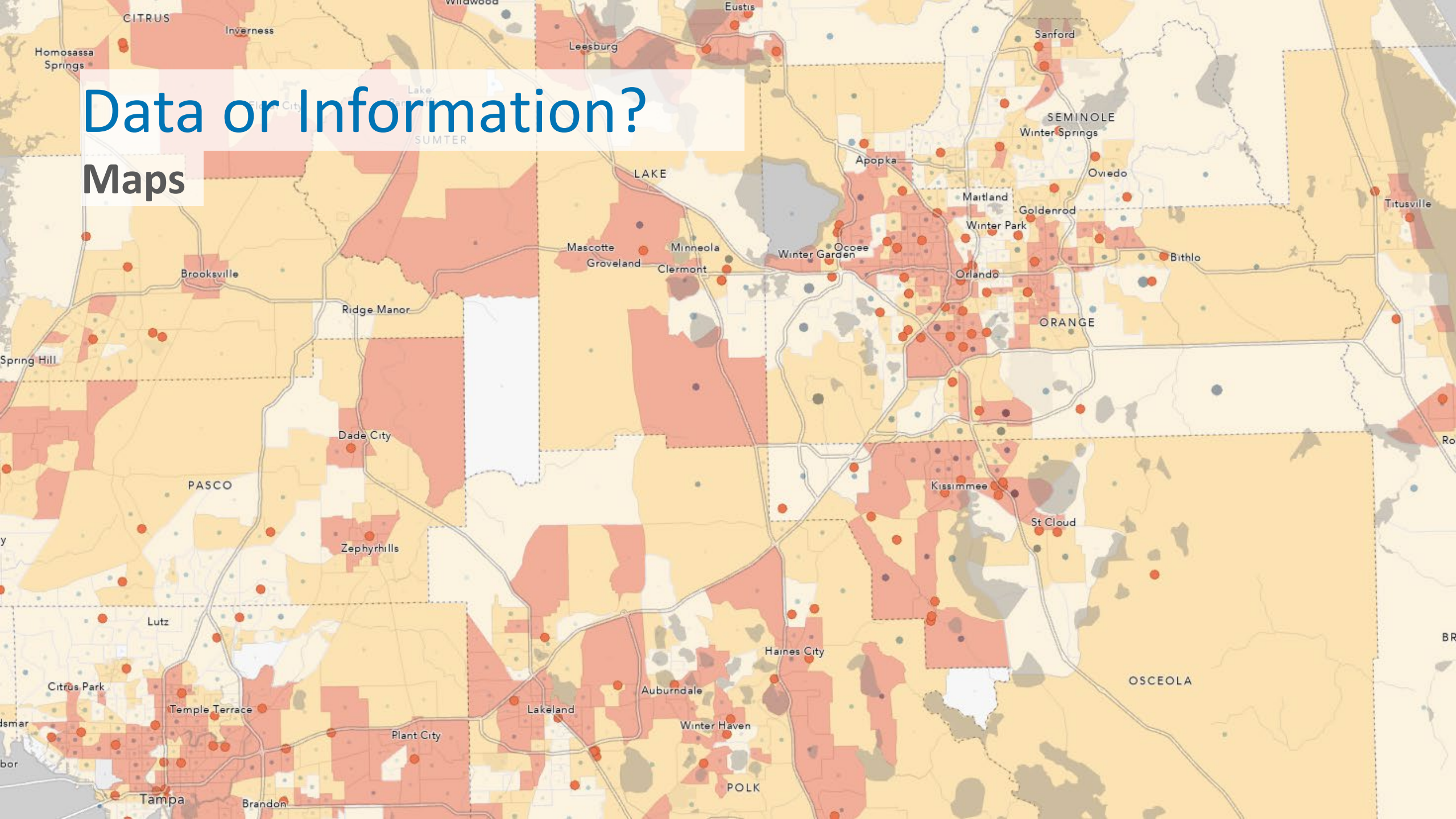
Turning **data** into **information**



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Data or Information?

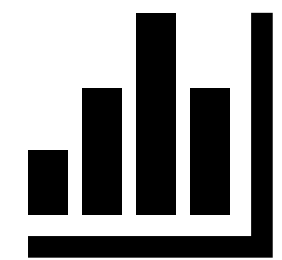
Maps



Data or Information?

Spreadsheets

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min

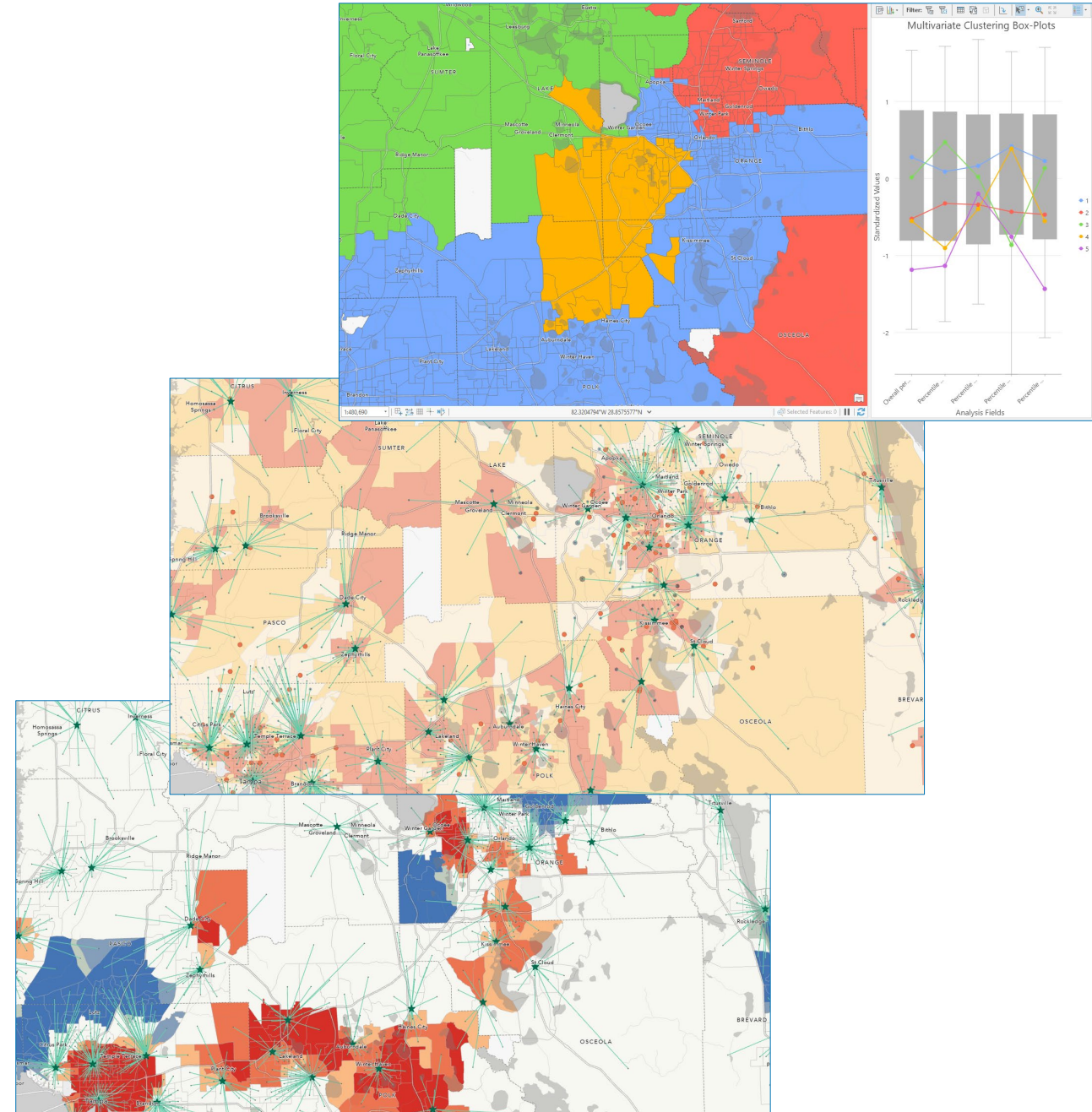
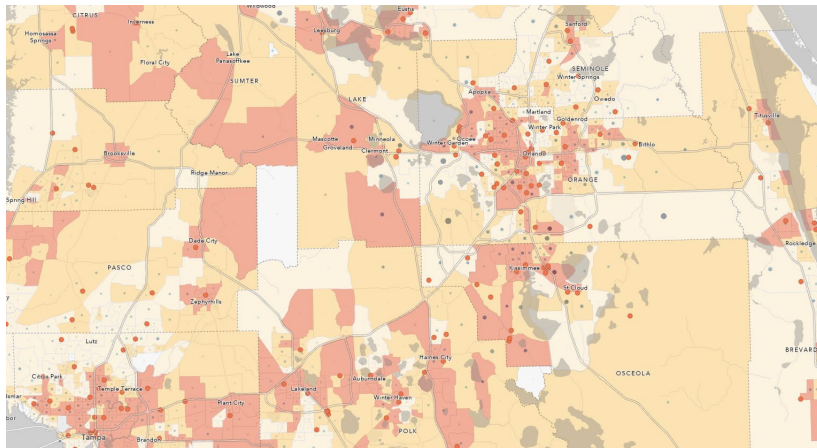
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Data or Information?

Maps



Spatial Analysis & Data Science



Data
Engineering



Visualization
& Exploration



Spatial
Analysis



Machine
Learning & AI



Big Data
Analytics



Modeling
& Scripting



Sharing &
Collaboration

What's new?

- **Data Engineering**
 - Explore
 - Visualize
 - Clean
 - Prepare
- **Dimension Reduction**
- **Neighborhood Summary Statistics**
- **Density-based Clustering with Time**
- **Spatial Association Between Zones**

Data Engineering

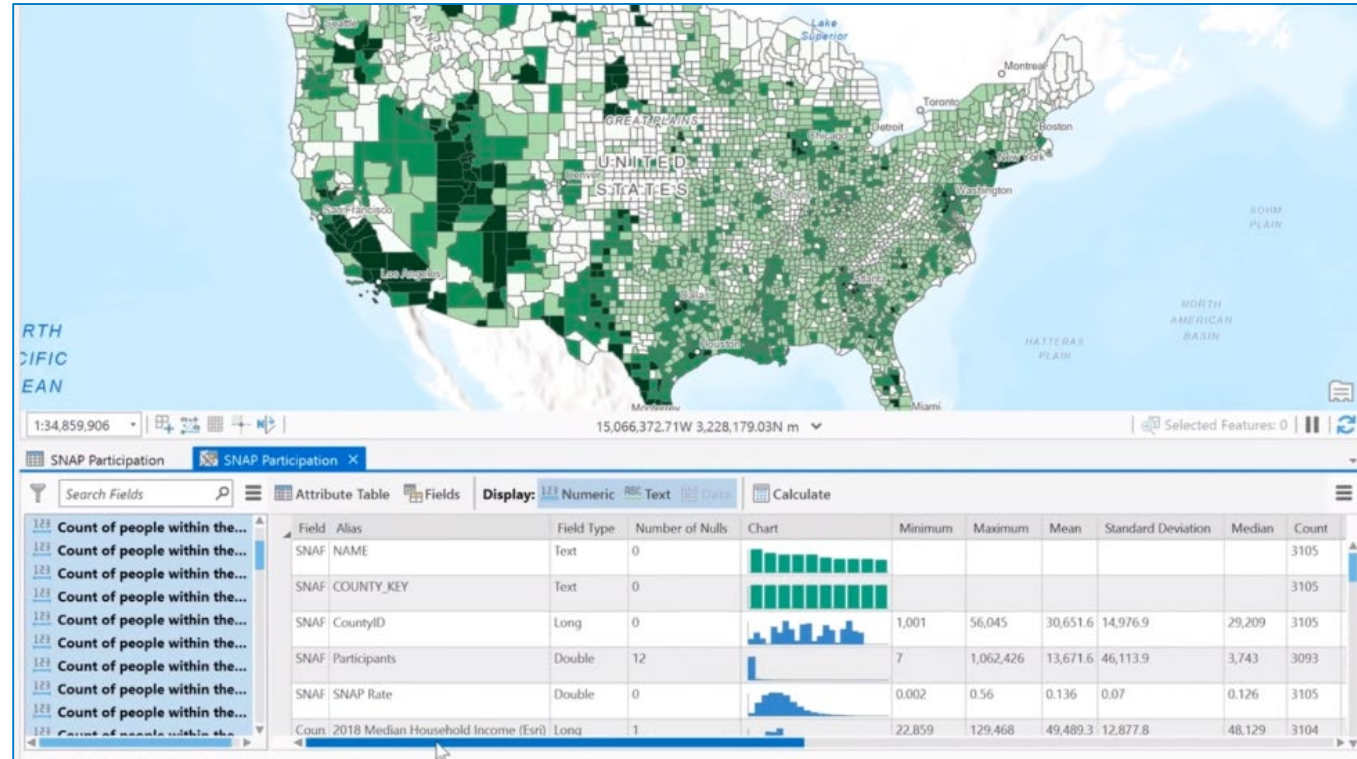
- Getting your data **ready for analysis**
 - What's my data really look like?
 - What's missing?
 - What's wrong?
 - What can you add?
 - What should you transform?

Data Engineering

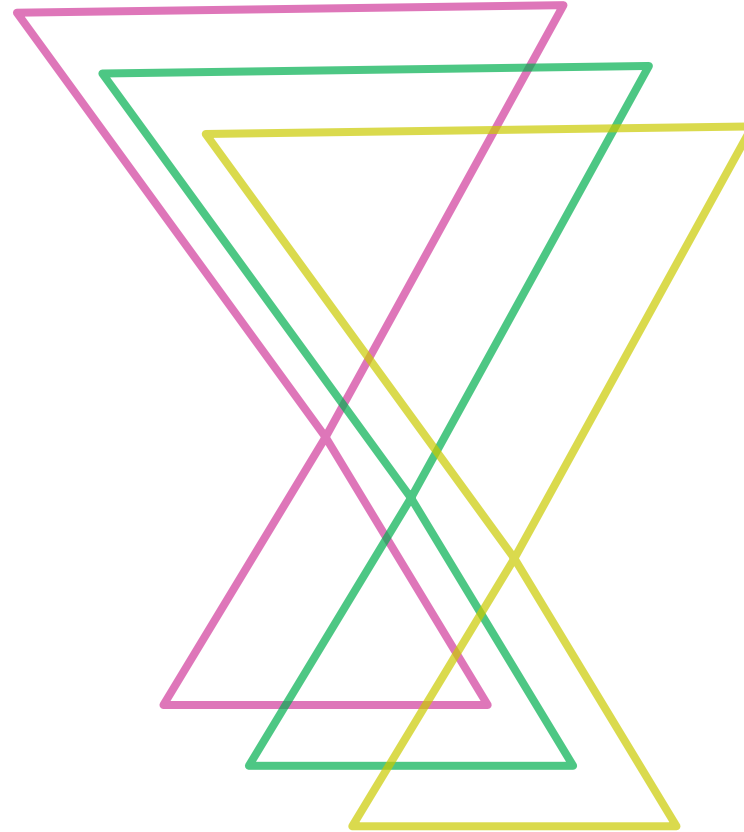
The Fun Stuff



Demo



Dimension Reduction



variance

Variables... they vary!

Variance in explanatory variables help us
predict variance in the outcome variable

2019 Per Capita Income
2019 Average Household Income
2019 Disposable Income <\$15000 : Percent
2019 Disposable Income \$15000-\$24999 : Percent
2019 Disposable Income \$25000-\$34999 : Percent
2019 Disposable Income \$35000-\$49999 : Percent
2019 Disposable Income \$50000-\$74999 : Percent
2019 Disposable Income \$75000-\$99999 : Percent
2019 Disposable Income \$100000-\$149999 : Percent
2019 Disposable Income \$150000-\$199999 : Percent
2019 Disposable Income \$200000+ : Percent
2019 Median Disposable Income
2019 Average Disposable Income
2019 HH Income \$25000-34999 : Percent
2019 HH Income \$75000-99999 : Percent
2019 HH Income \$200000+ : Percent
2019 HH Income \$150000-199999 : Percent
2019 HH Income \$100000-149999 : Percent
2019 HH Income <\$15000 : Percent
2019 HH Income \$50000-74999 : Percent
2019 HH Income \$35000-49999 : Percent
2019 HH Income \$15000-24999 : Percent
ACS HHs: Inc Below Poverty Level
ACS HHs: Inc Below Poverty Level : Percent
2019 Value: Stocks/Bonds/Mutual Funds : Average
2019 Value: Credit Card Debt : Average

SO MANY INCOME VARIABLES

Reduce the number of explanatory
variables while maintaining as
much **variance** as possible

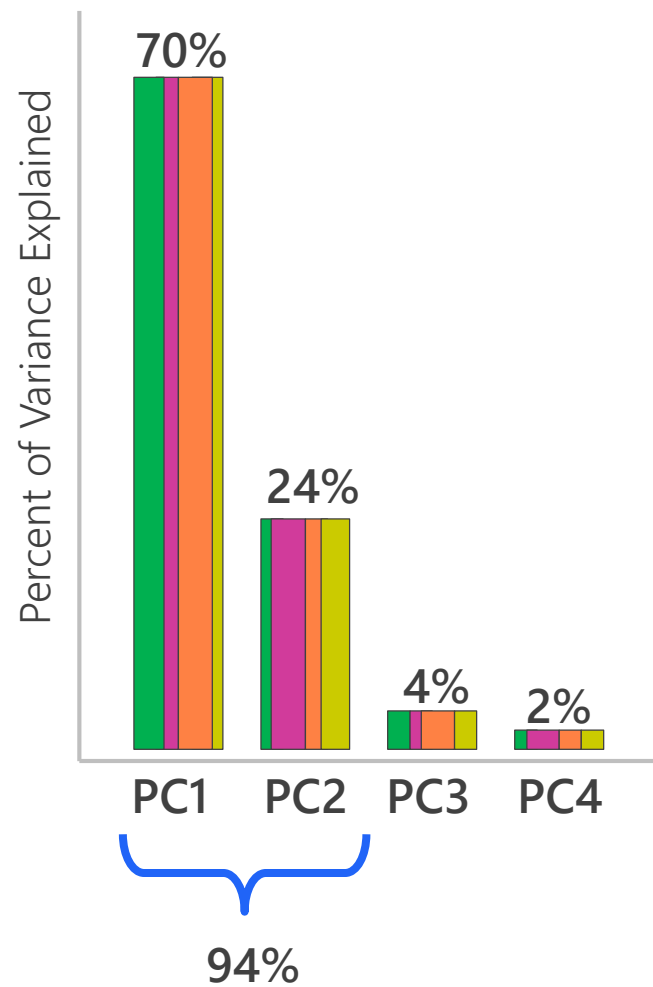
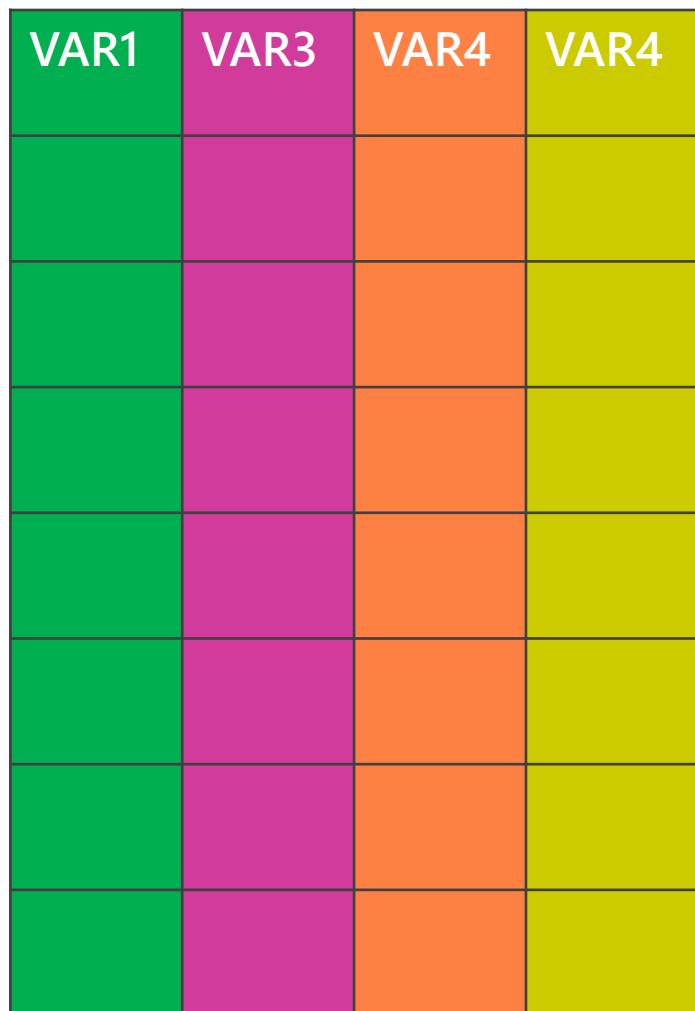
26 income variables

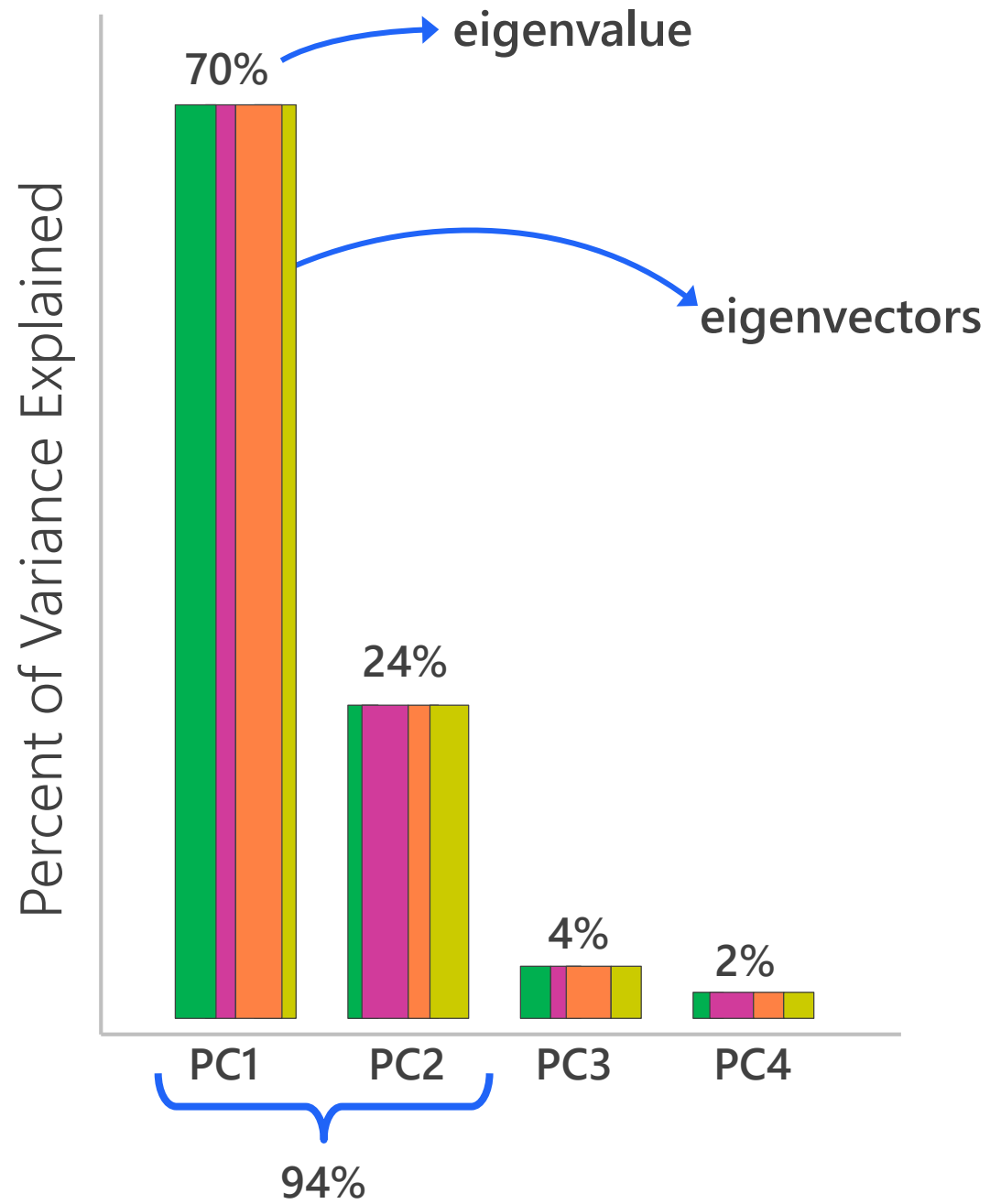
2019 Per Capita Income
2019 Average Household Income
2019 Disposable Income <\$15000 : Percent
2019 Disposable Income \$15000-\$24999 : Percent
2019 Disposable Income \$25000-\$34999 : Percent
2019 Disposable Income \$35000-\$49999 : Percent
2019 Disposable Income \$50000-\$74999 : Percent
2019 Disposable Income \$75000-\$99999 : Percent
2019 Disposable Income \$100000-\$149999 : Percent
2019 Disposable Income \$150000-\$199999 : Percent
2019 Disposable Income \$200000+ : Percent
2019 Median Disposable Income
2019 Average Disposable Income
2019 HH Income \$25000-34999 : Percent
2019 HH Income \$75000-99999 : Percent
2019 HH Income \$200000+ : Percent
2019 HH Income \$150000-199999 : Percent
2019 HH Income \$100000-149999 : Percent
2019 HH Income <\$15000 : Percent
2019 HH Income \$50000-74999 : Percent
2019 HH Income \$35000-49999 : Percent
2019 HH Income \$15000-24999 : Percent
ACS HHs: Inc Below Poverty Level
ACS HHs: Inc Below Poverty Level : Percent
2019 Value: Stocks/Bonds/Mutual Funds : Average
2019 Value: Credit Card Debt : Average

7 components

Component 1
Component 2
Component 3
Component 4
Component 5
Component 6
Component 7

95% of variance explained





Dimension Reduction Methods

PCA

Principal Component Analysis

Use when the variable components will be used to predict a continuous variable



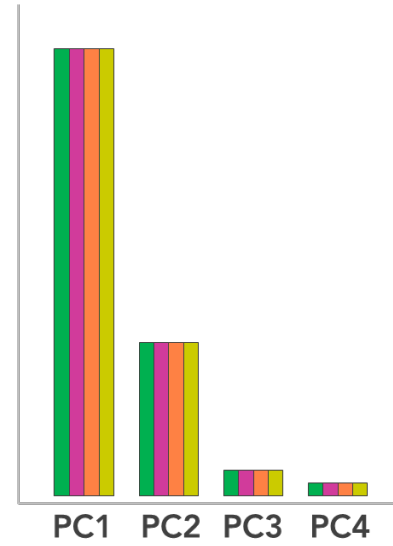
LDA

Reduced-Rank Linear Discriminant Analysis

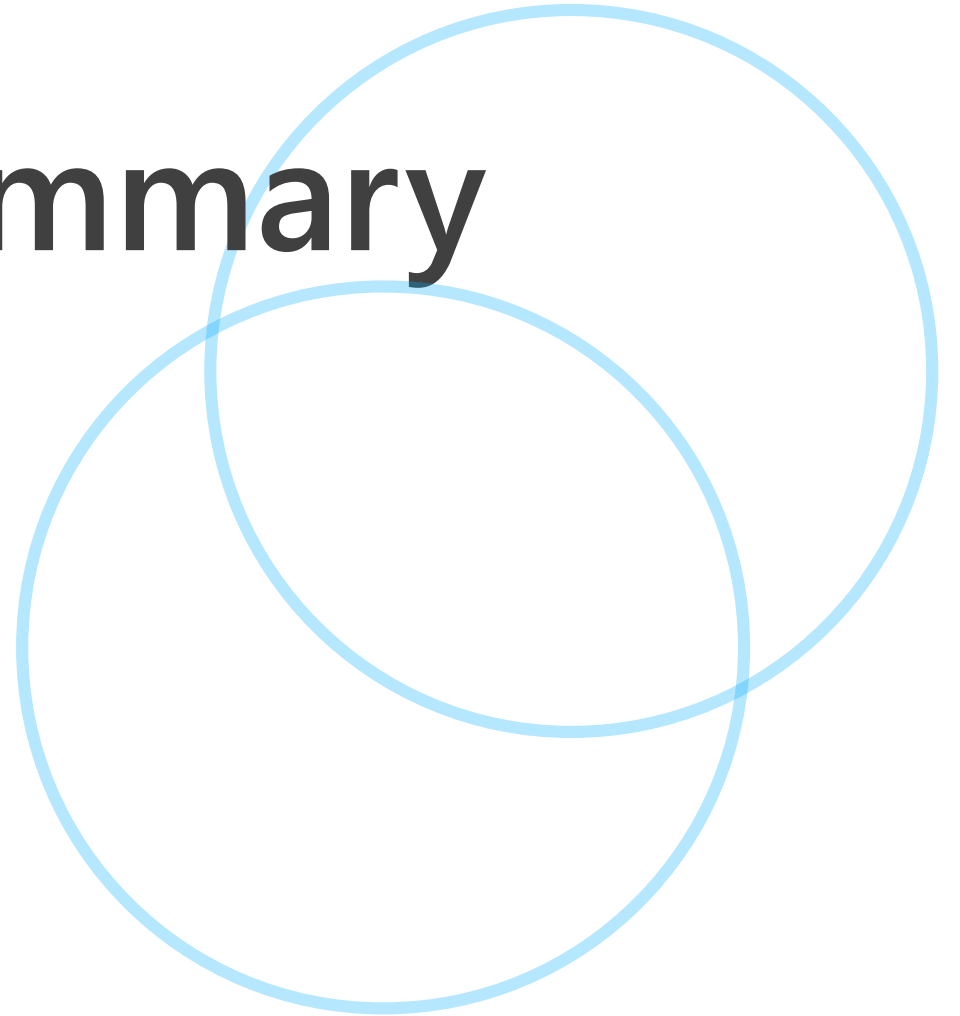
Use when the variable components will be used to predict a categorical variable

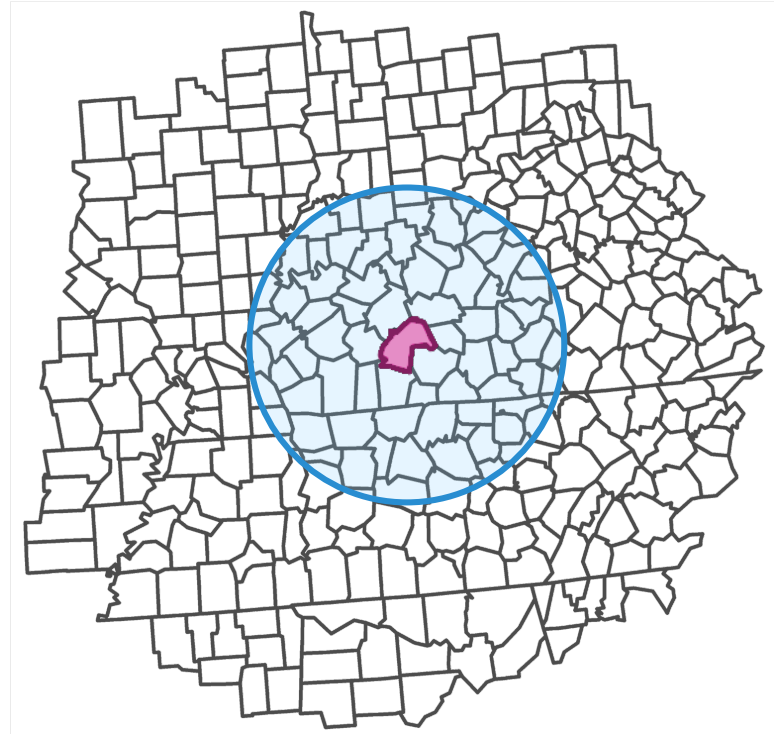
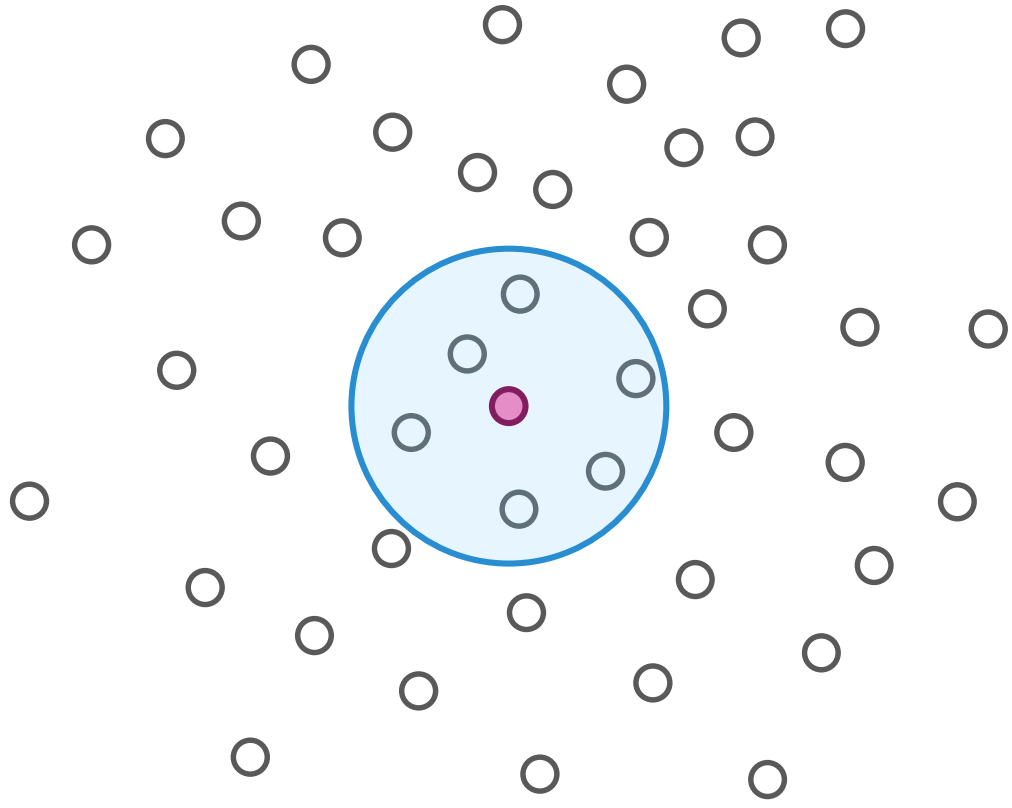


demo



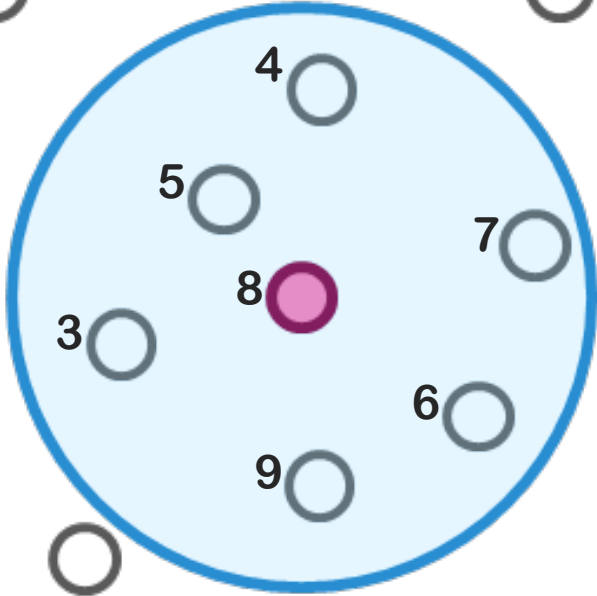
Neighborhood Summary Statistics



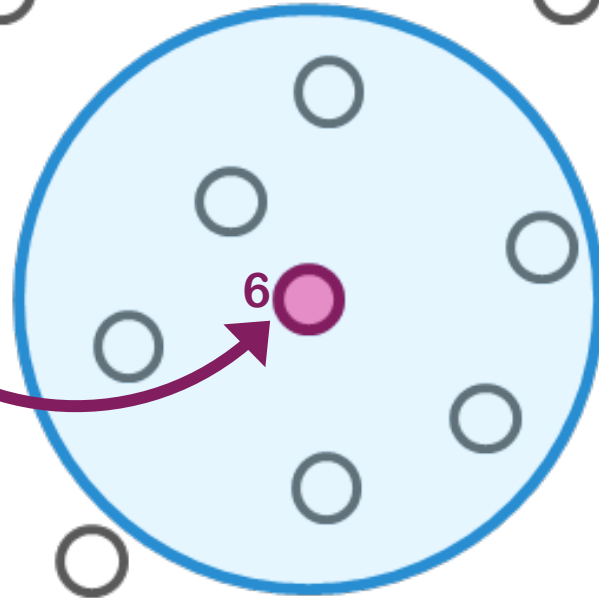


neighborhood

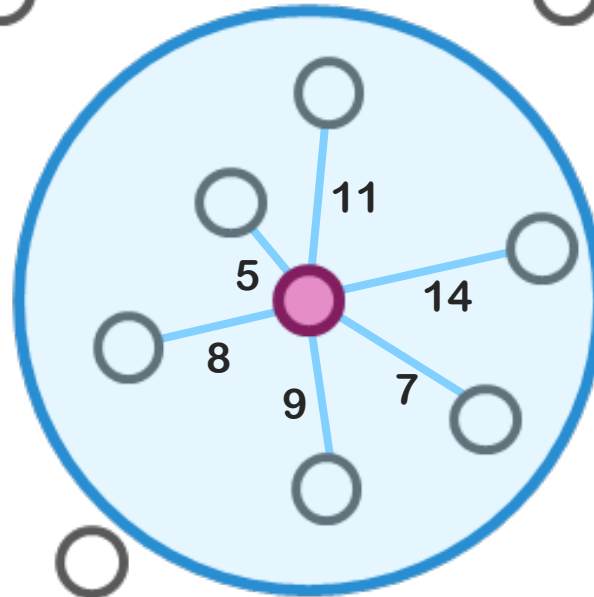
$$(8+3+9+6+7+4+5) / 7 = 6$$



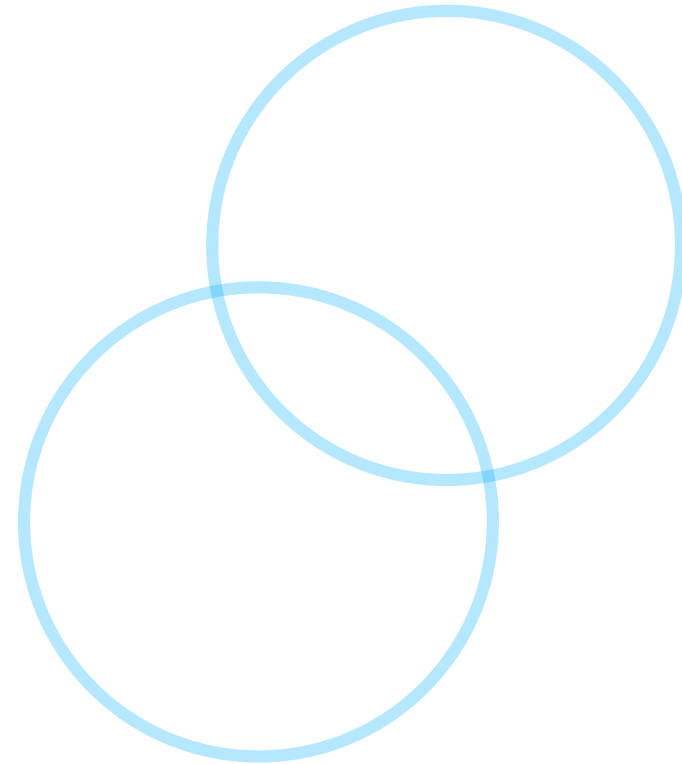
$$(8+3+9+6+7+4+5) / 7 = 6$$



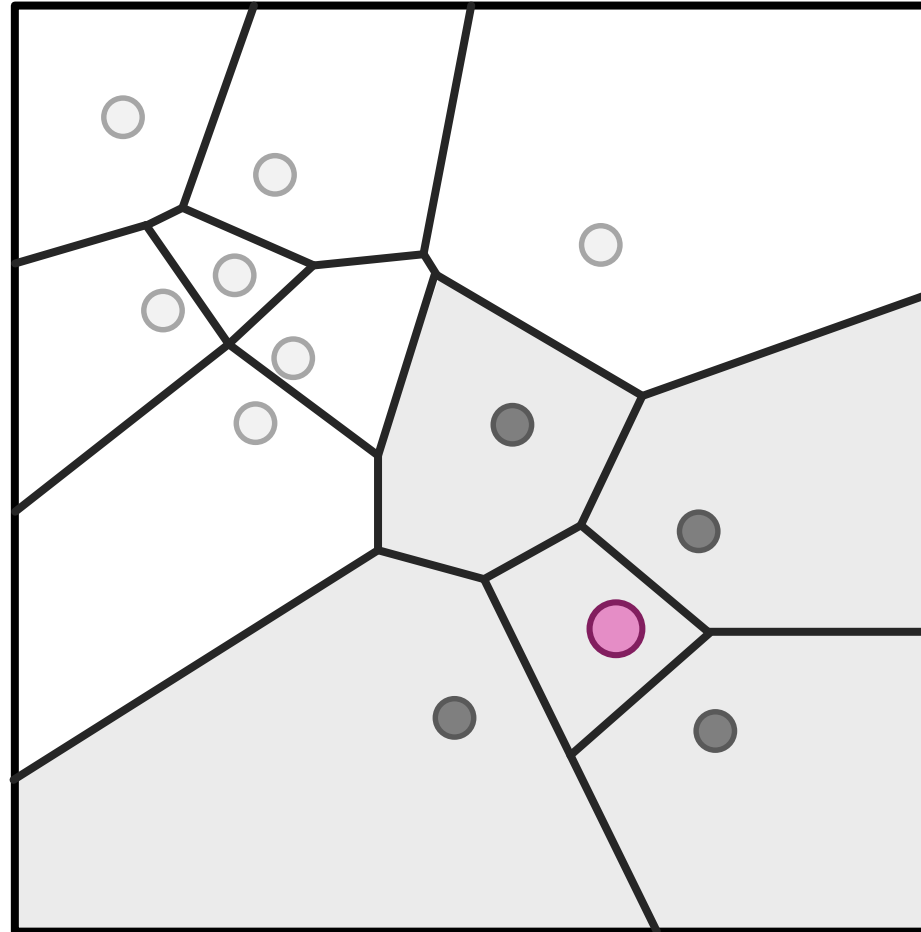
$$(5+11+14+7+9+8) / 6 = 9$$



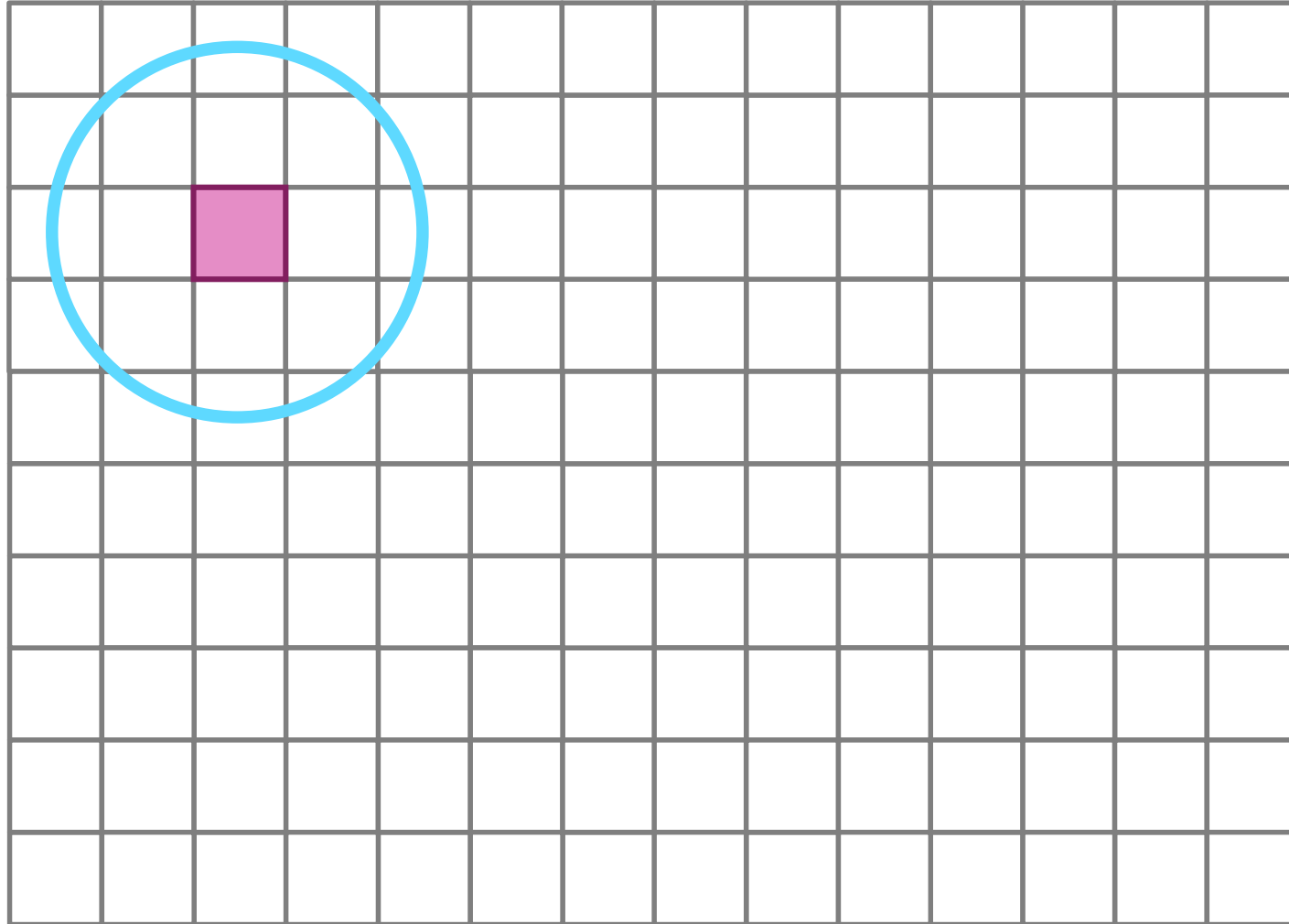
neighborhood types



Delaunay Triangulation



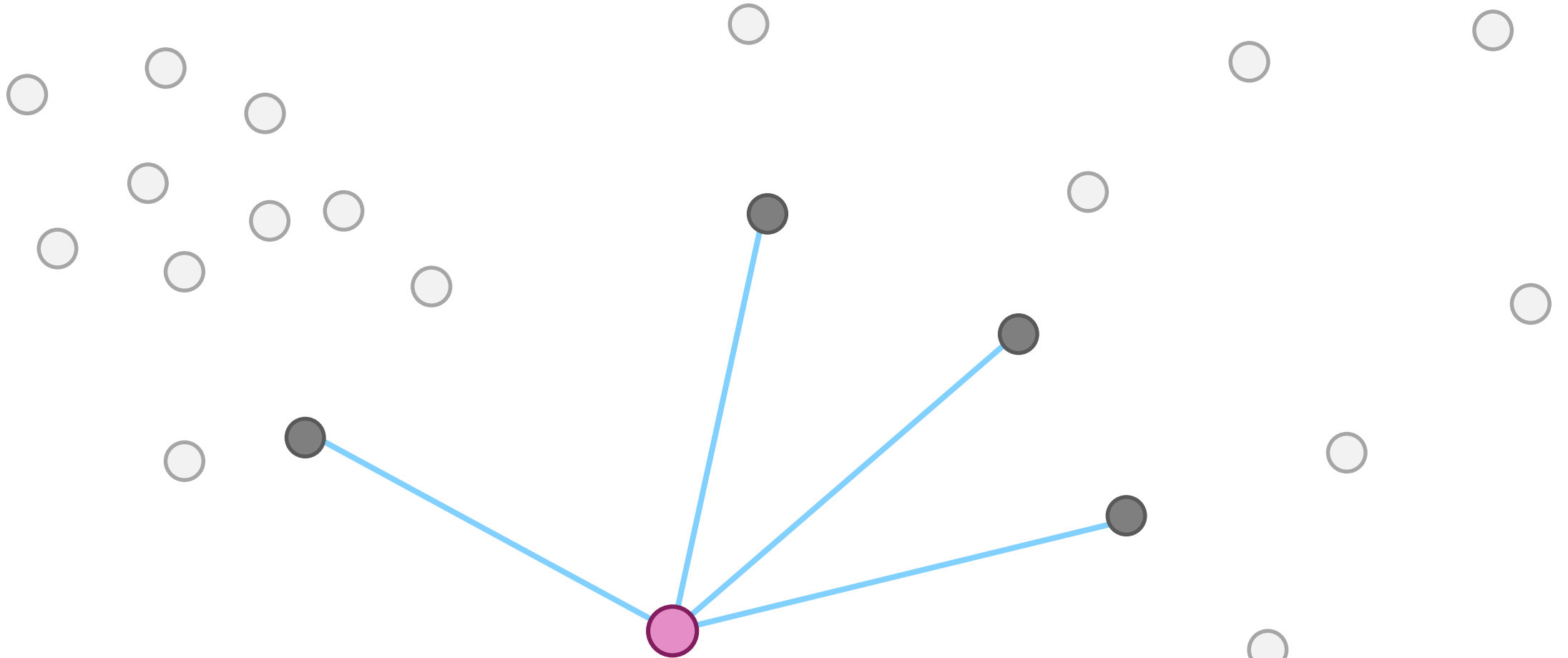
Distance Band



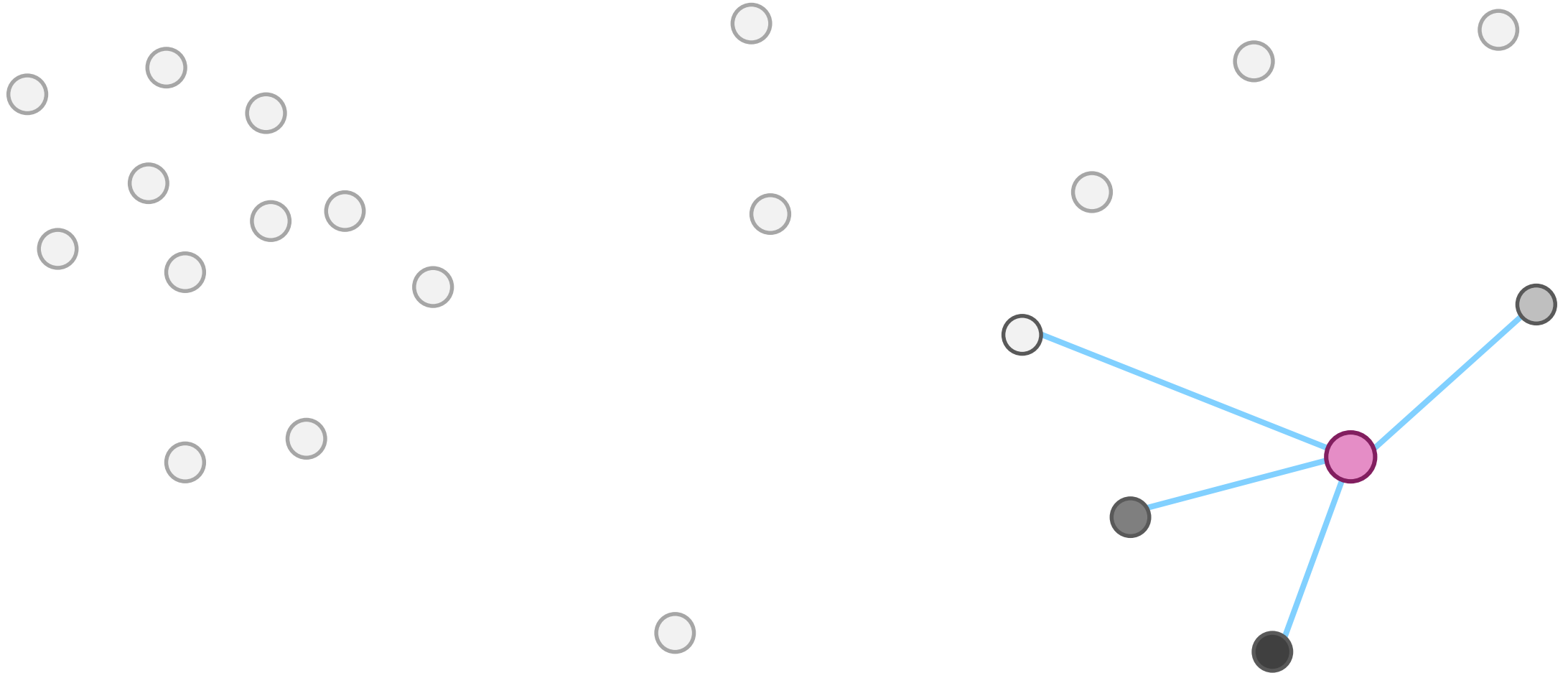
Number of Neighbors



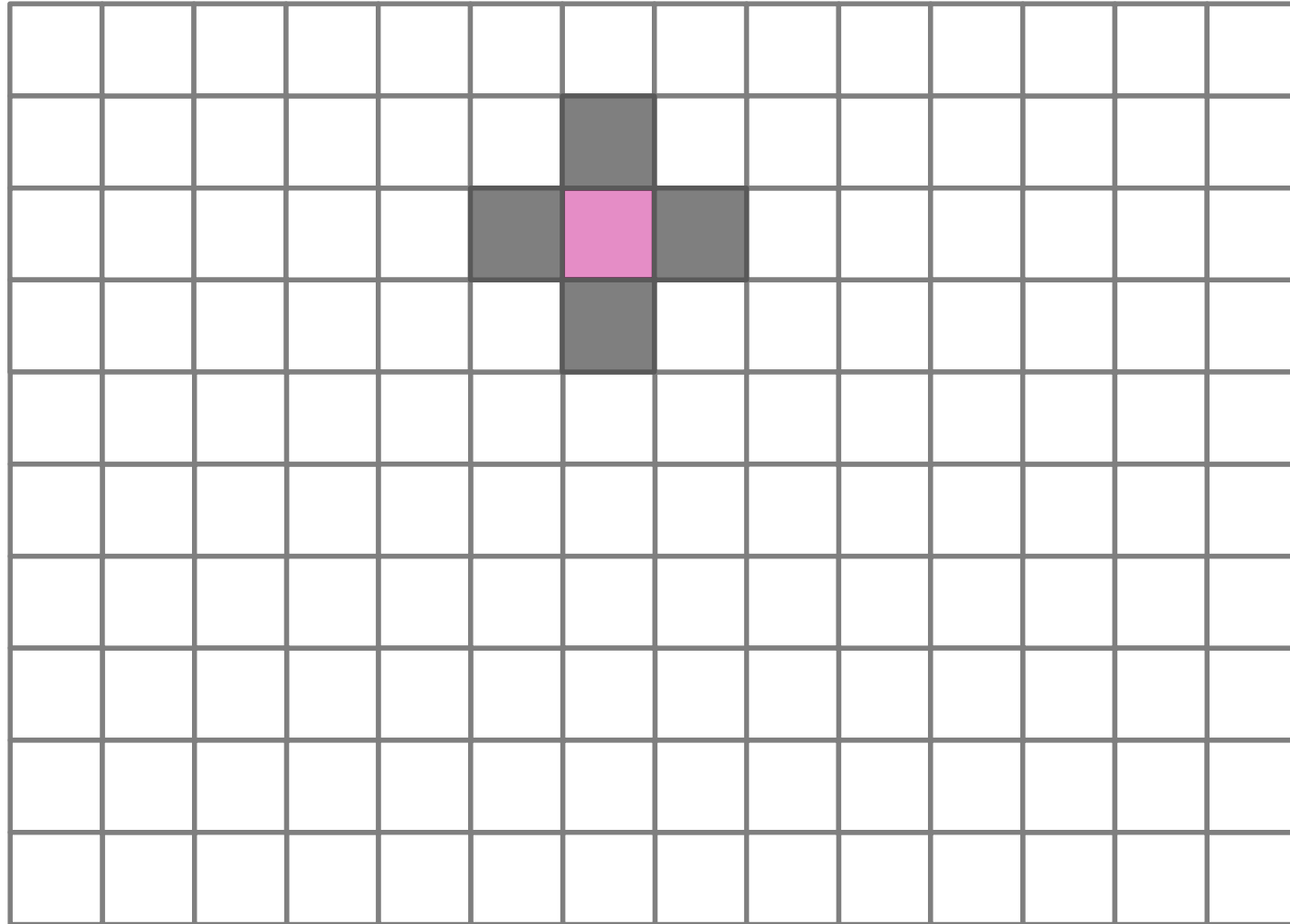
Number of Neighbors



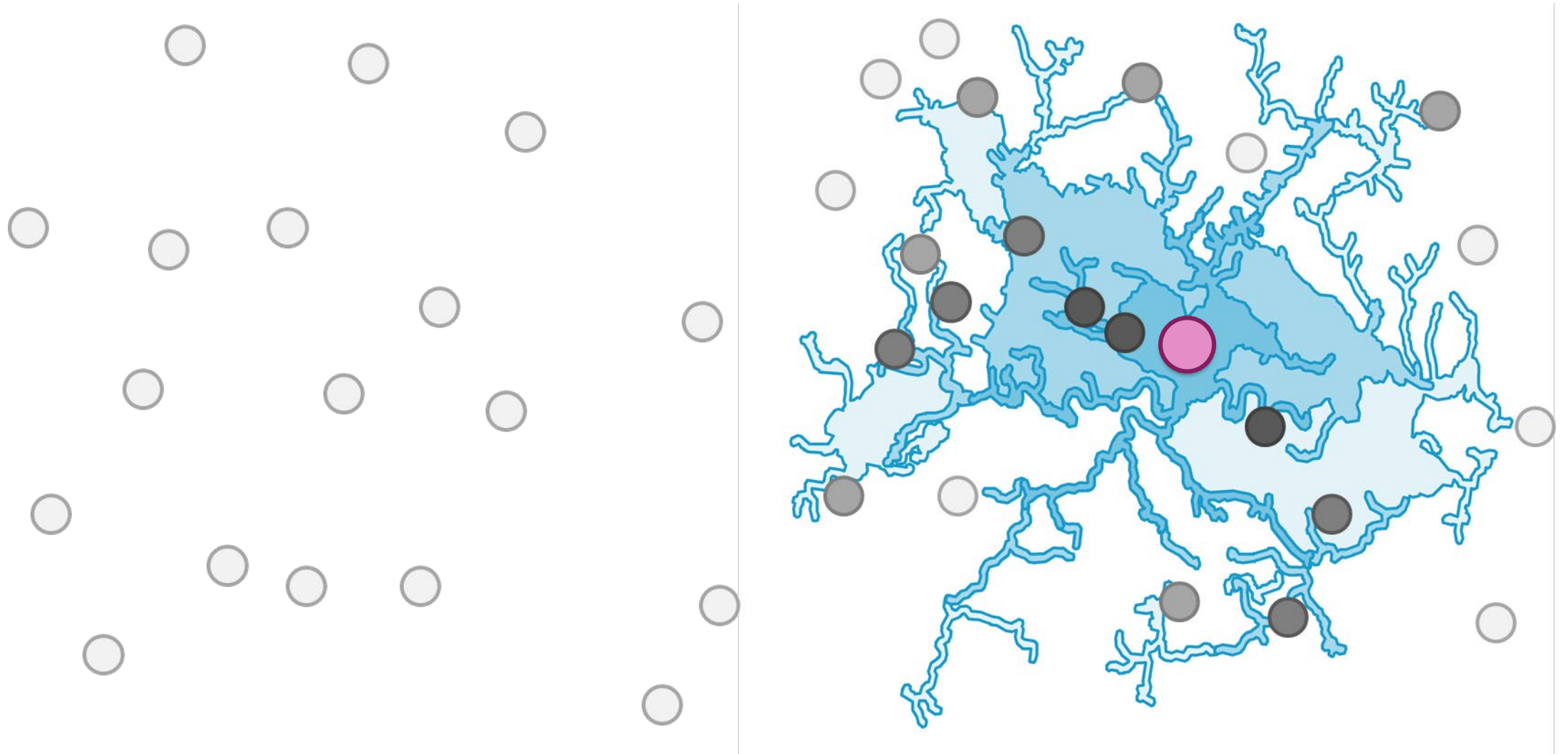
Number of Neighbors



Contiguity Edges



Network Spatial Weights

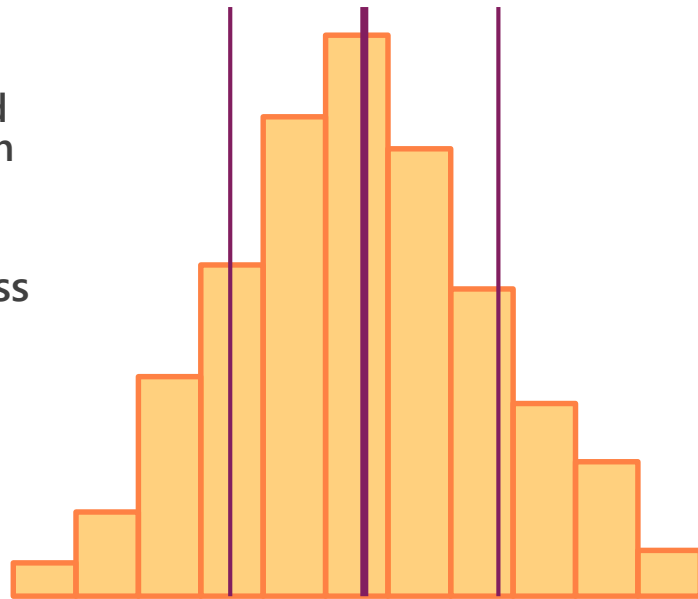


Traditional Statistics

Mean

Standard deviation

Skewness

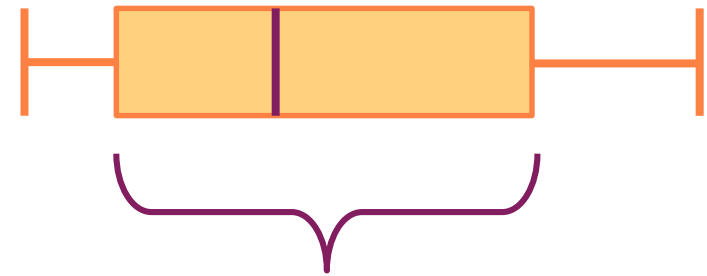


Robust Statistics

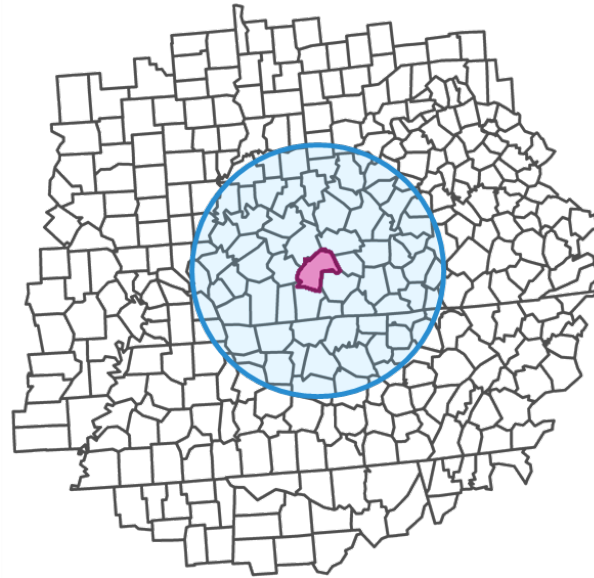
Median

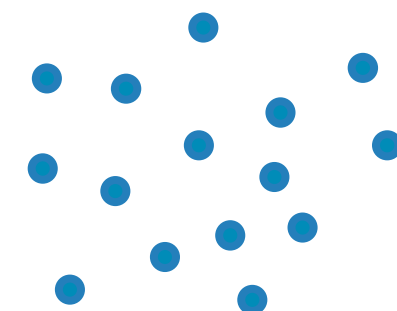
Interquartile range

Quantile imbalance



demo





Density-based Clustering

finds clusters based on feature locations
and time

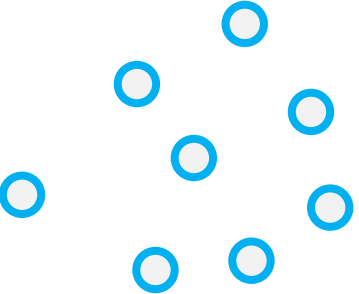
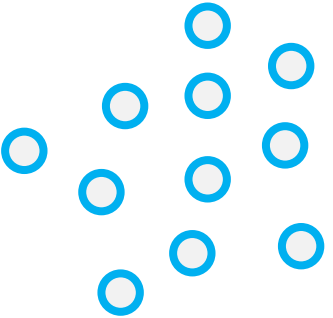
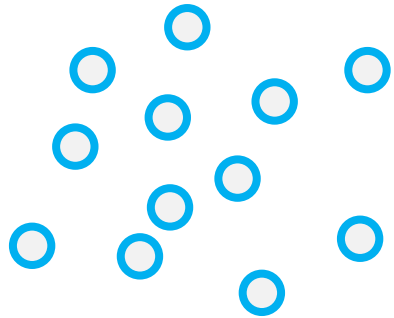
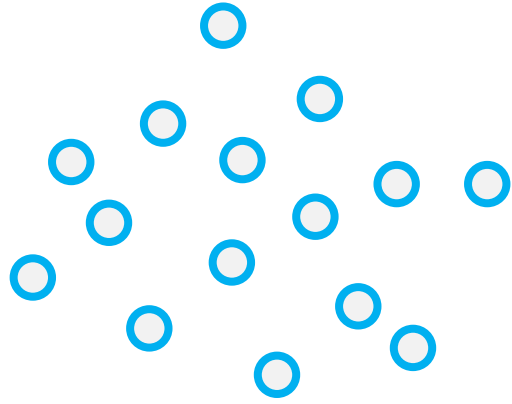
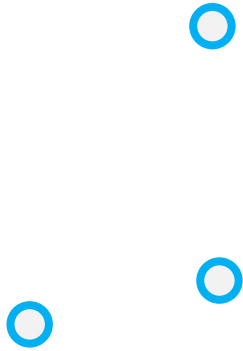
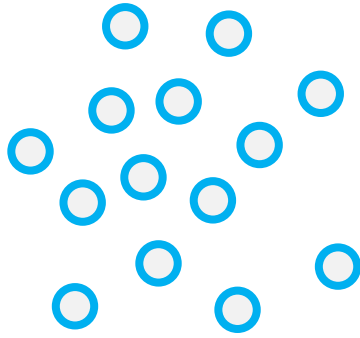
DBSCAN – defined distance *with time*

OPTICS – multi-scale *with time*

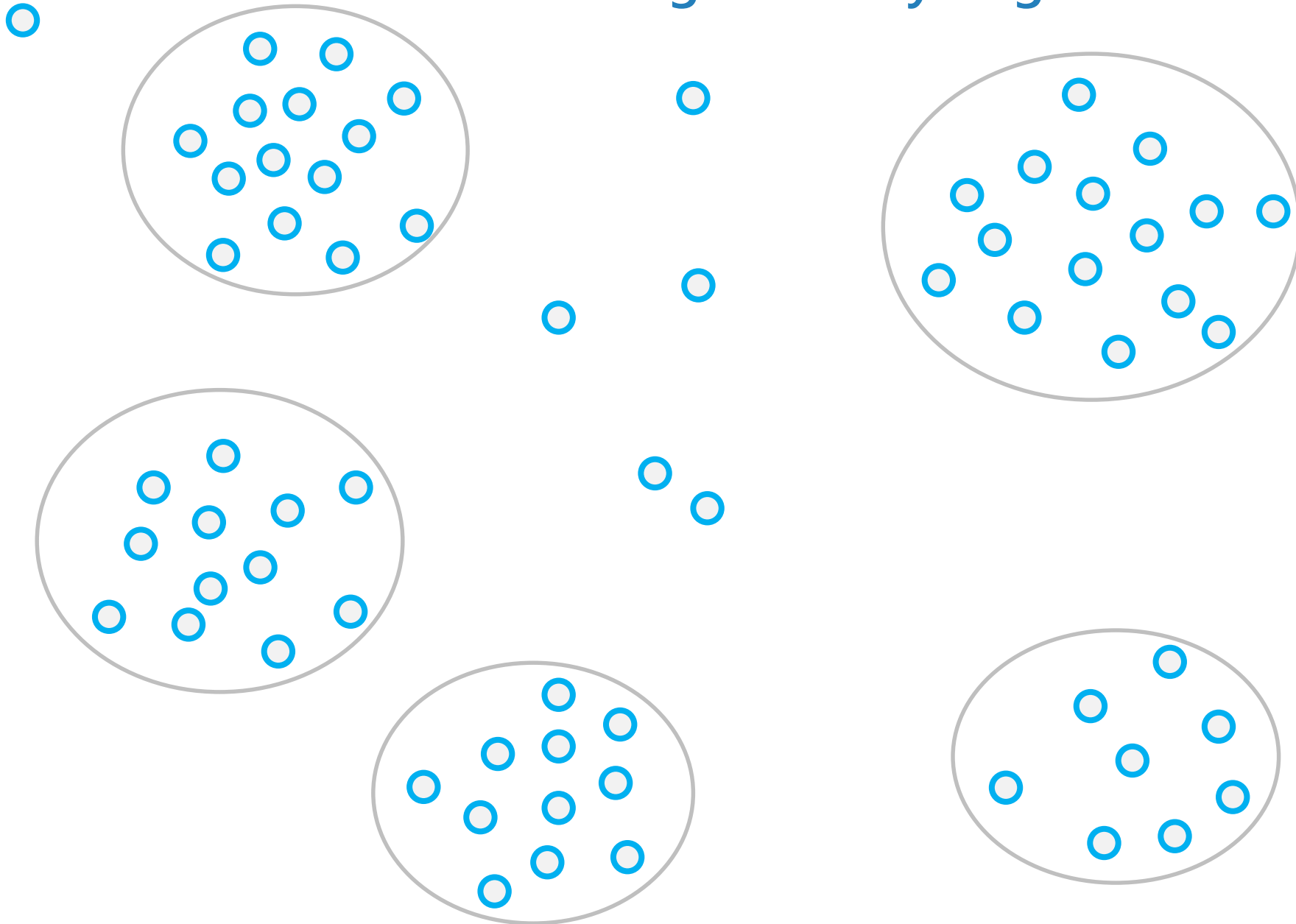
DBSCAN

Density-Based Spatial Clustering of Applications with Noise

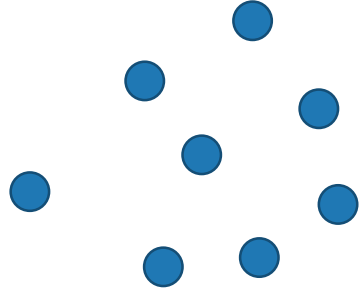
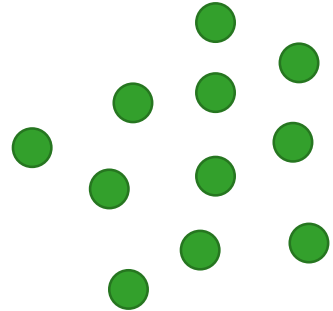
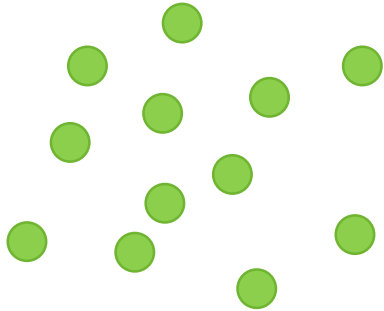
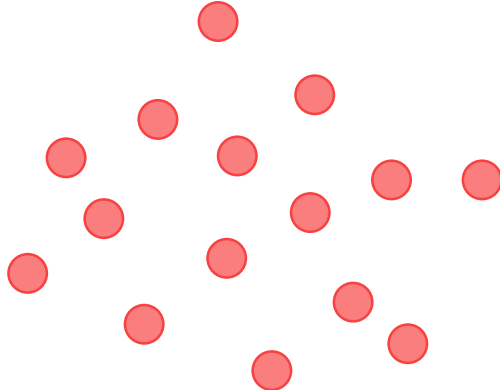
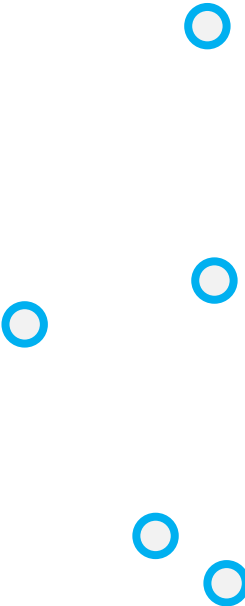
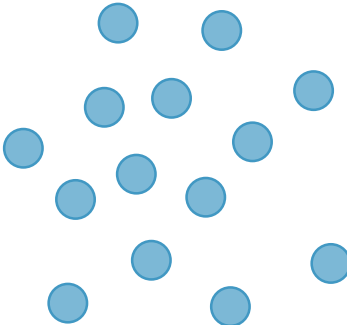
- Groups points as clusters in high density regions
- And mark points as noise in low density regions



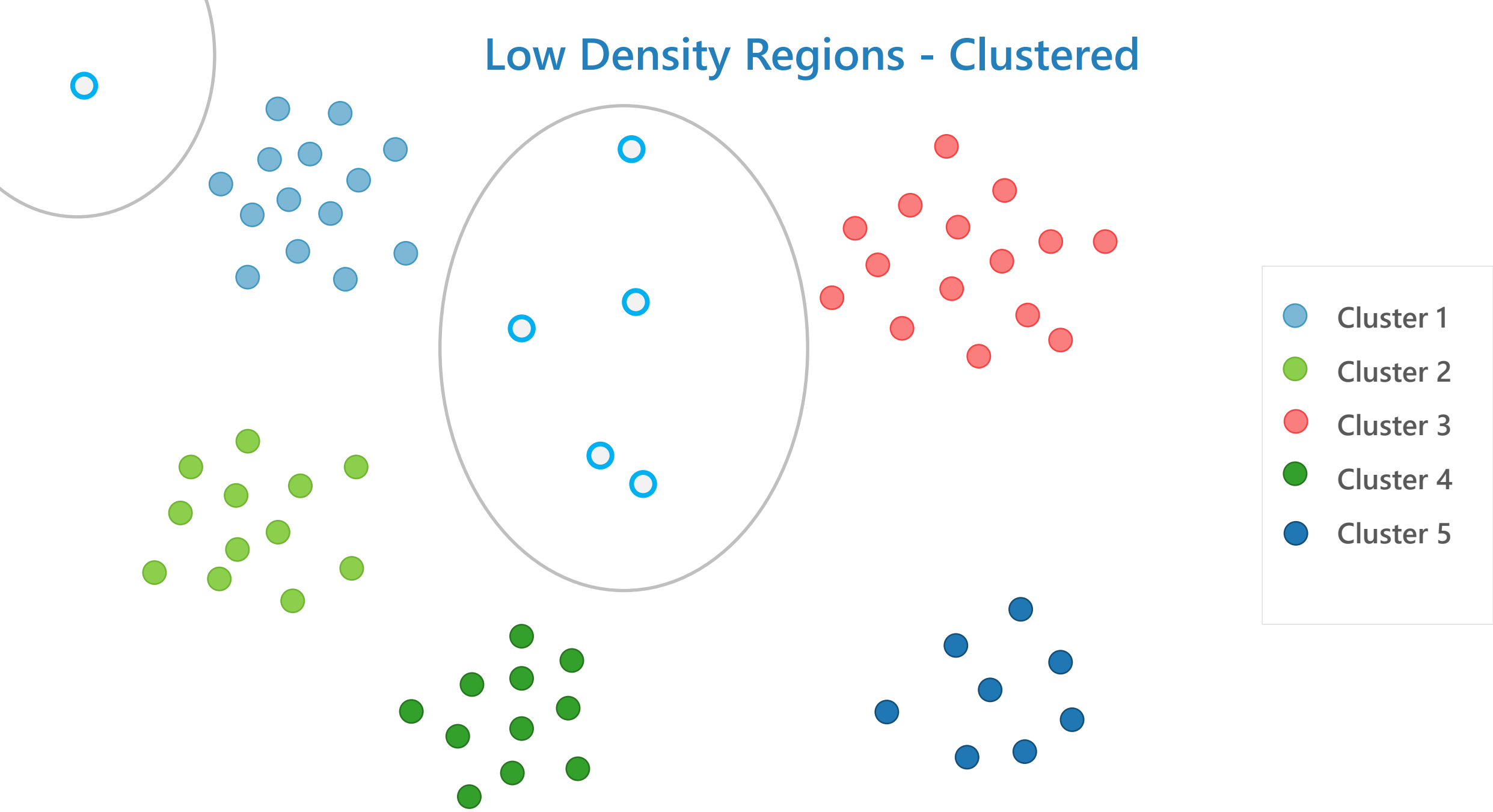
High Density Regions



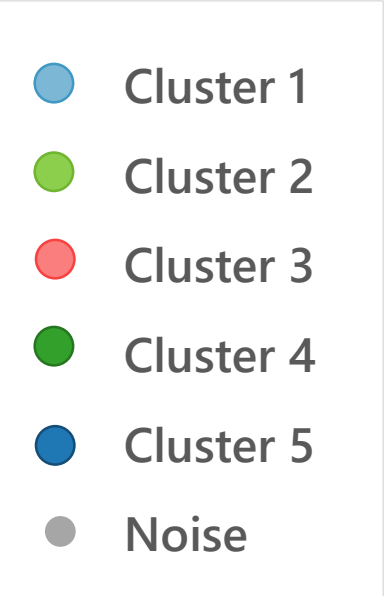
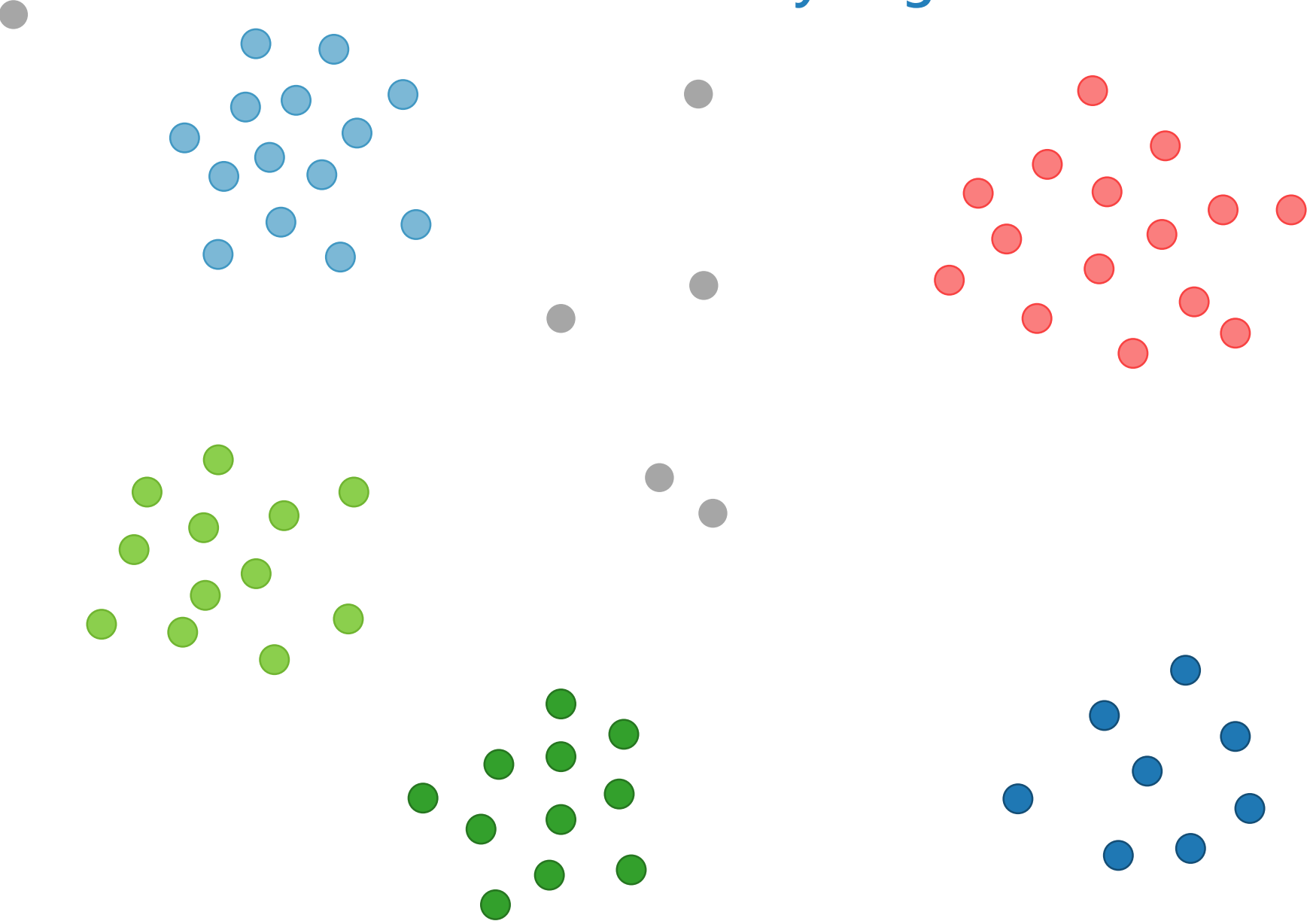
High Density Regions - Clustered



Low Density Regions - Clustered



Low Density Regions - Noise



How do you define a
high or low density
region?

Using the 2 parameters:

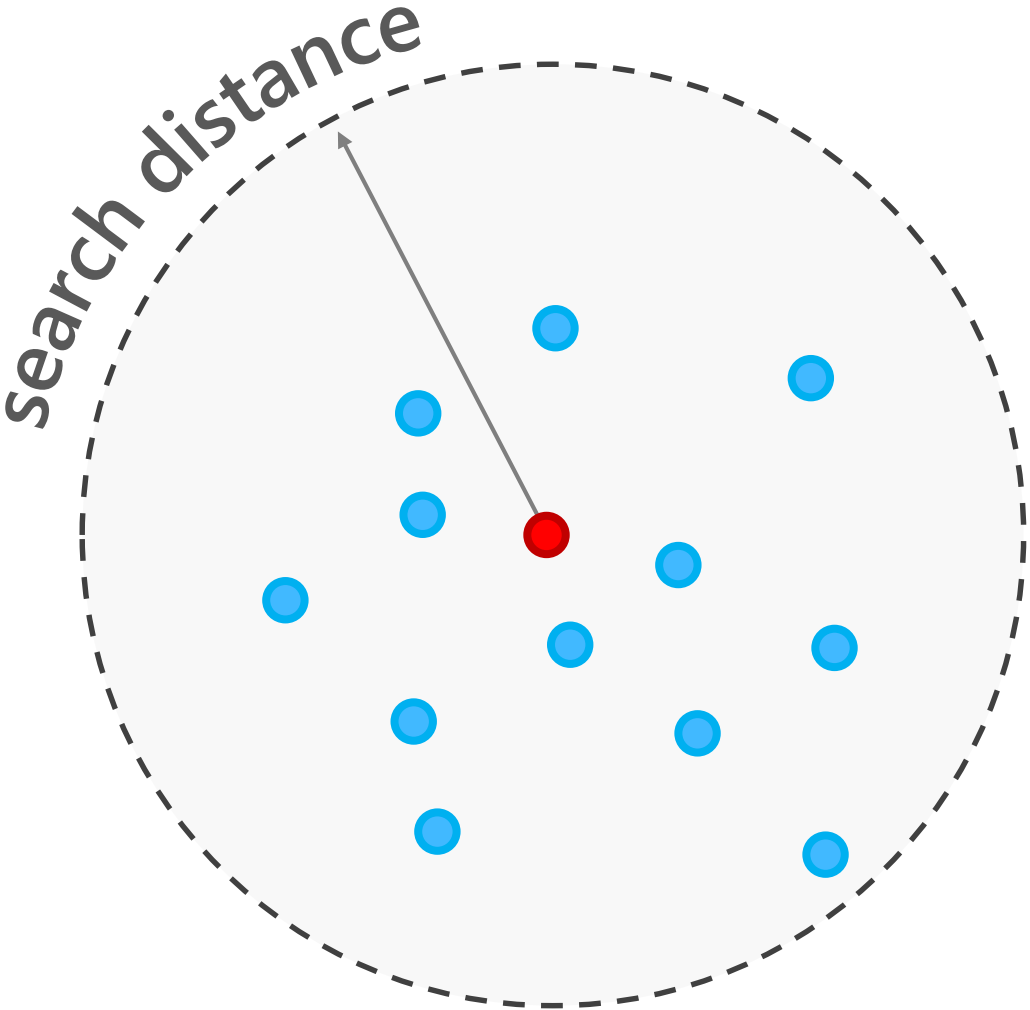
→ Search Distance

→ Minimum features per cluster

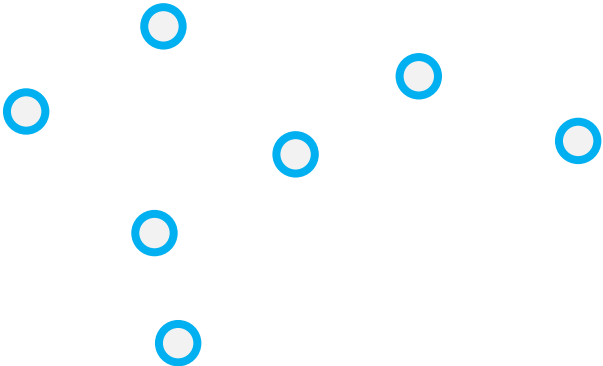
DBSCAN

Search Distance = 10 meters

Minimum features per cluster = 10



High Density Region



DBSCAN

Search Distance = 10 meters

Minimum features per cluster = 10

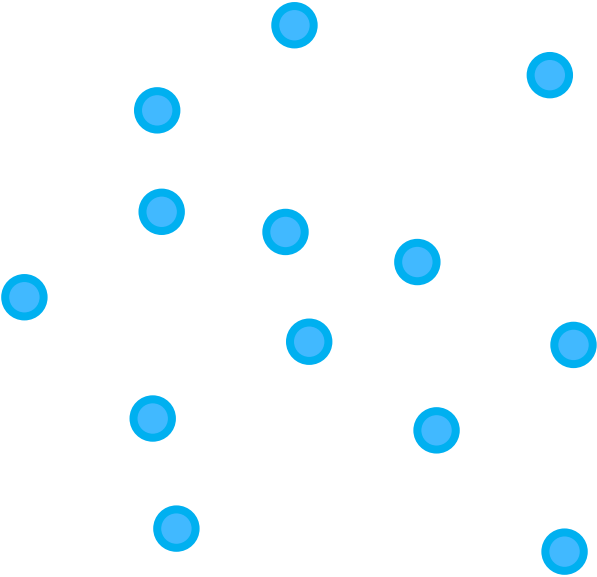


Low Density Region

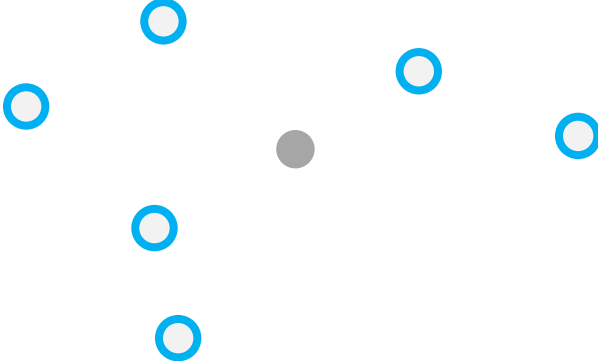
DBSCAN

Search Distance = 10 meters

Minimum features per cluster = 10



Cluster

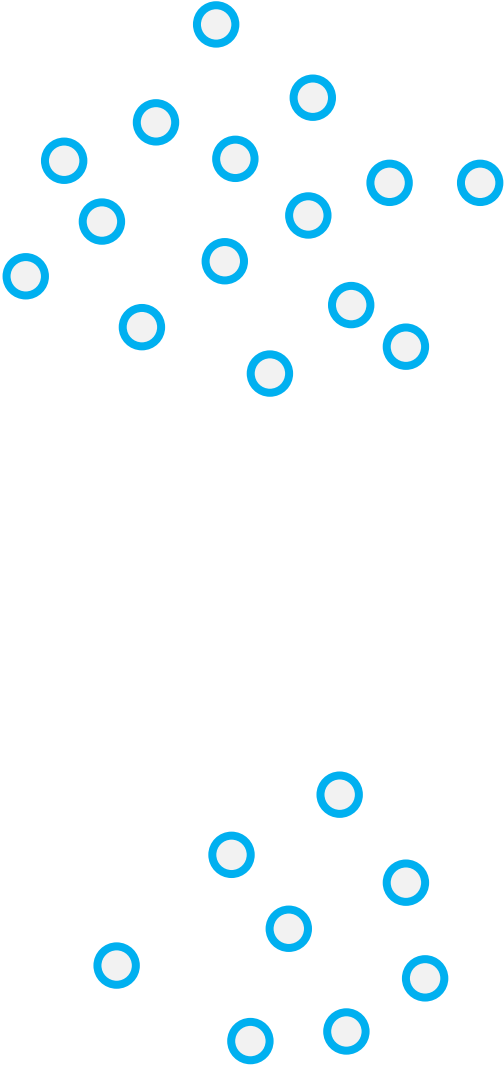
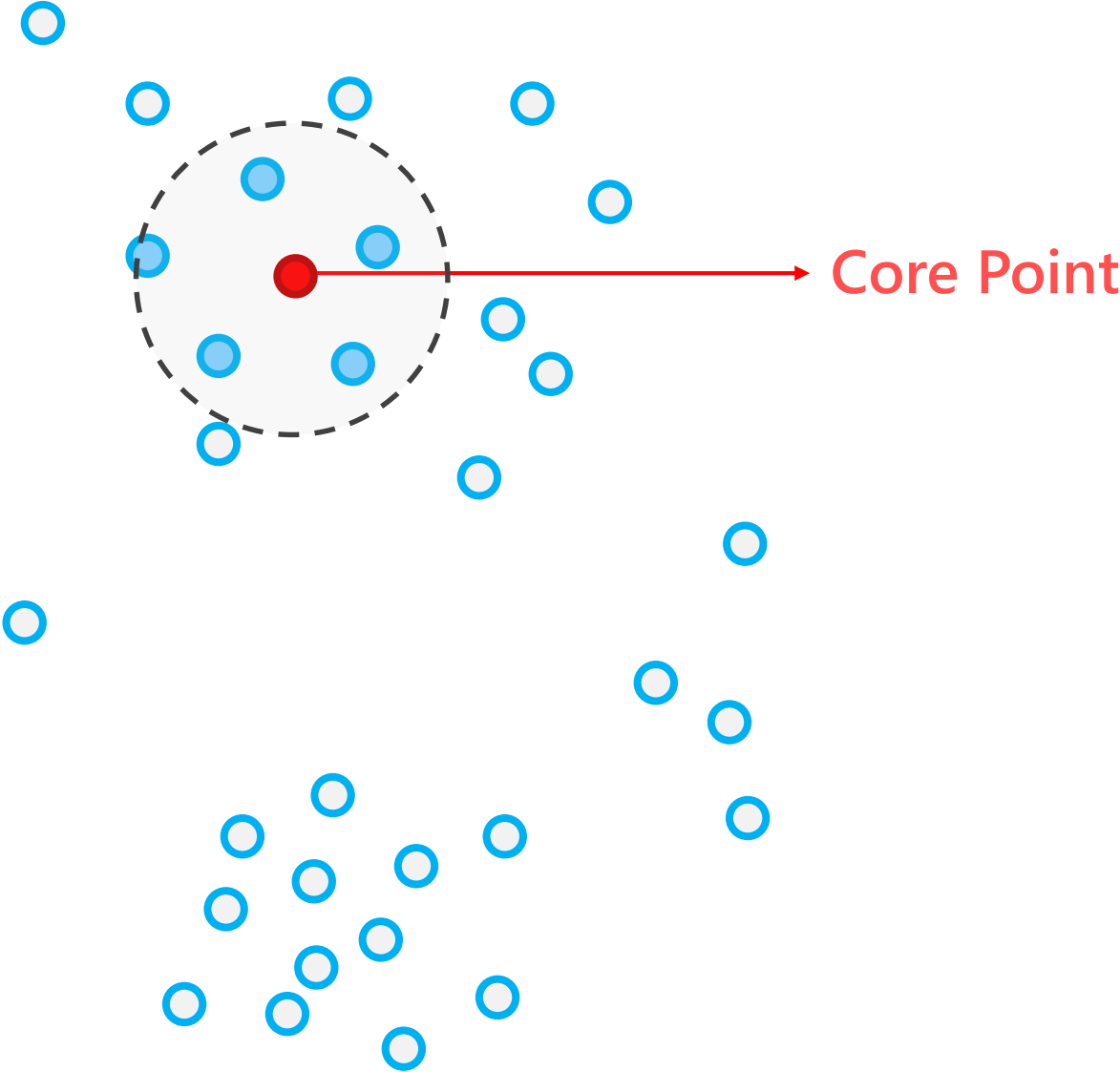


Noise

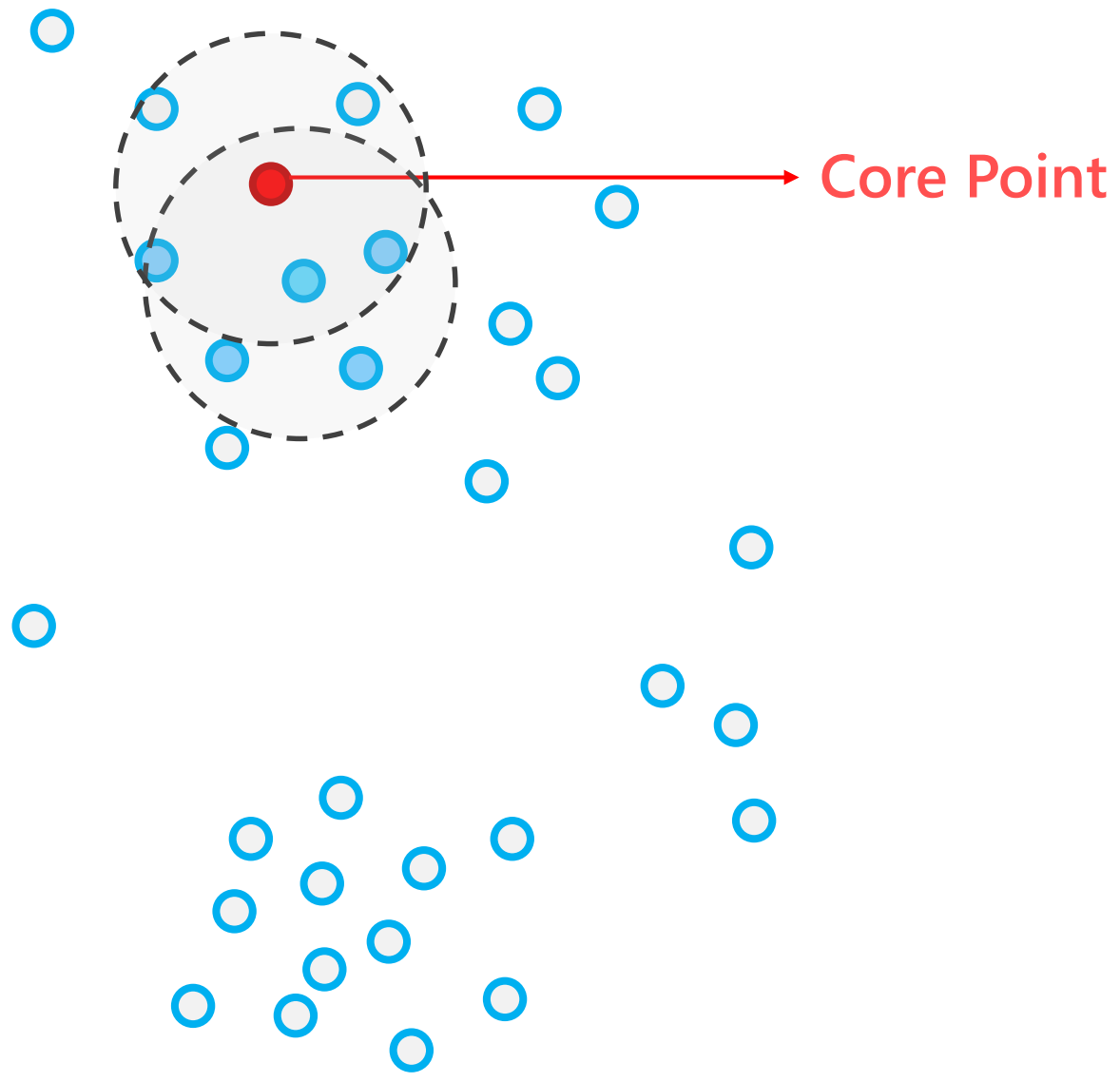
How does a
cluster grow?

DBSCAN

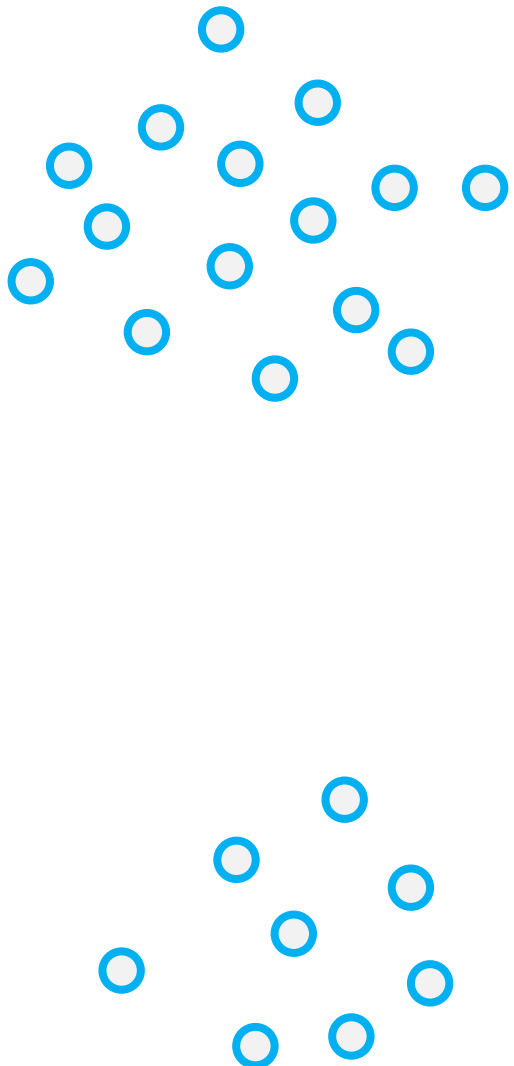
Search Distance = 5 meters
Minimum features per cluster = 5



DBSCAN

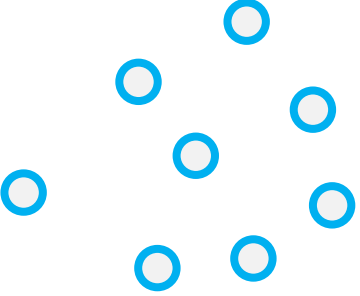
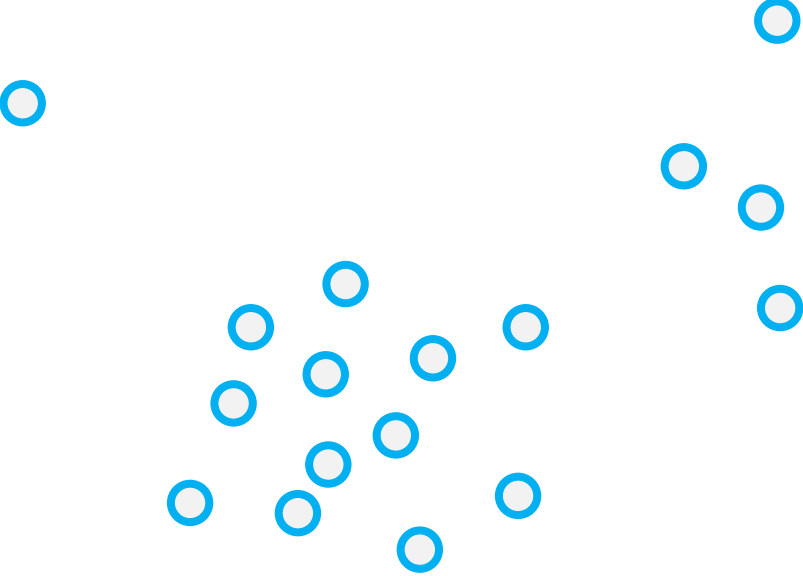
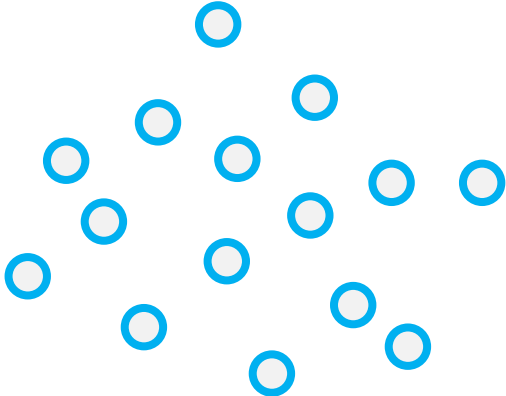
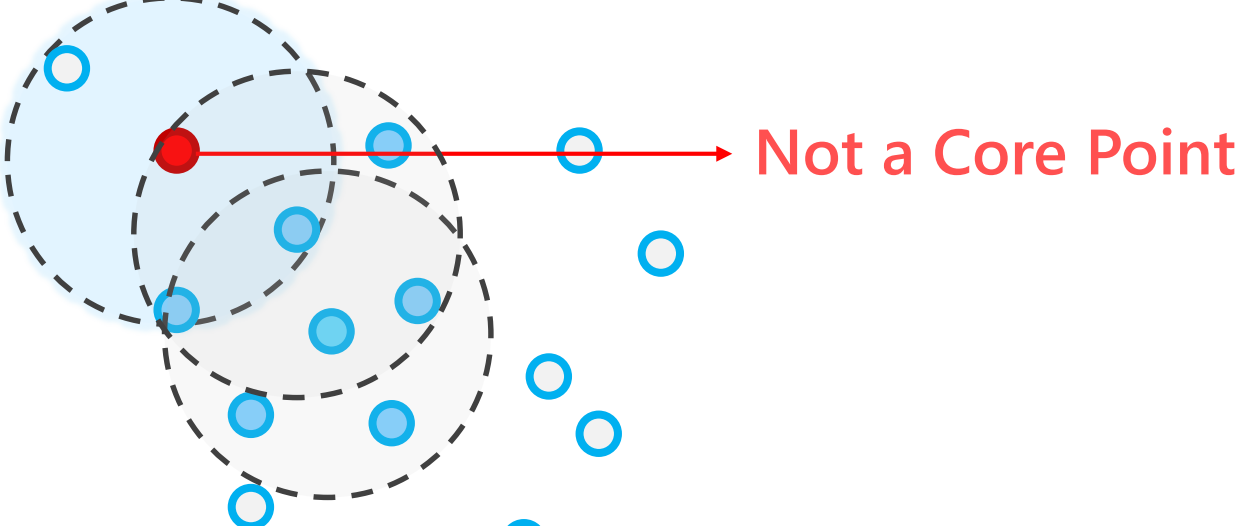


Search Distance = 5 meters
Minimum features per cluster = 5

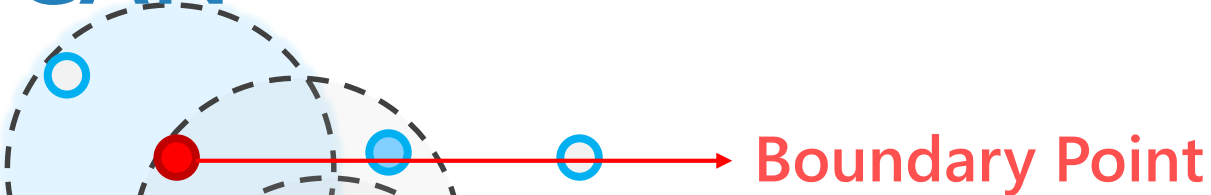


DBSCAN

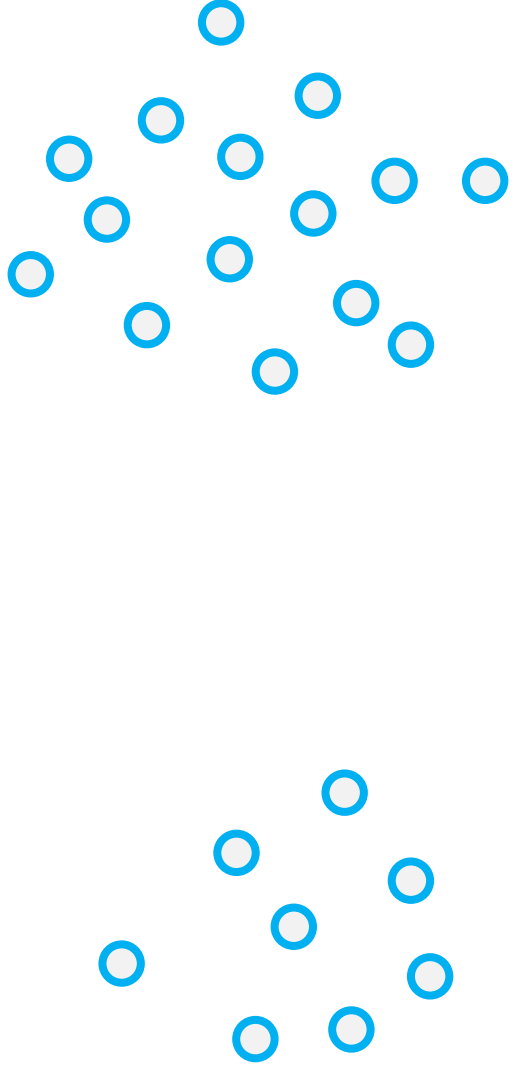
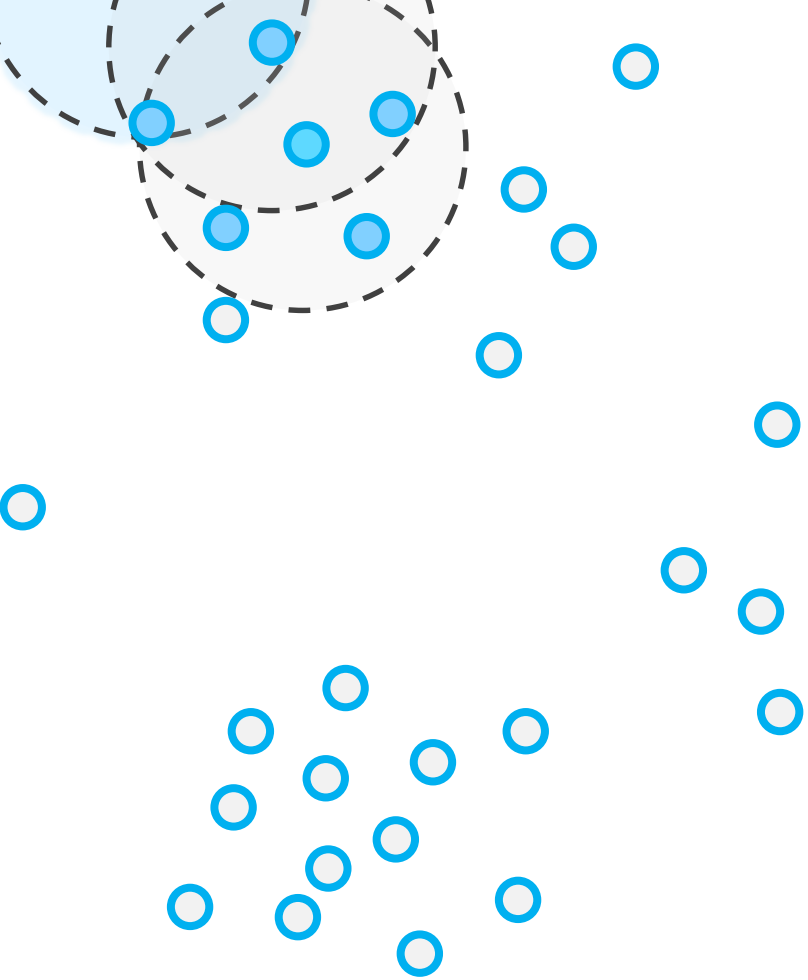
Search Distance = 5 meters
Minimum features per cluster = 5



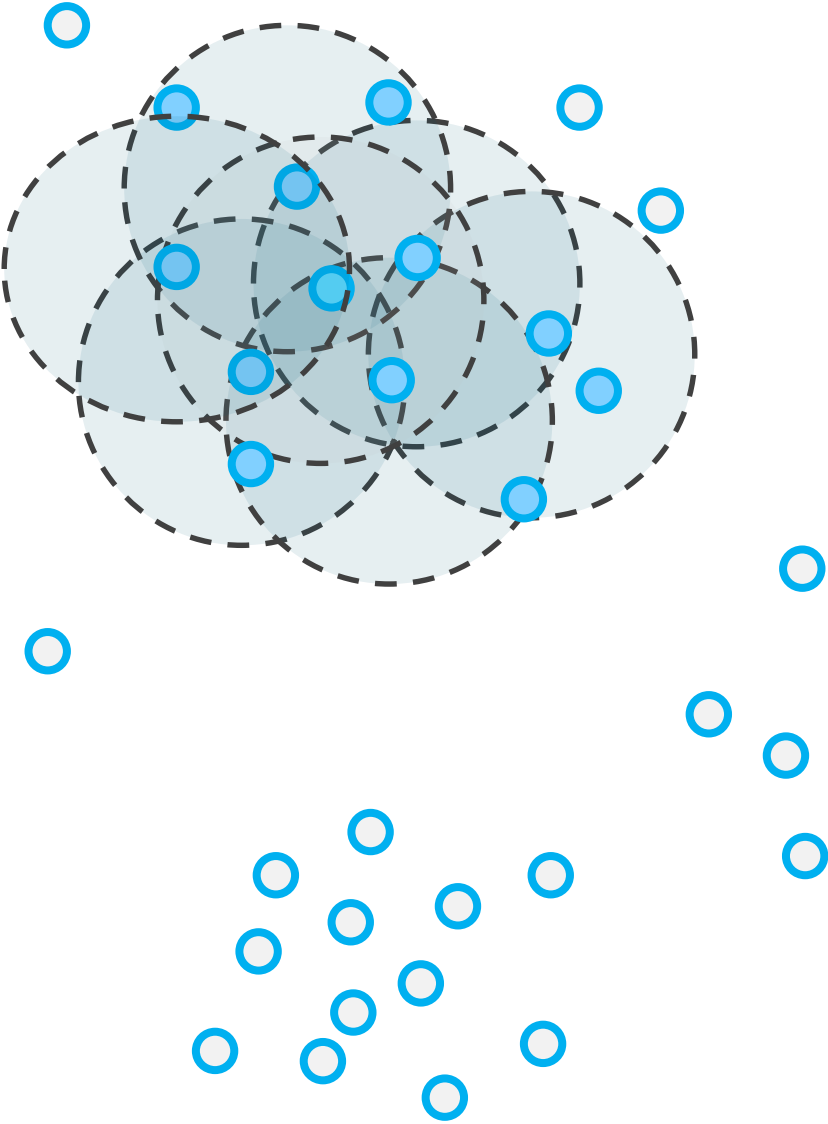
DBSCAN



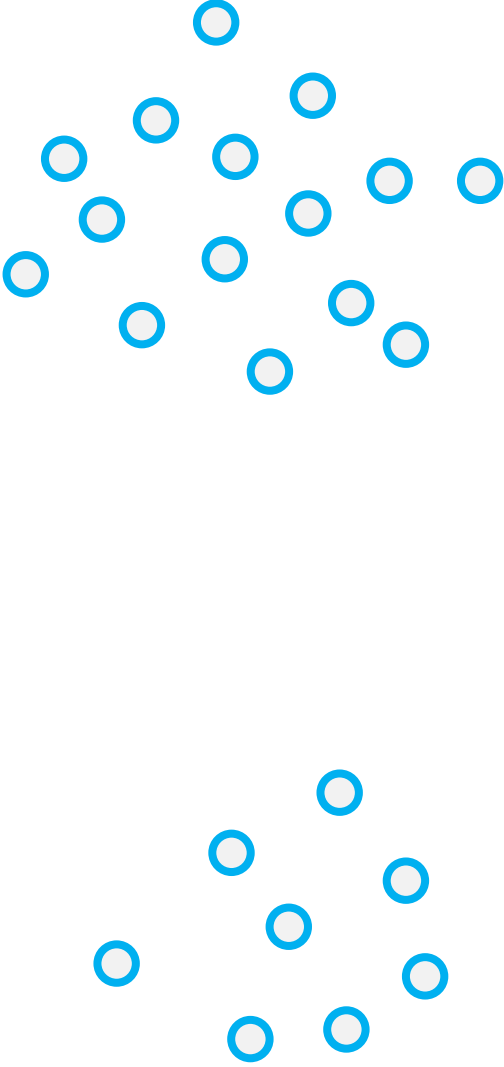
Search Distance = 5 meters
Minimum features per cluster = 5



DBSCAN

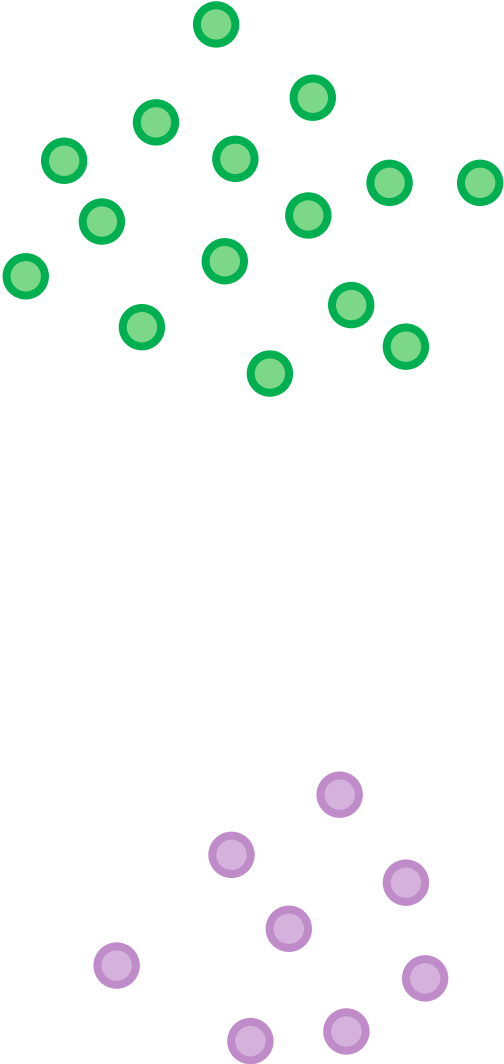
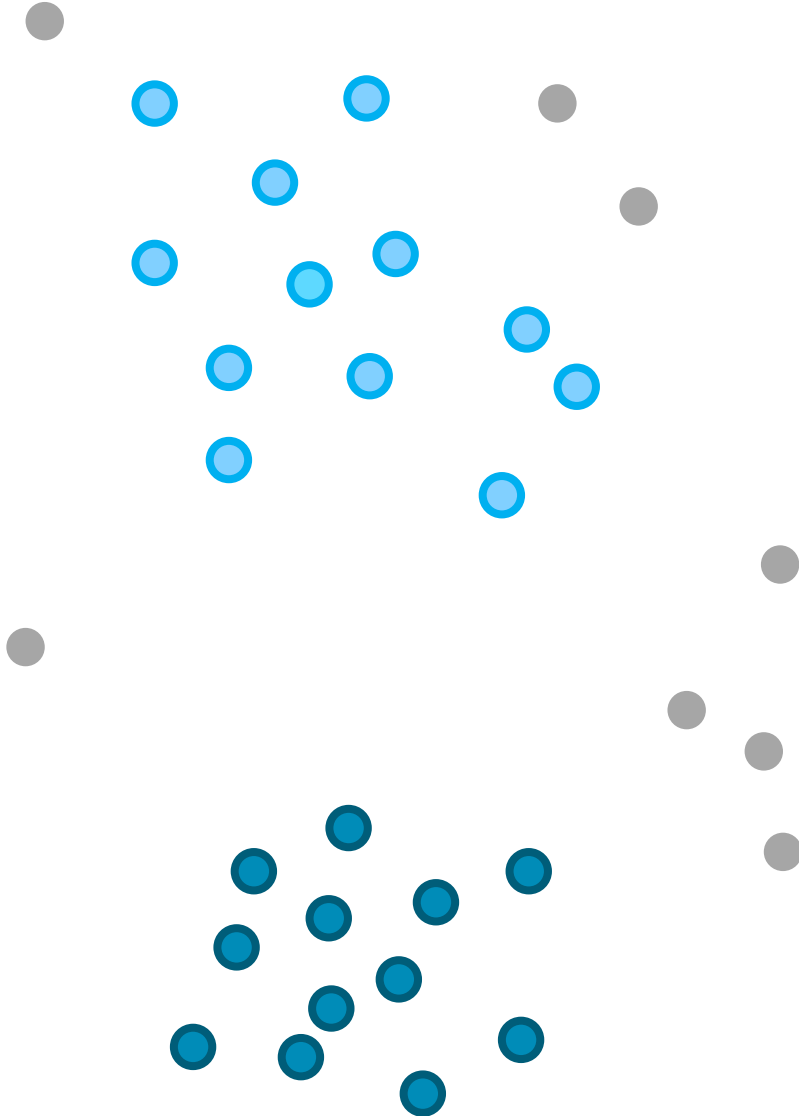


Search Distance = 5 meters
Minimum features per cluster = 5



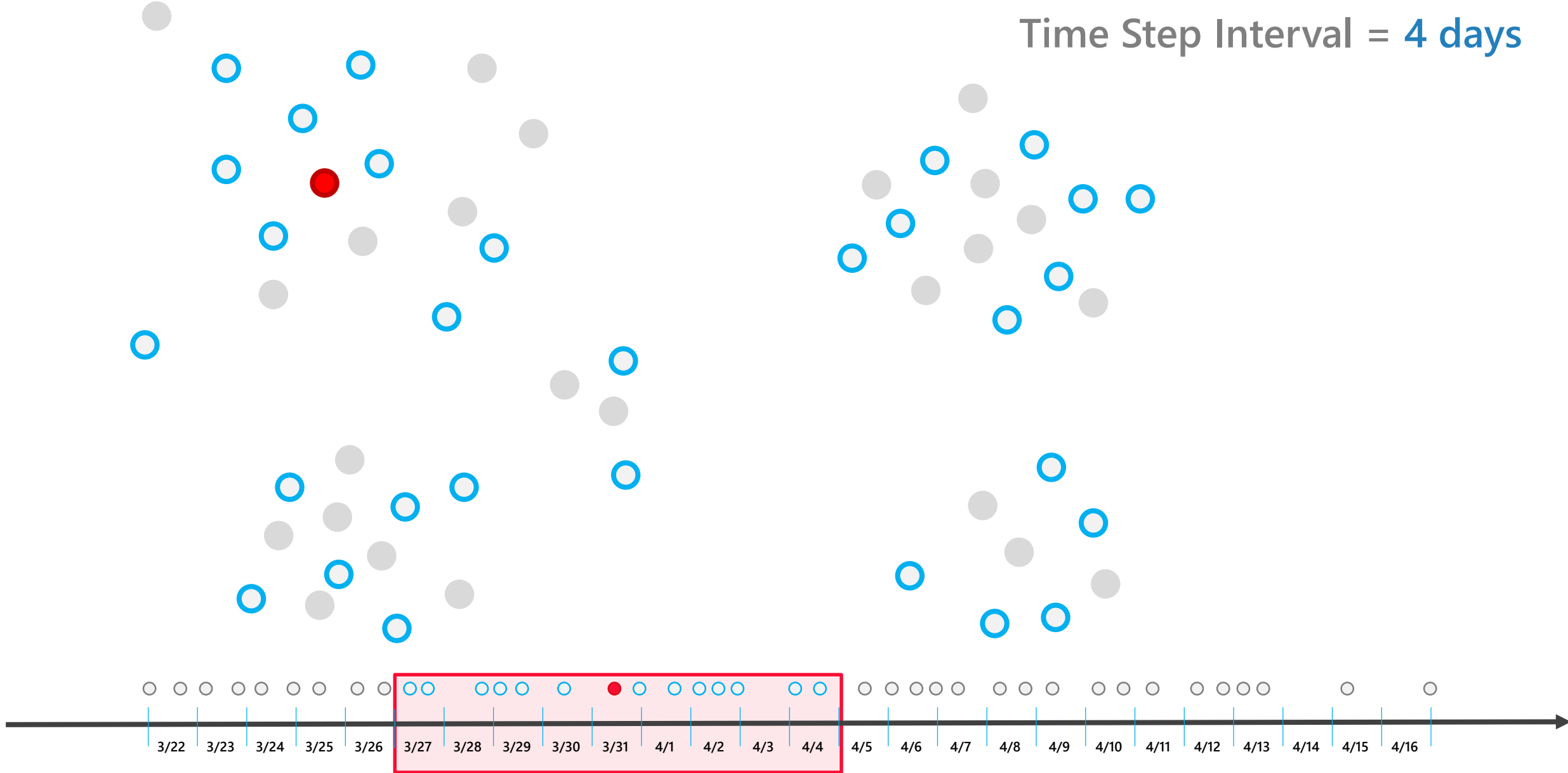
DBSCAN

Search Distance = 5 meters
Minimum features per cluster = 5

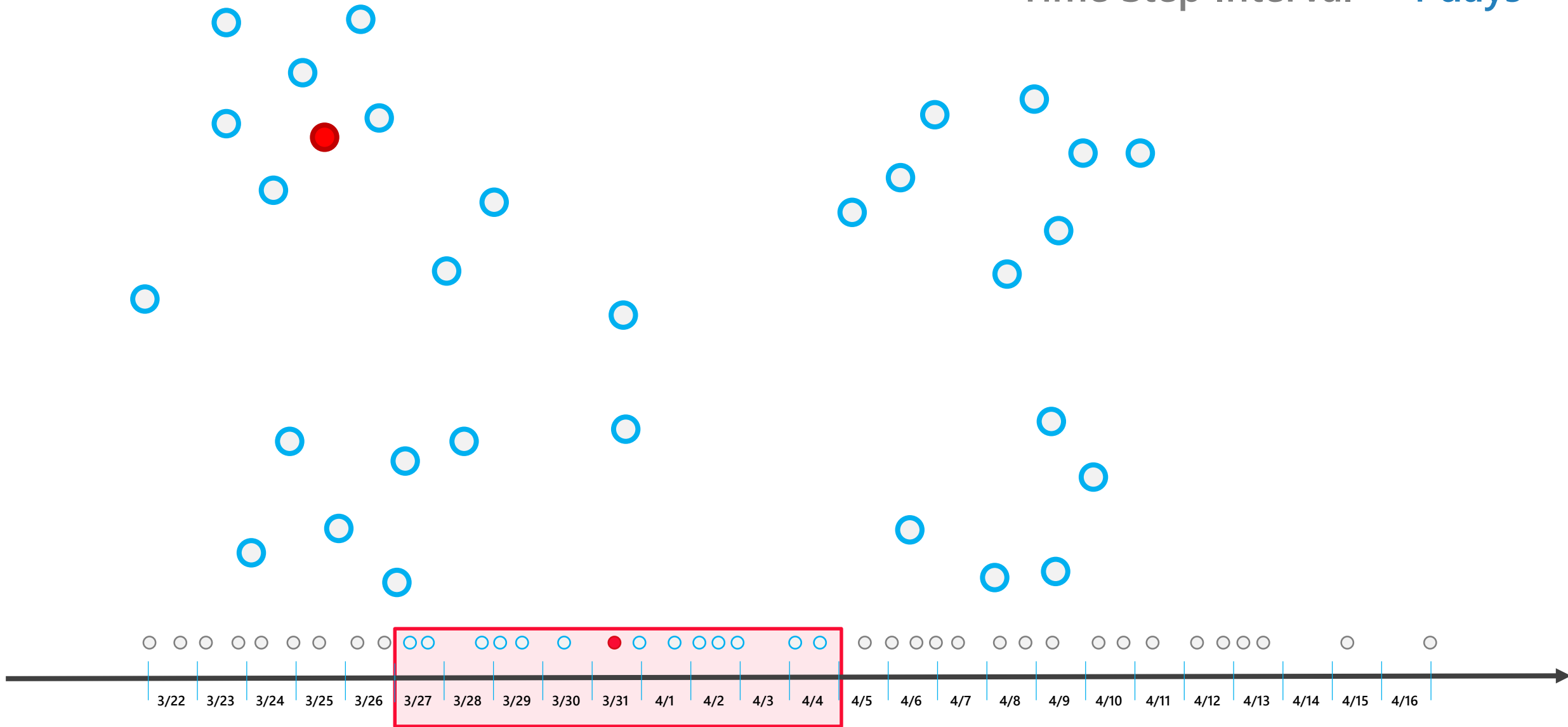


When **time** is added...

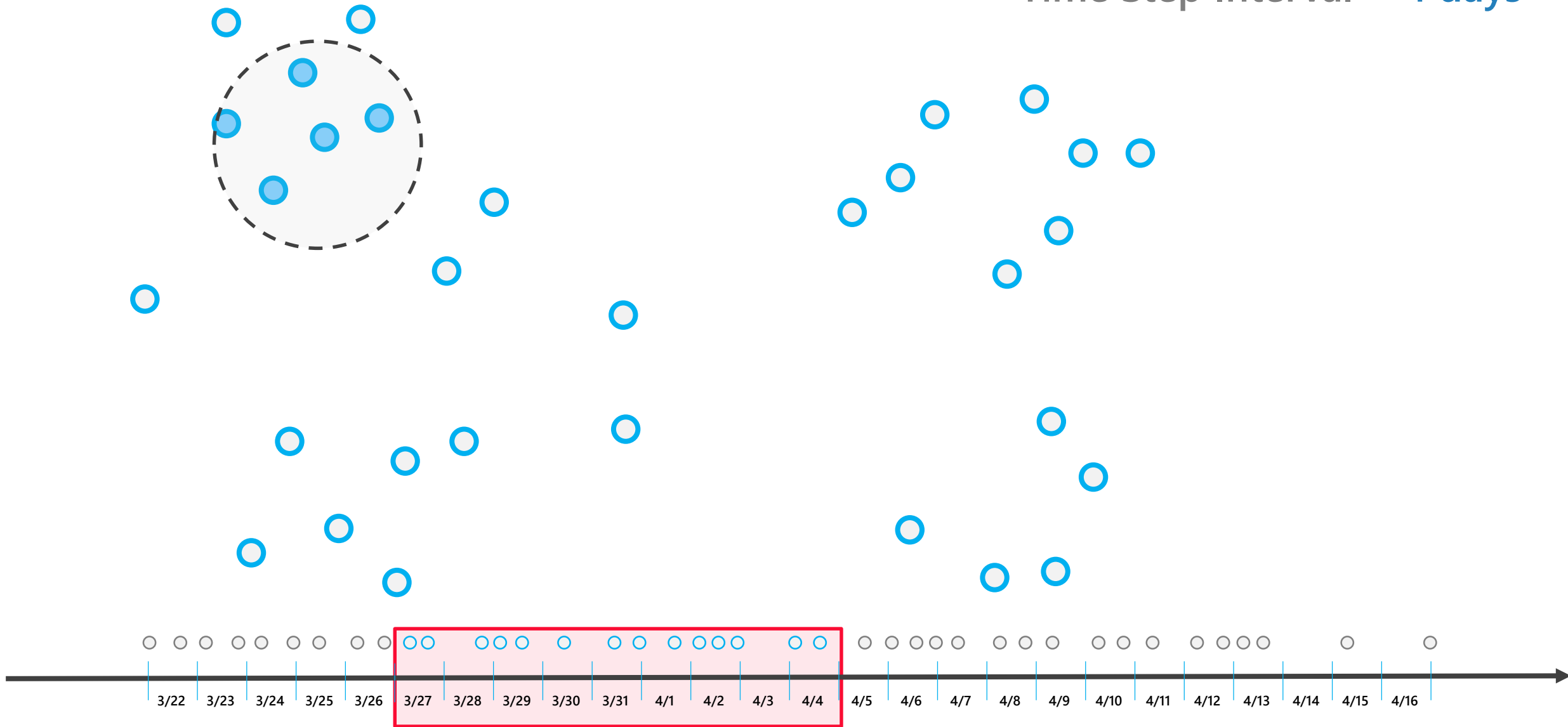
Search Distance = 5 m
Min. features = 5
Time Step Interval = 4 days



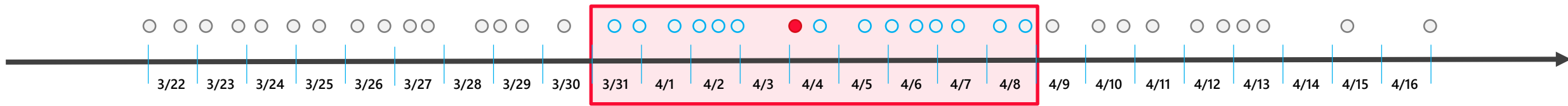
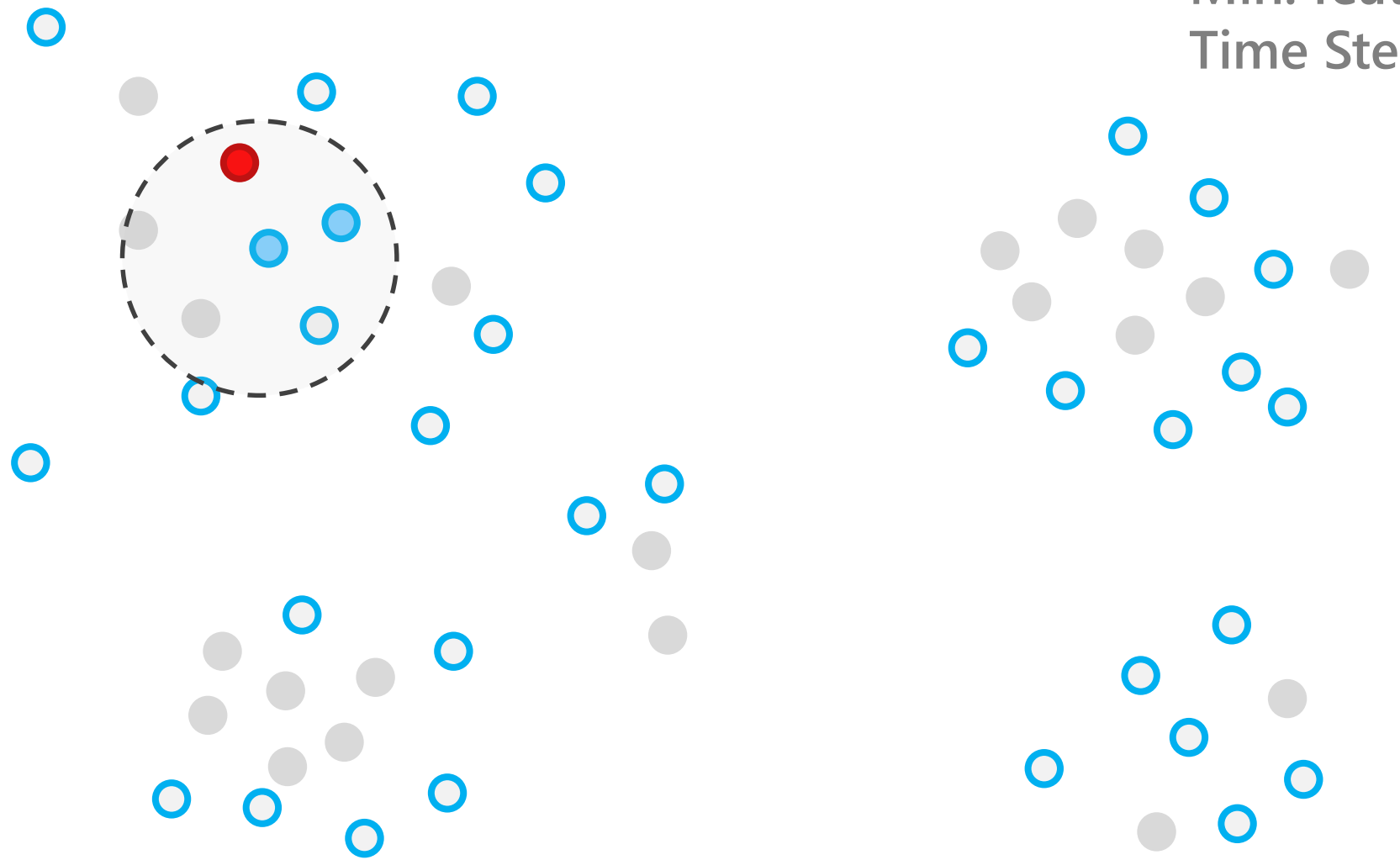
Search Distance = 5 m
Min. features = 5
Time Step Interval = 4 days



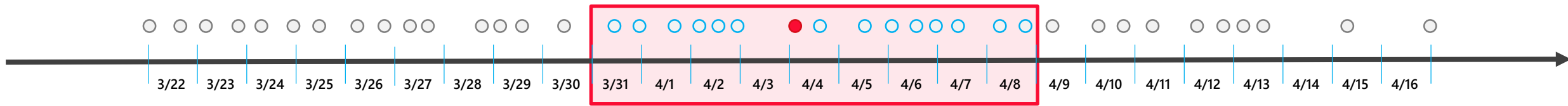
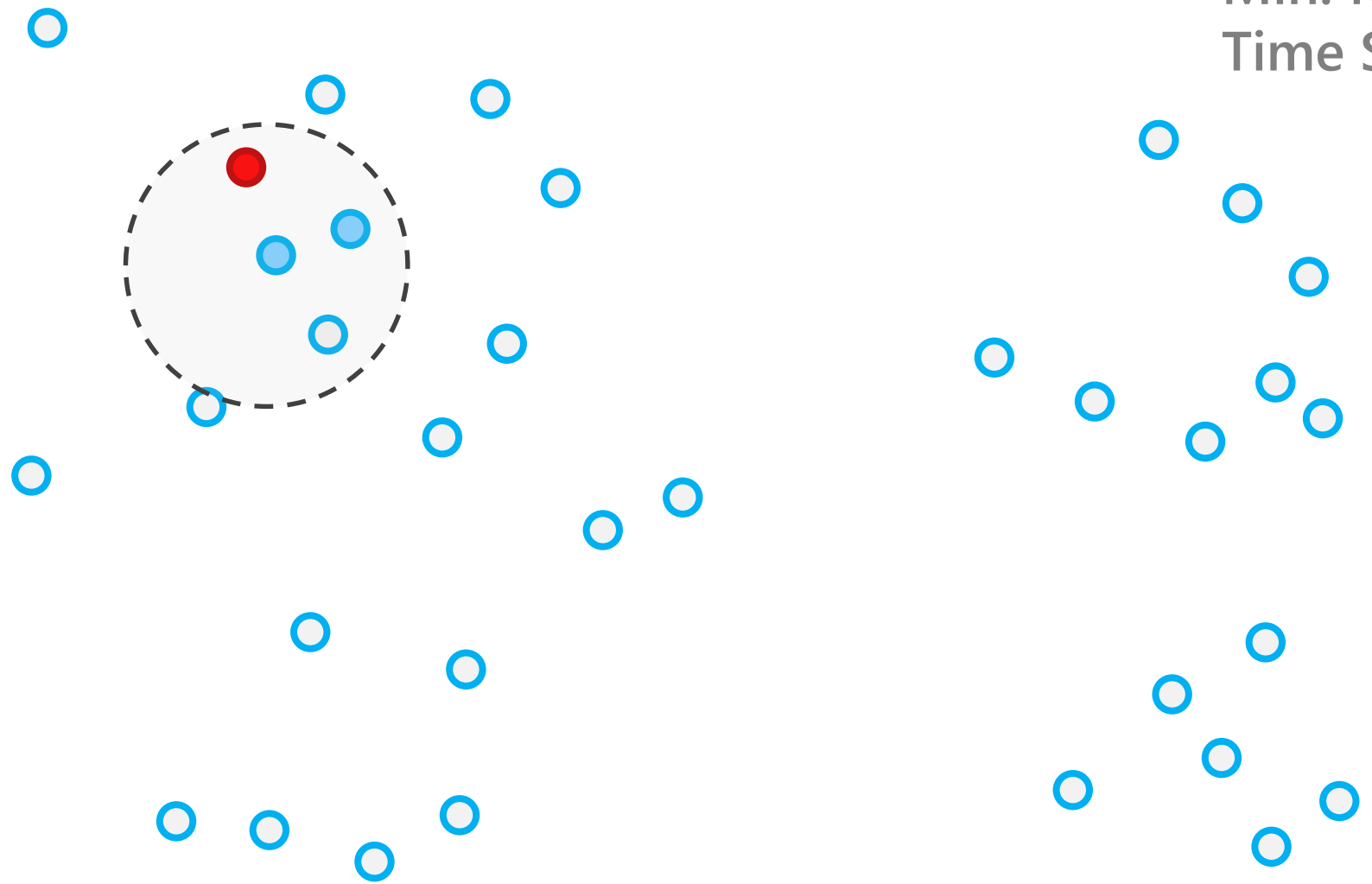
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Min. features = 5
Time Step Interval = 4 days



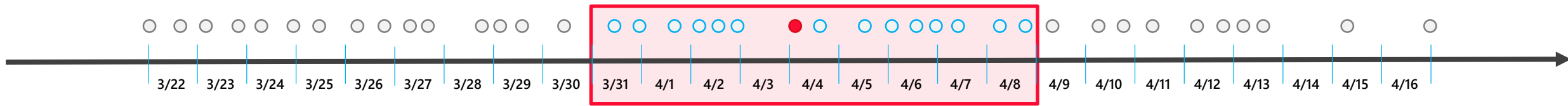
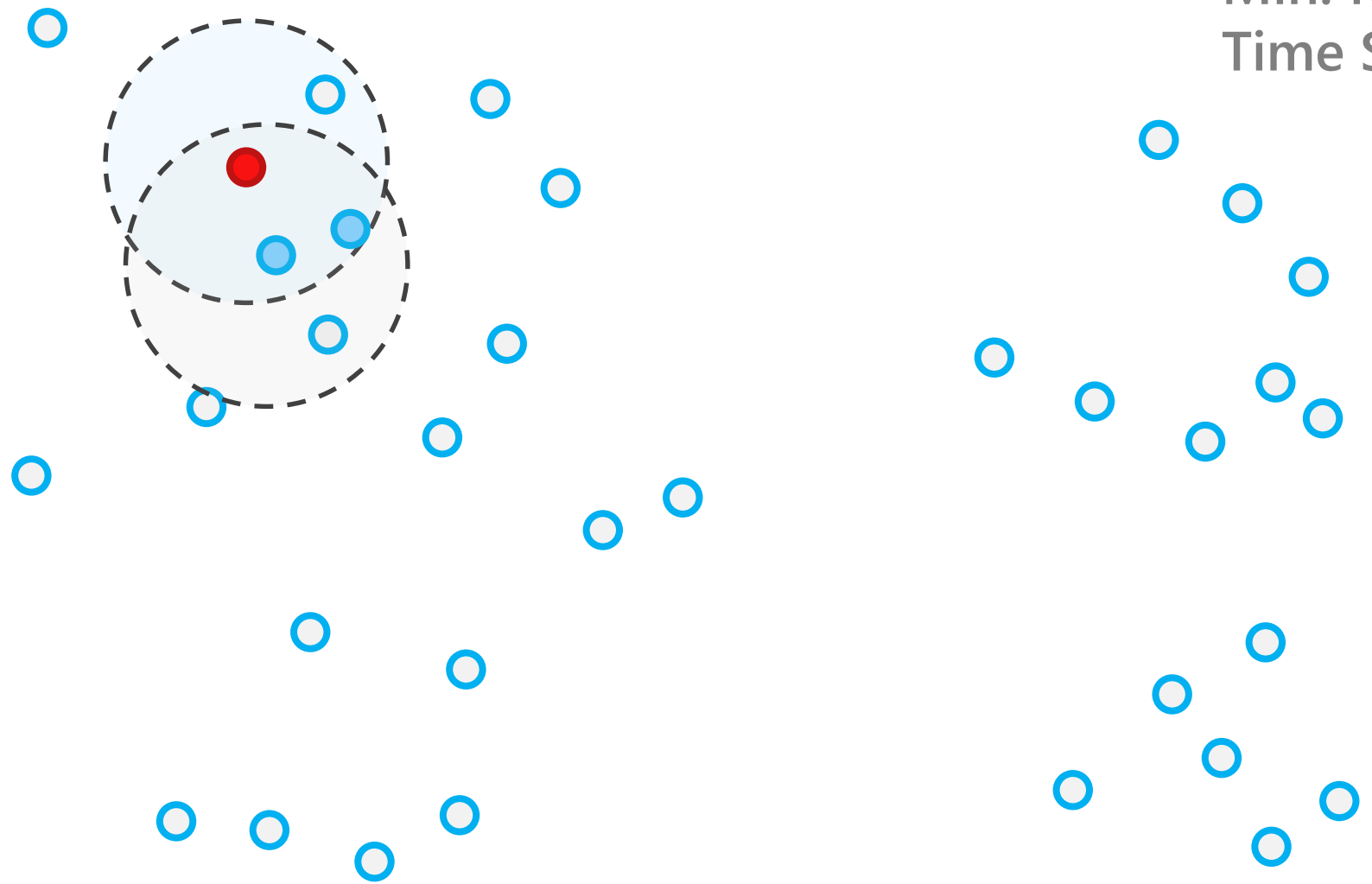
Search Distance = 5 m
Min. features = 5
Time Step Interval = 4 days



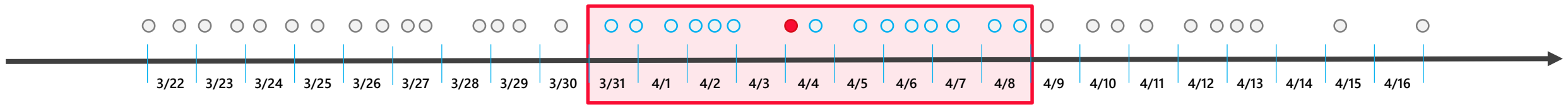
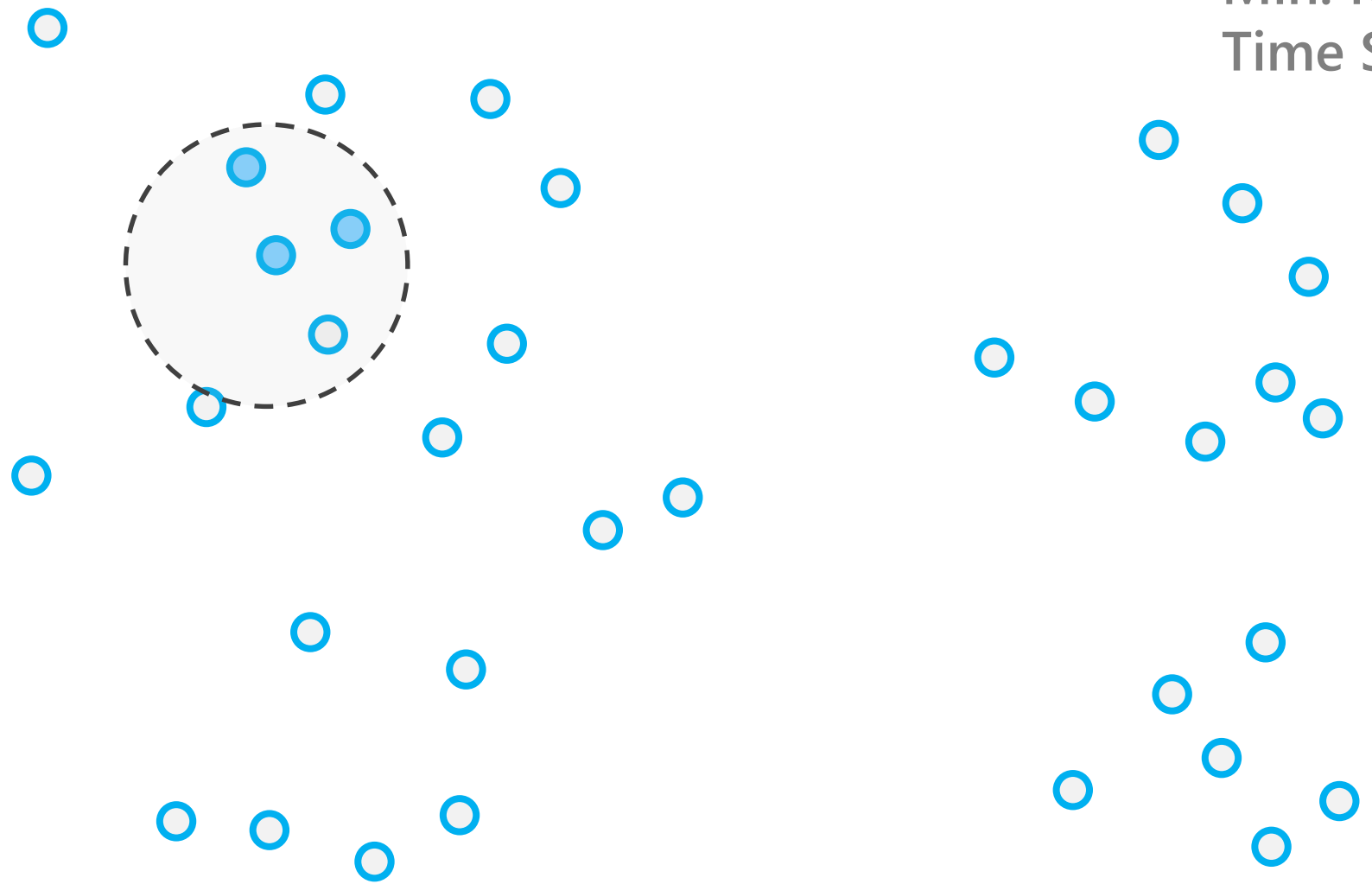
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Min. features = 5
Time Step Interval = 4 days



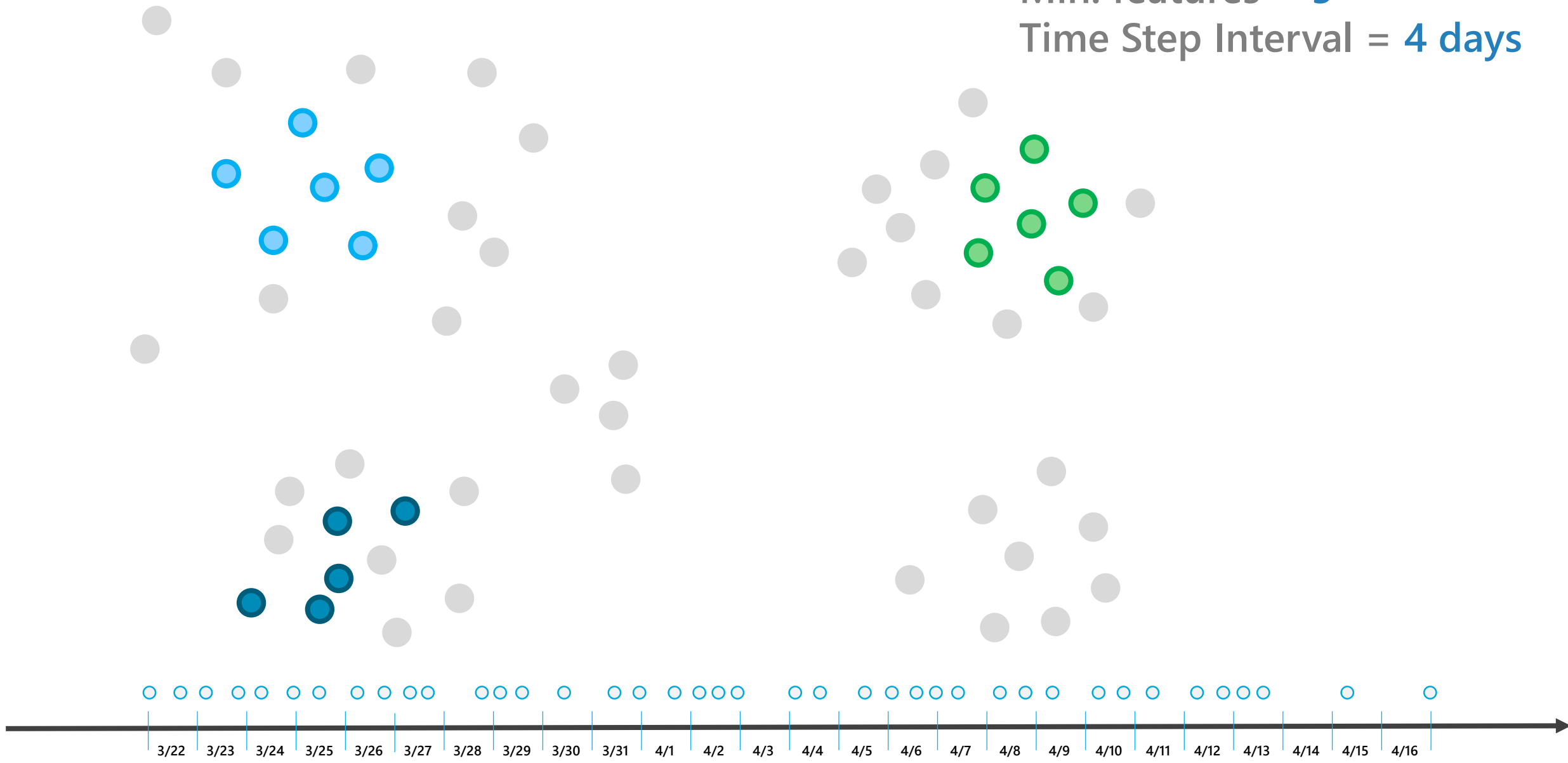
Search Distance = 5 m
Min. features = 5
Time Step Interval = 4 days



Search Distance = 5 m
Min. features = 5
Time Step Interval = 4 days



Search Distance = 5 m
Min. features = 5
Time Step Interval = 4 days



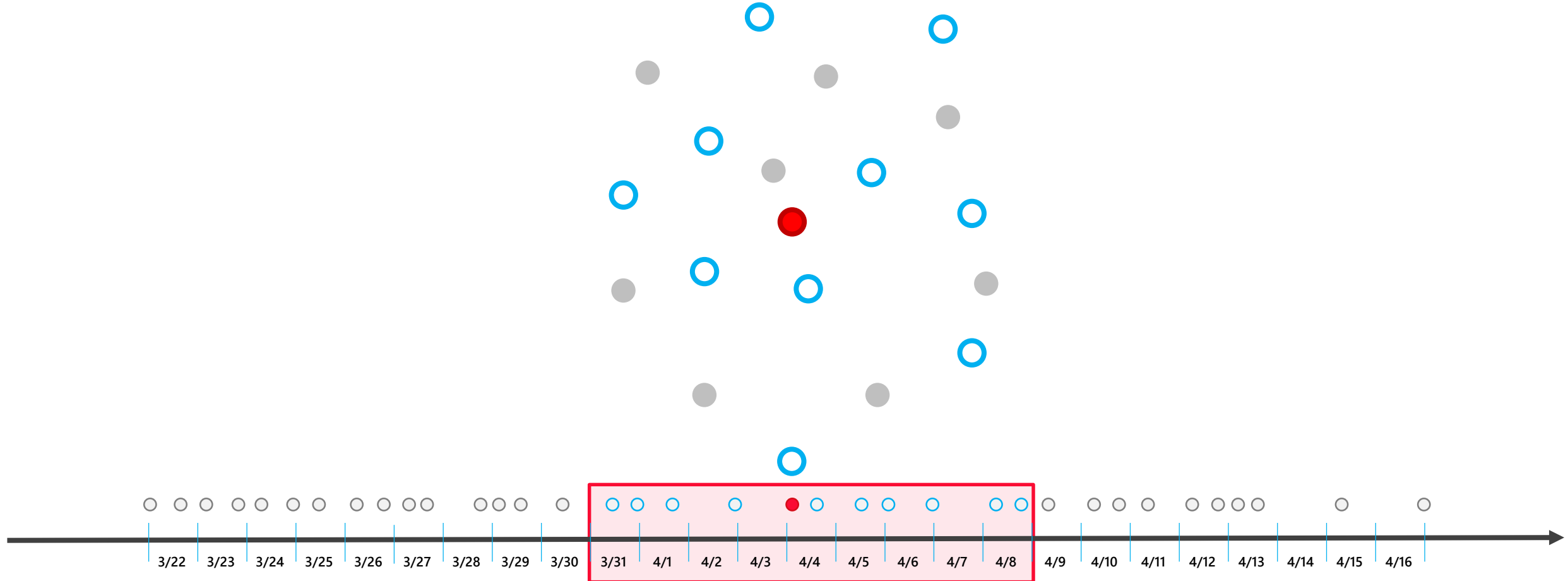
OPTICS

Ordering points to identify the clustering structure

→ Creates clusters based on reachability plot

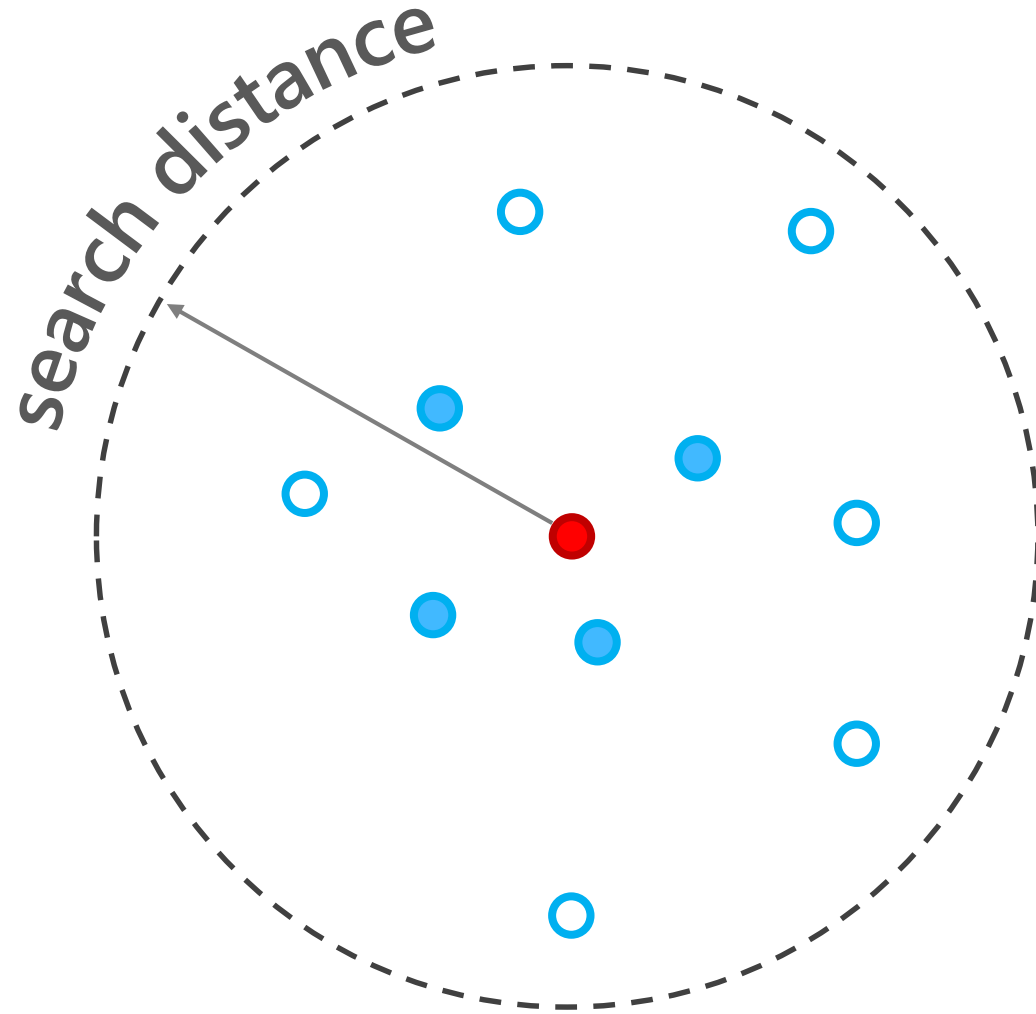
OPTICS

Search Distance = 10 m
Min. features = 5
Time Step Interval = 4 days



OPTICS

Search Distance = 10 m
Min. features = 5
Time Step Interval = 4 days

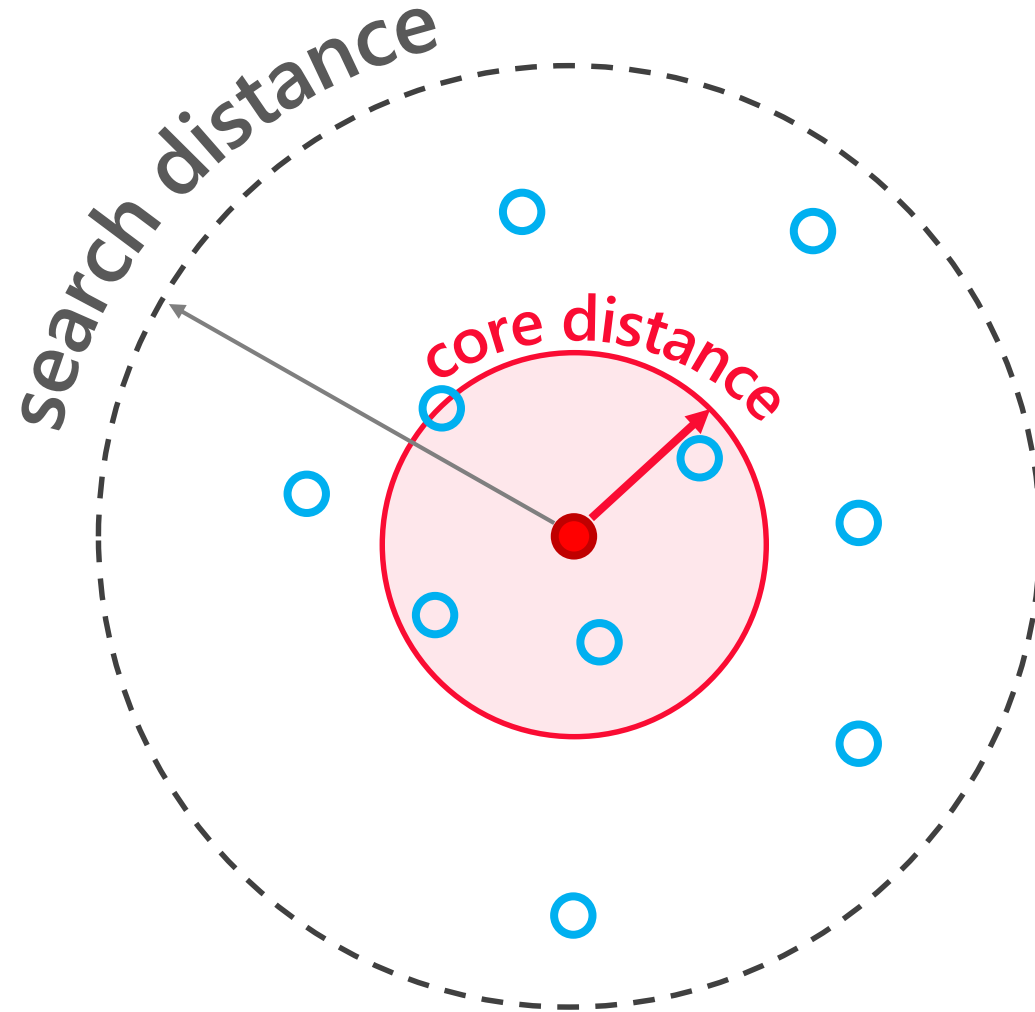


OPTICS

Search Distance = 10 m

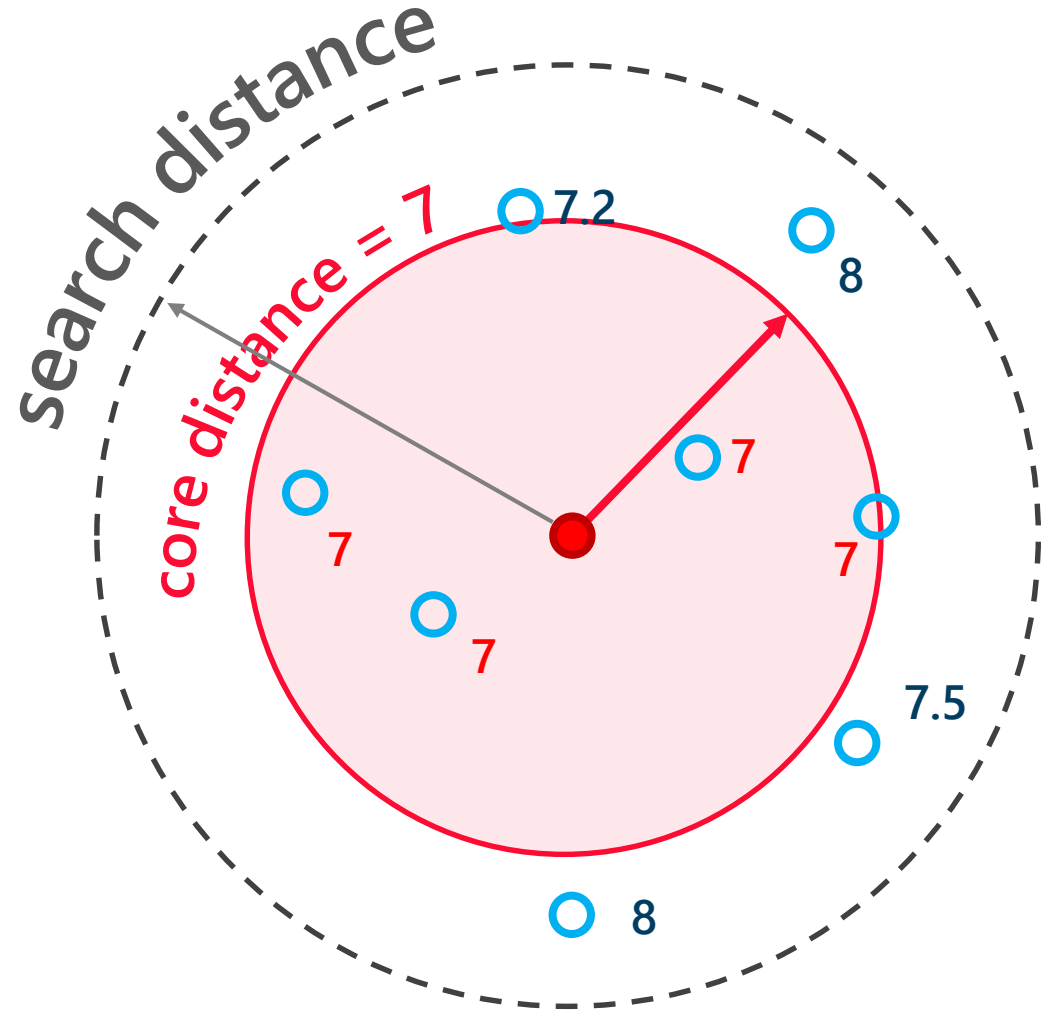
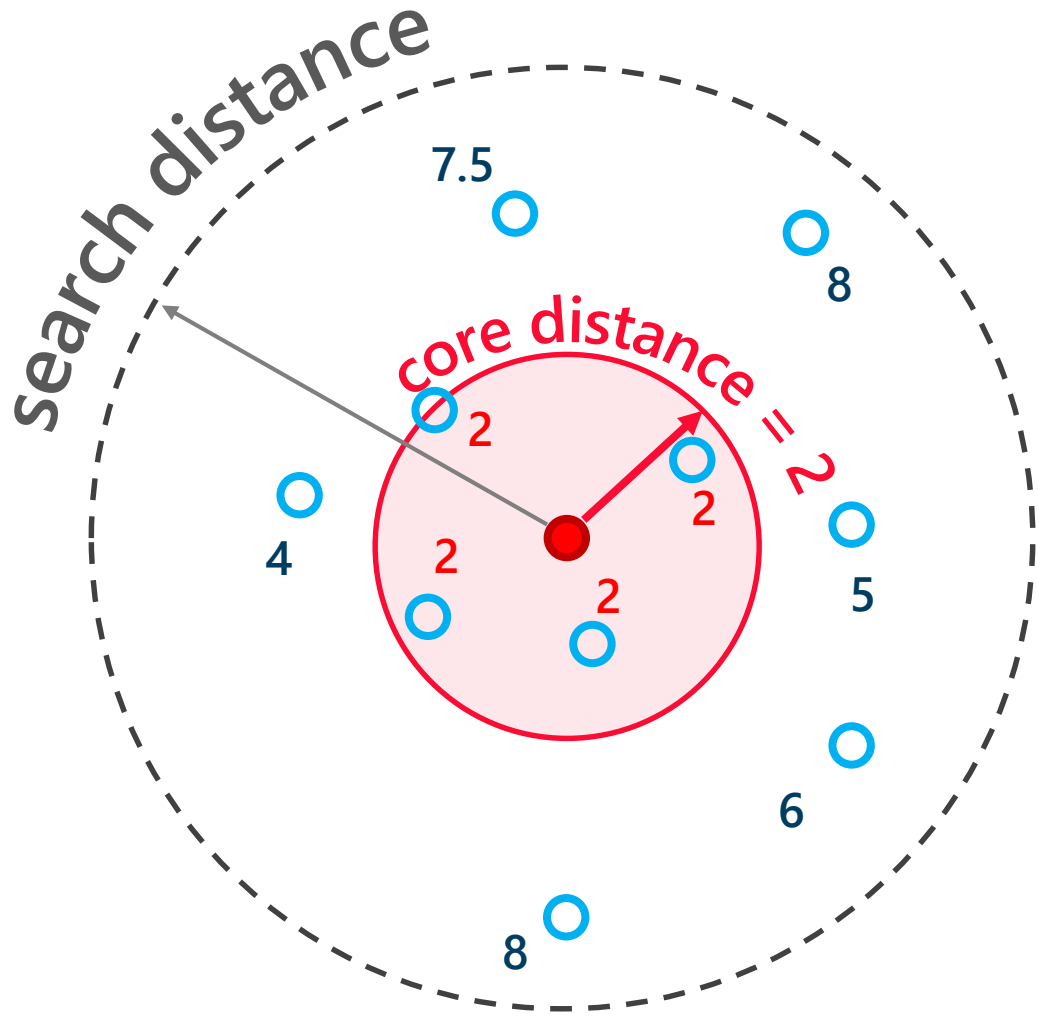
Min. features = 5

Time Step Interval = 4 days

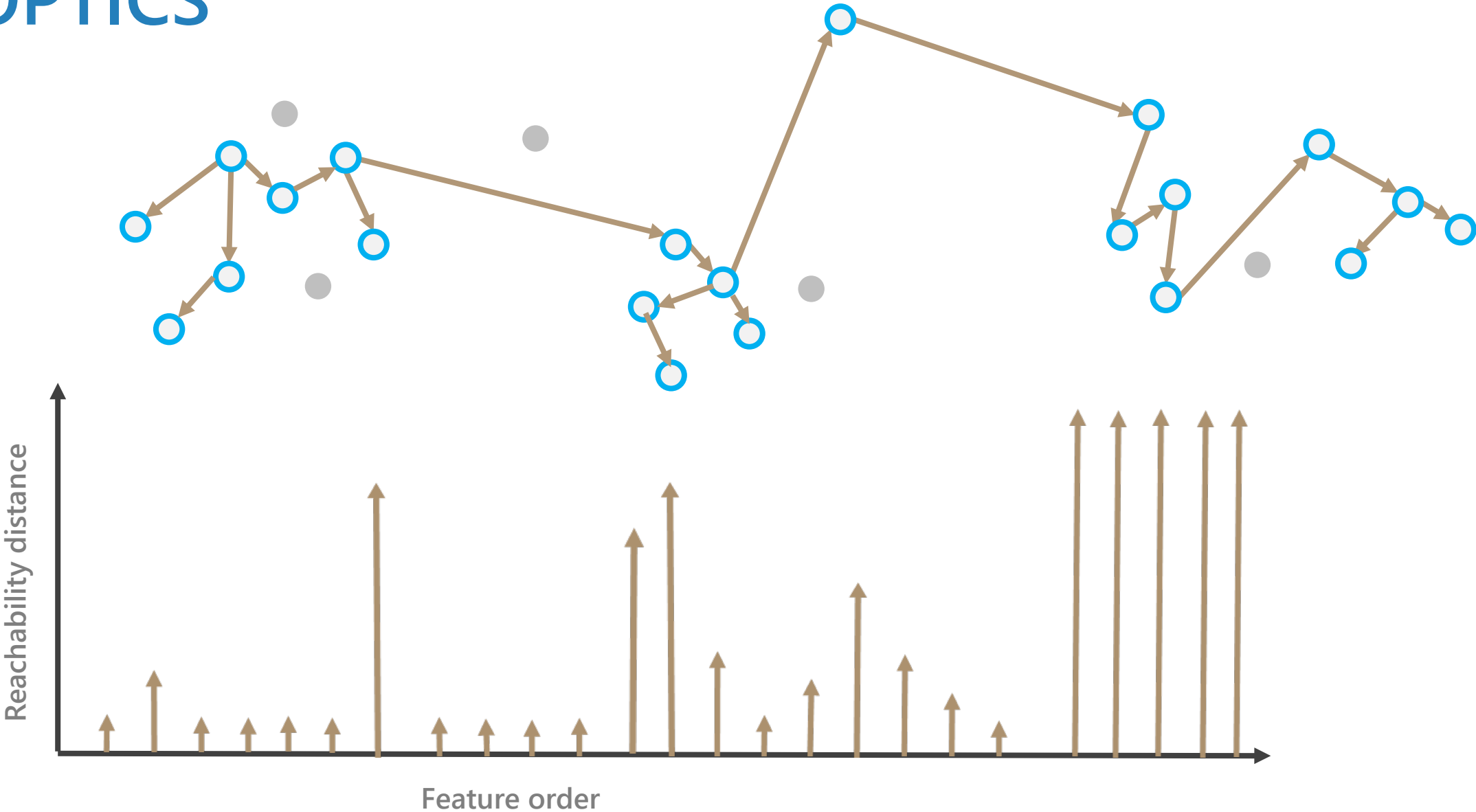


OPTICS

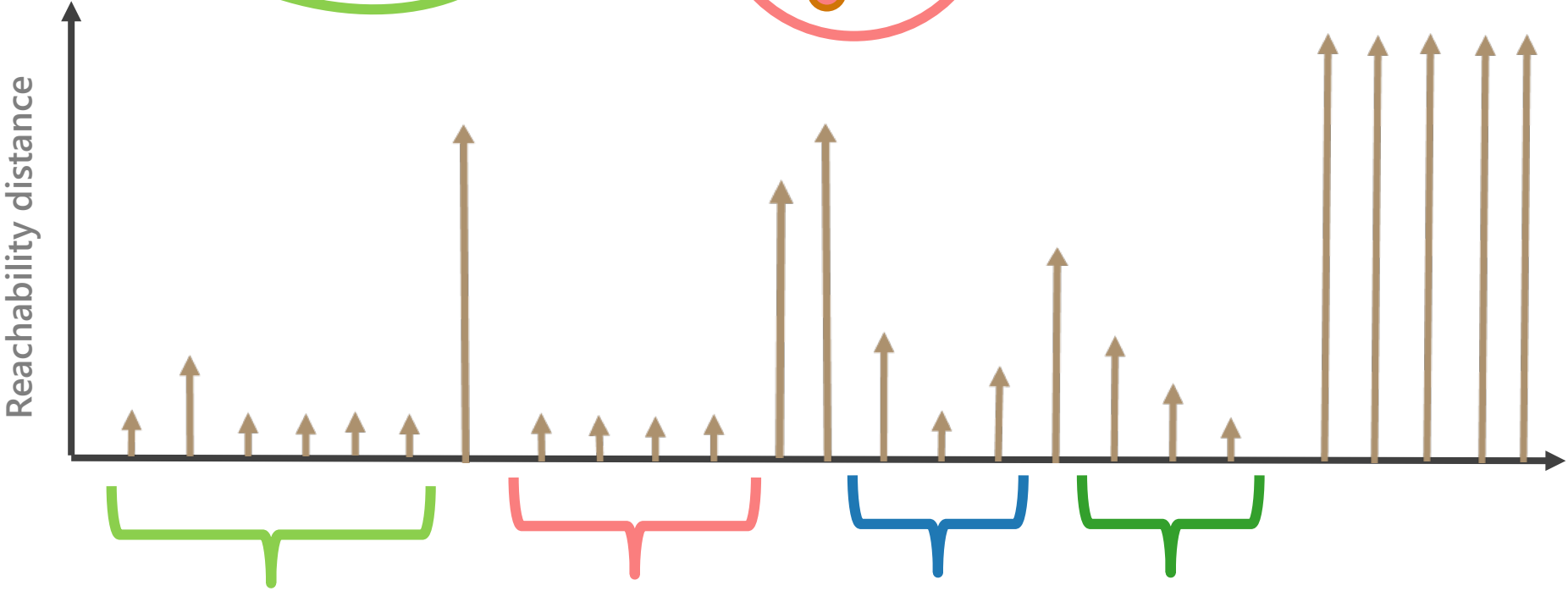
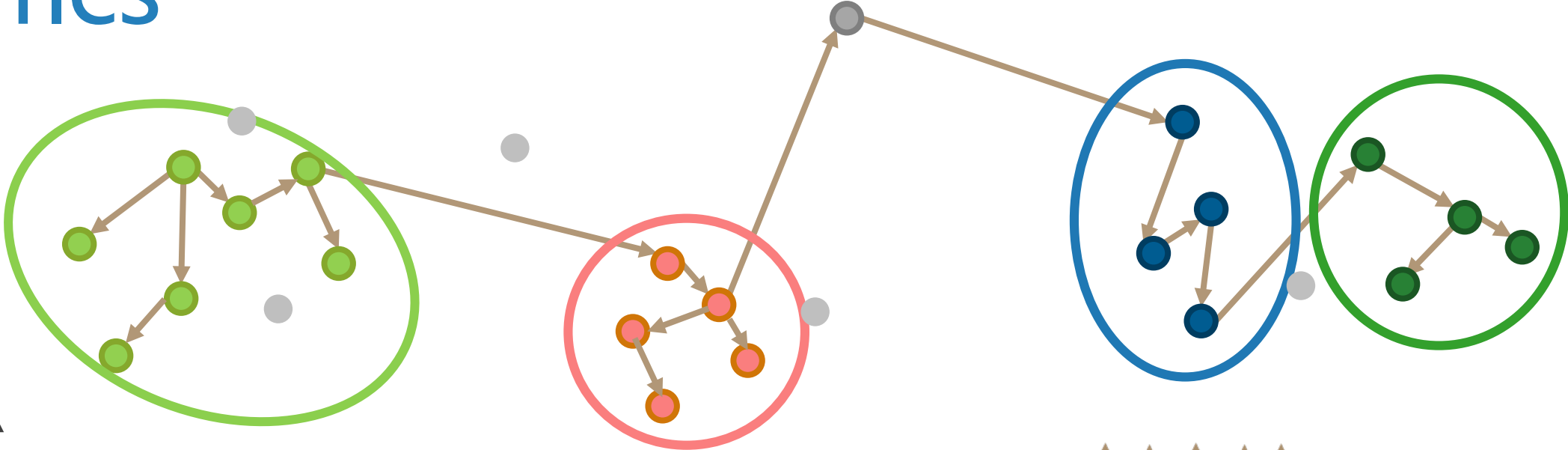
Search Distance = 10 m
Min. features = 5
Time Step Interval = 4 days



OPTICS



OPTICS



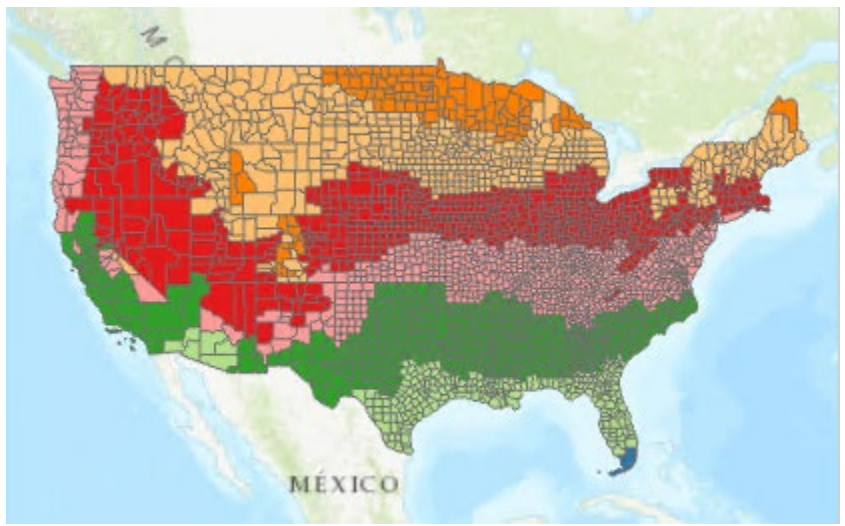
Demo



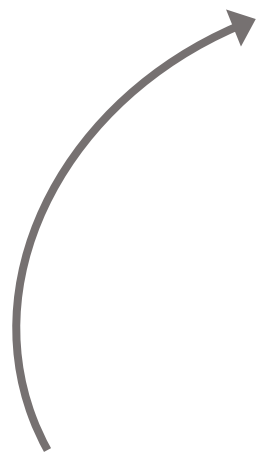
Spatial Association

Between Zones

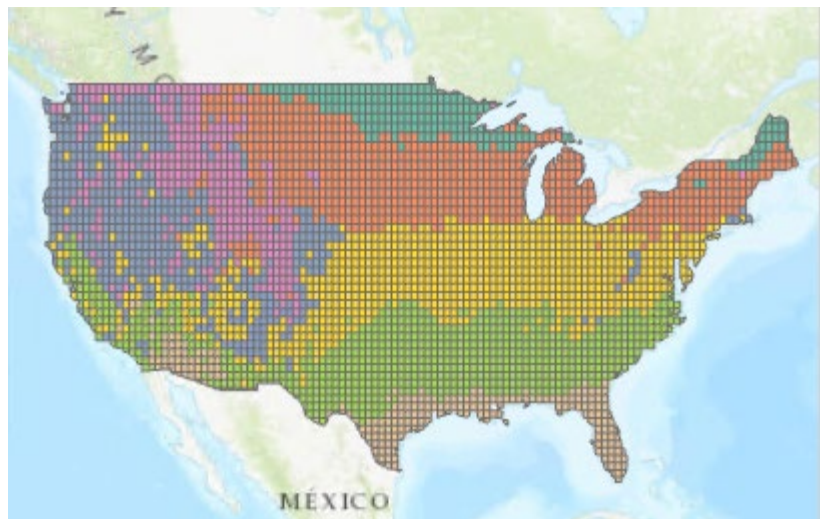
Map A



?



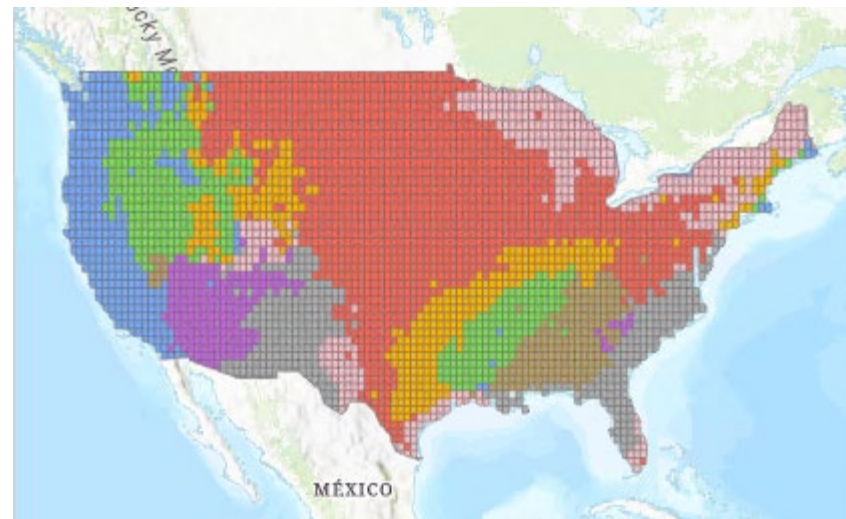
Map B



?

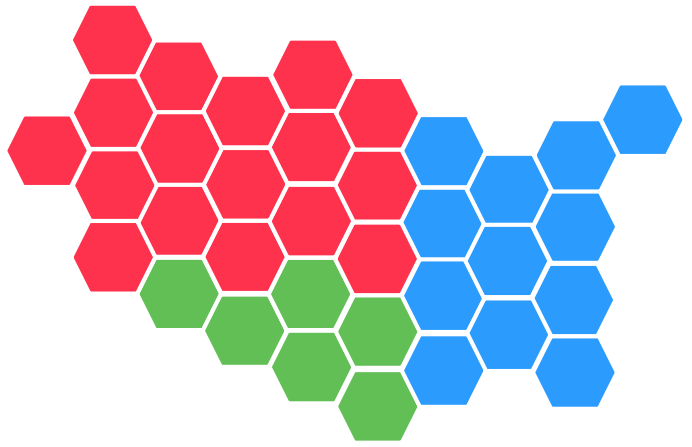


Map C

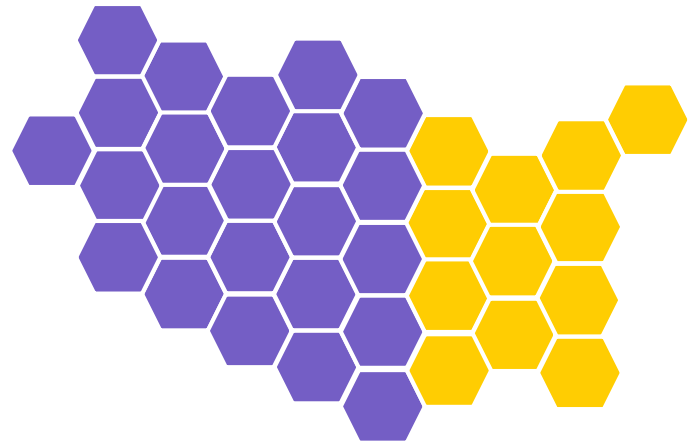


Local Correspondence

Map A

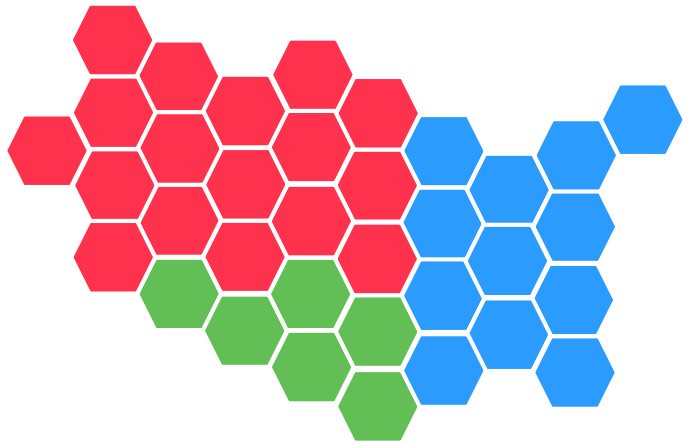


Map B

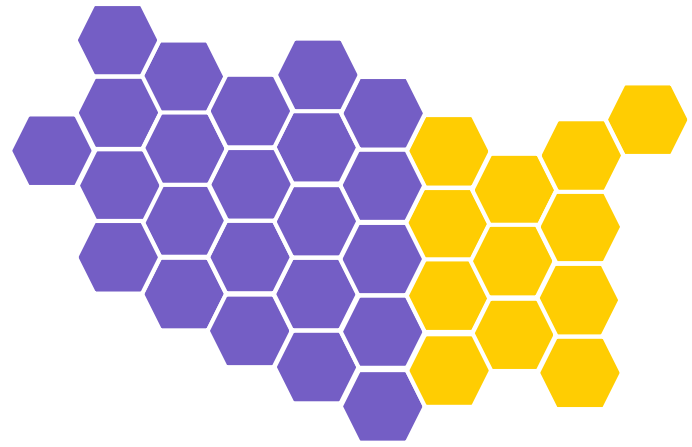


Local Correspondence

Map A

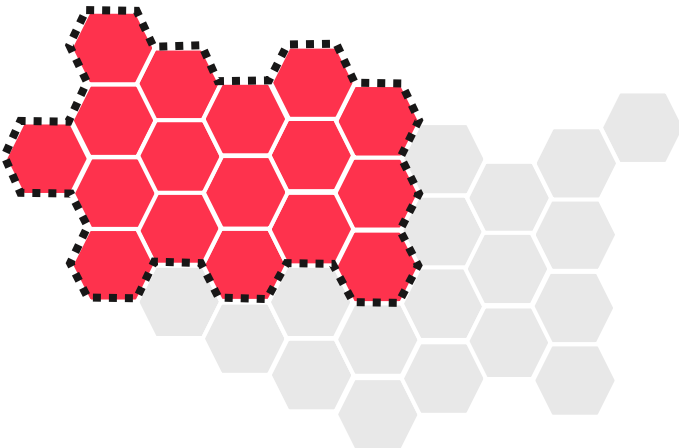


Map B

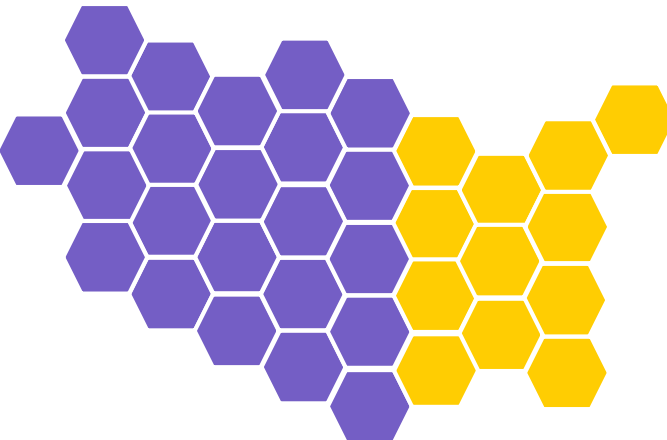


Local Correspondence

Map A

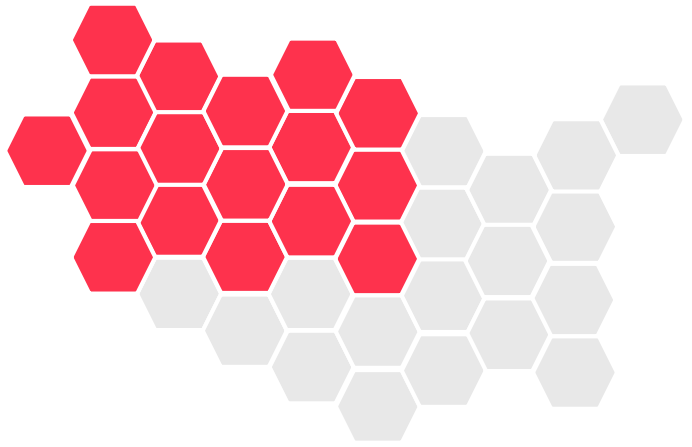


Map B

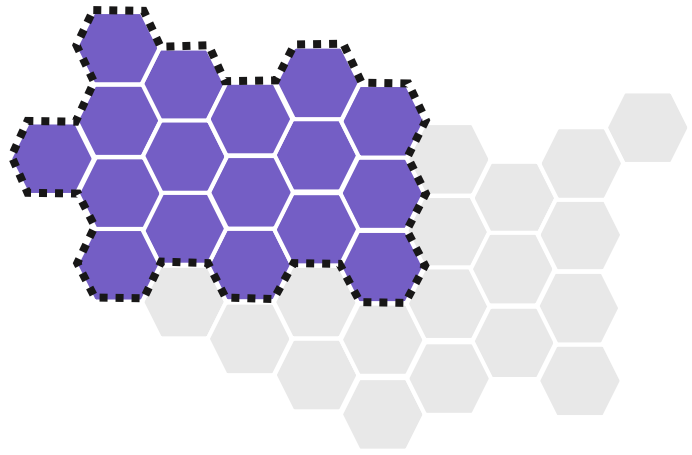


Local Correspondence

Map A

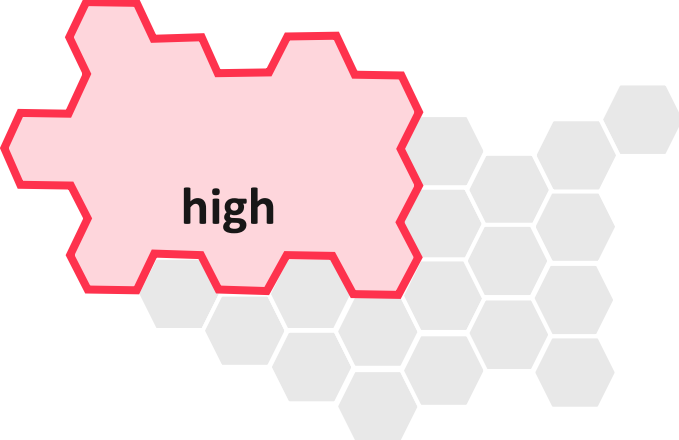


Map B

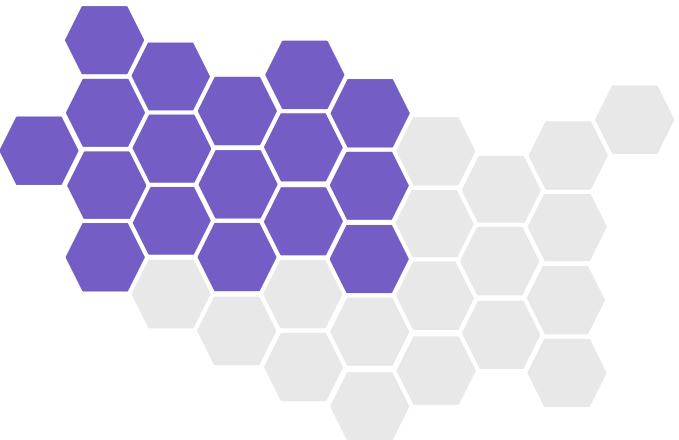


Local Correspondence

Map A

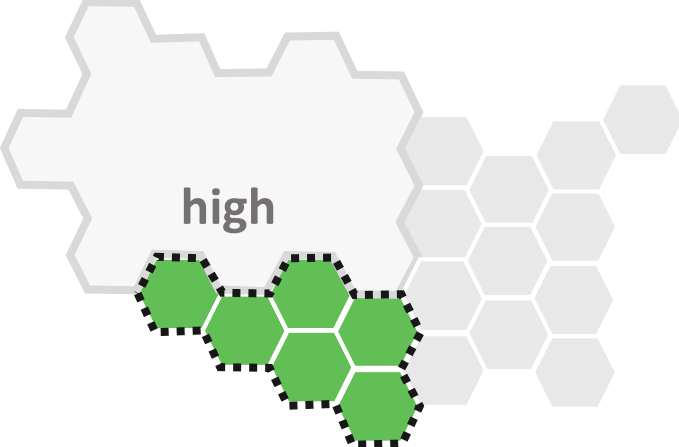


Map B

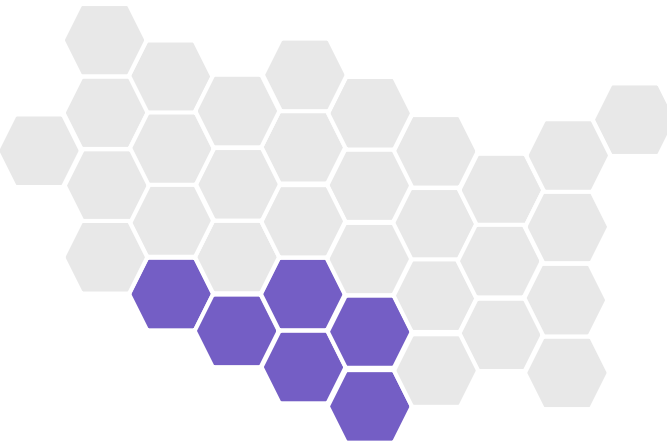


Local Correspondence

Map A

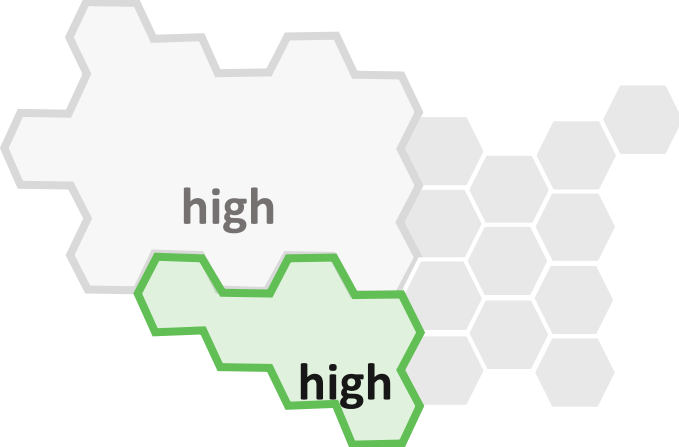


Map B

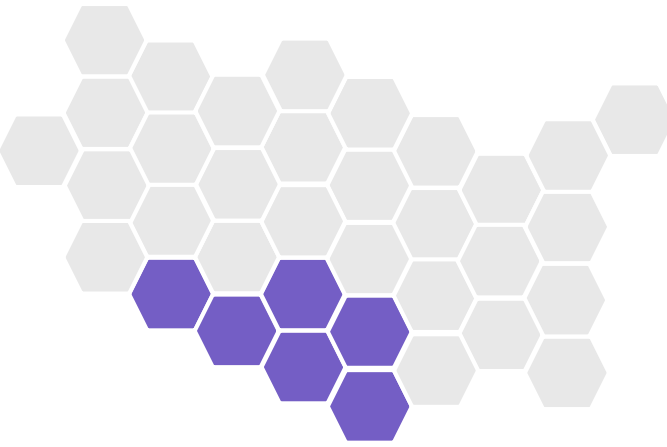


Local Correspondence

Map A

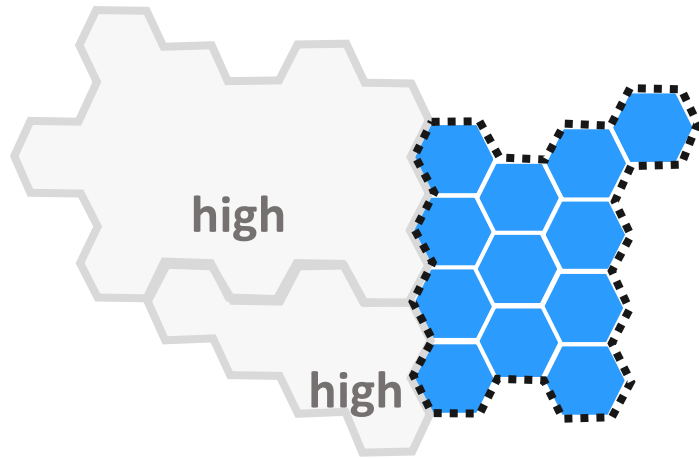


Map B

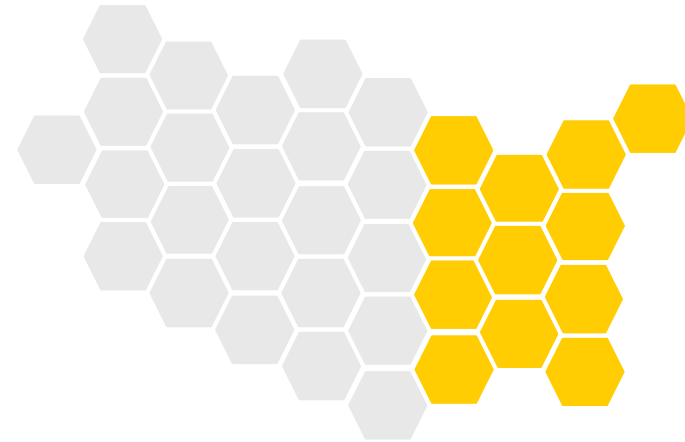


Local Correspondence

Map A

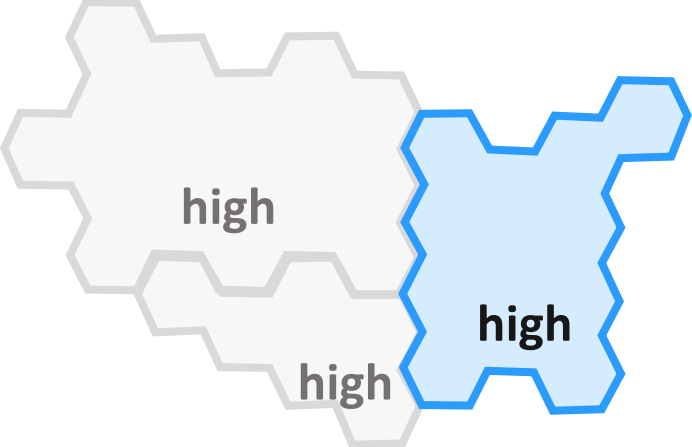


Map B

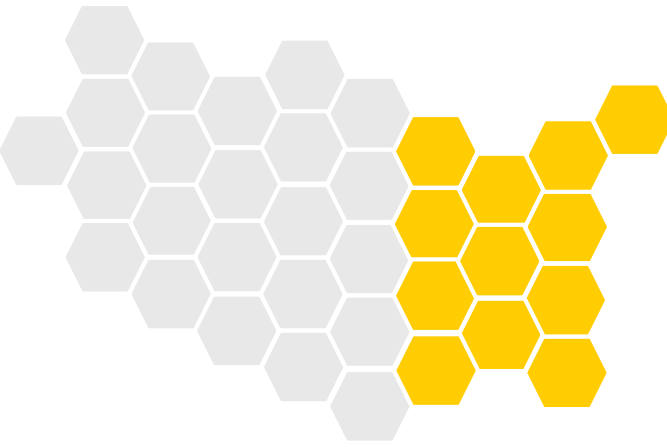


Local Correspondence

Map A

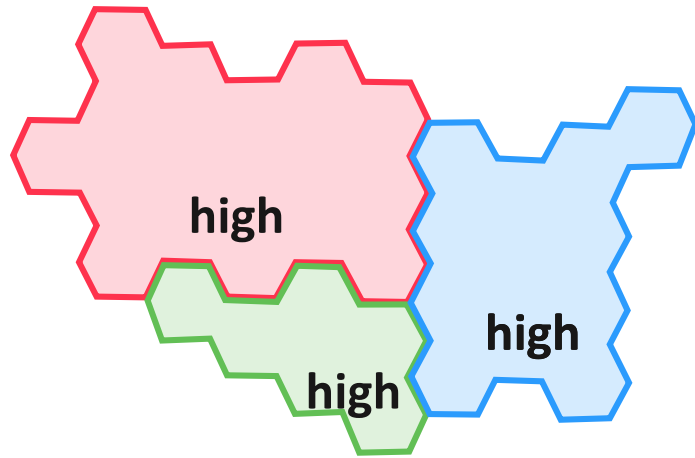


Map B

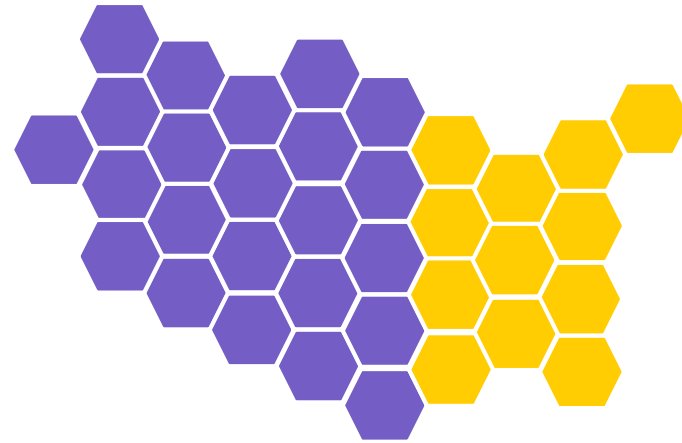


Local Correspondence

Map A

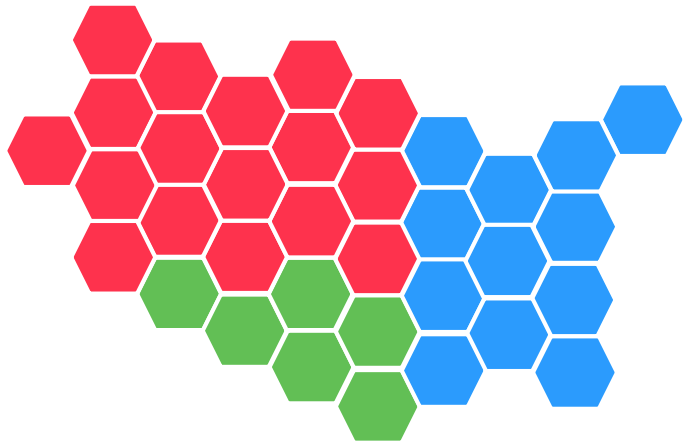


Map B

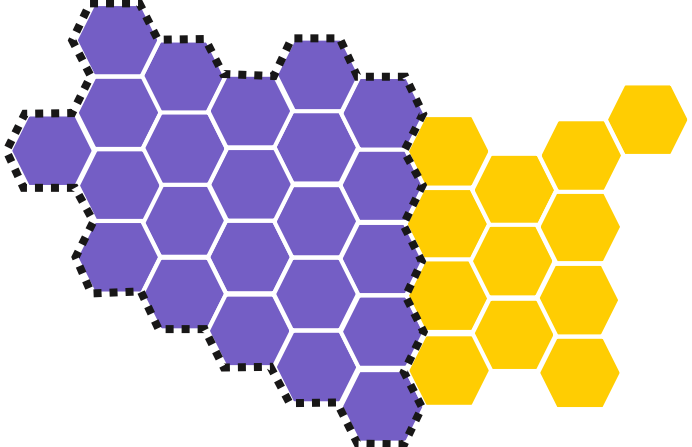


Local Correspondence

Map A

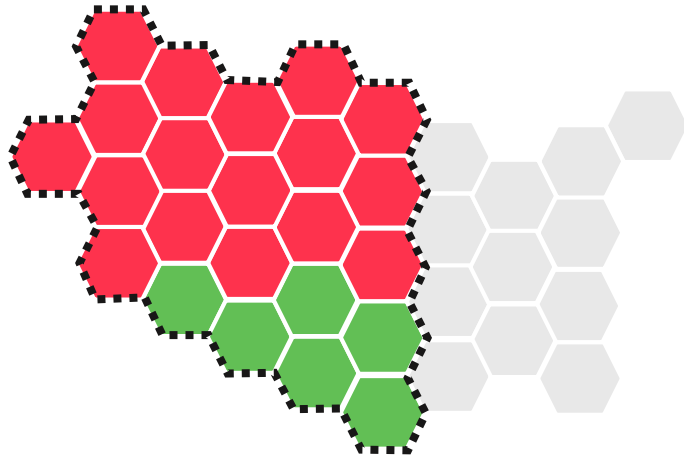


Map B

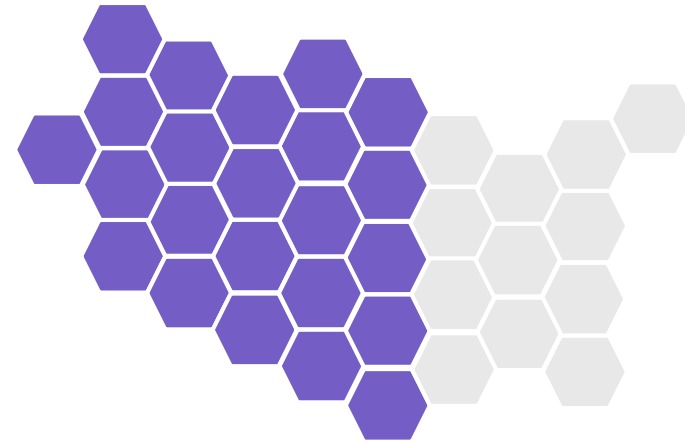


Local Correspondence

Map A

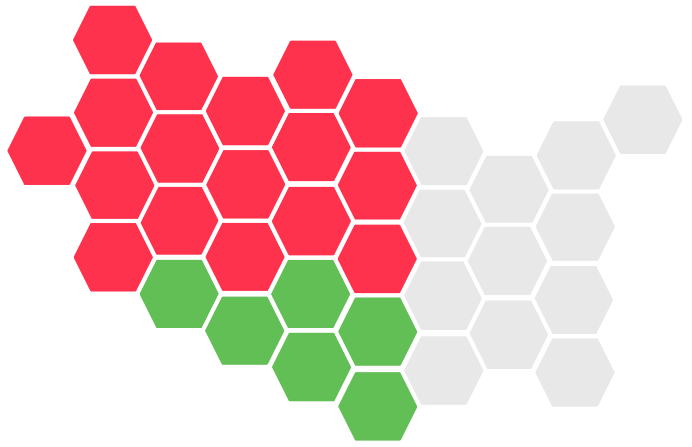


Map B



Local Correspondence

Map A

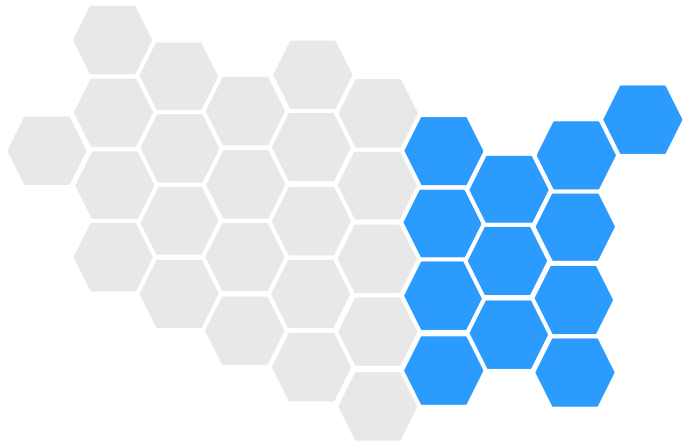


Map B



Local Correspondence

Map A

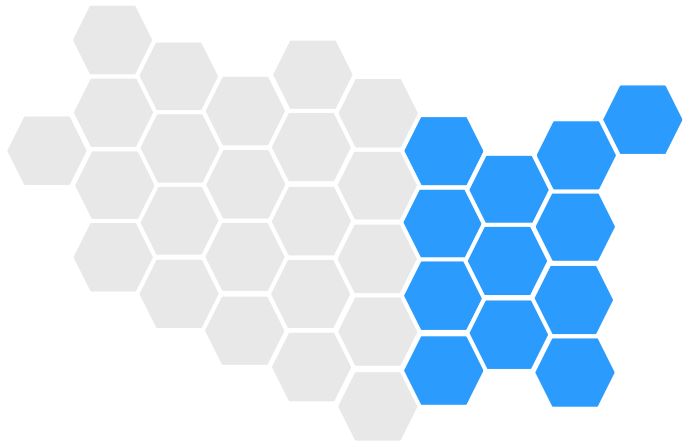


Map B

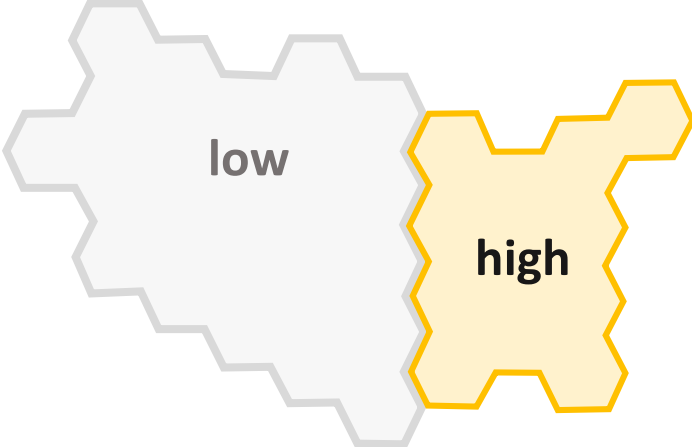


Local Correspondence

Map A

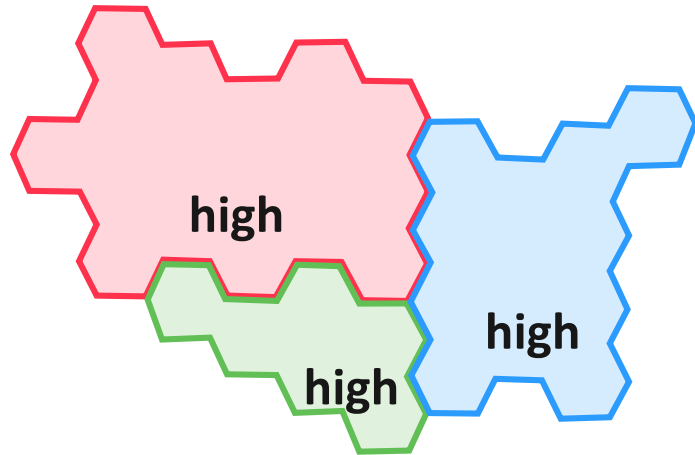


Map B

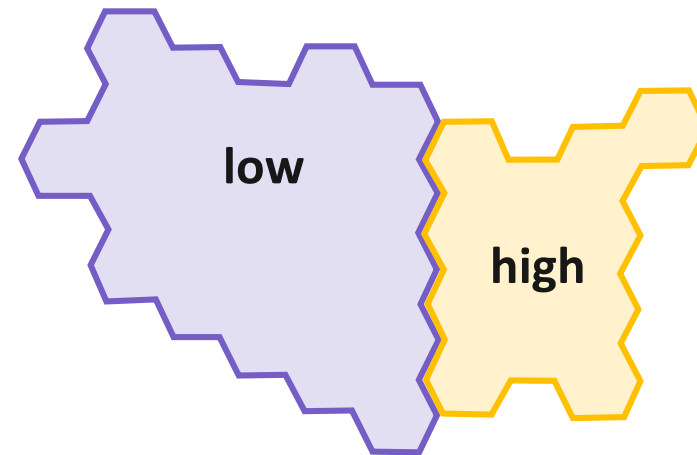


Local Correspondence

Map A

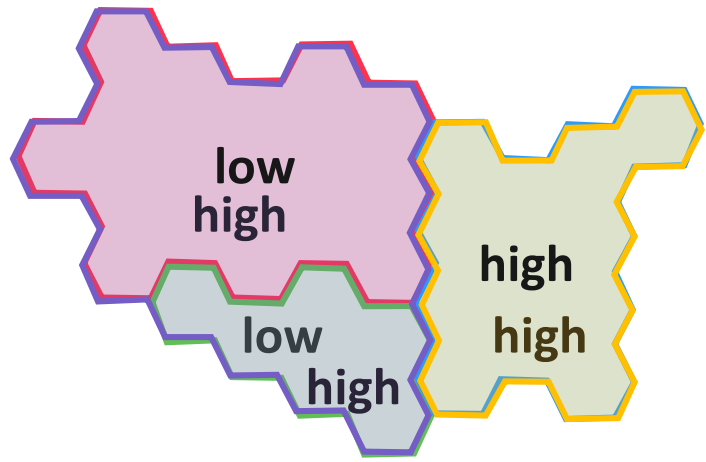


Map B

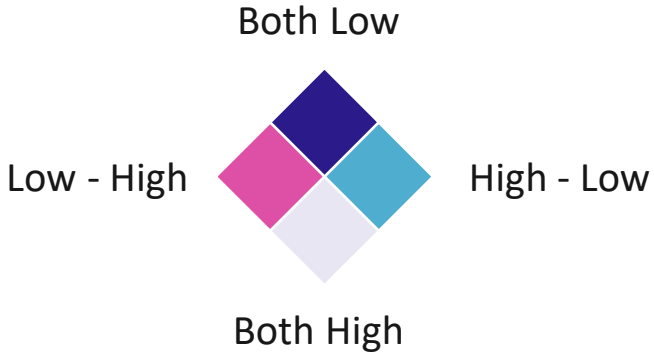
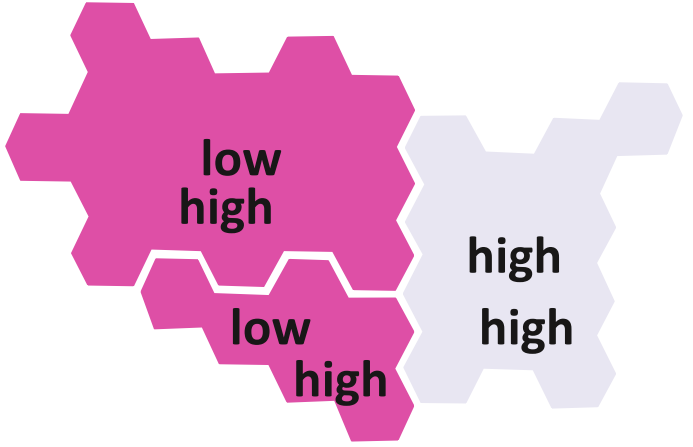


Local Correspondence

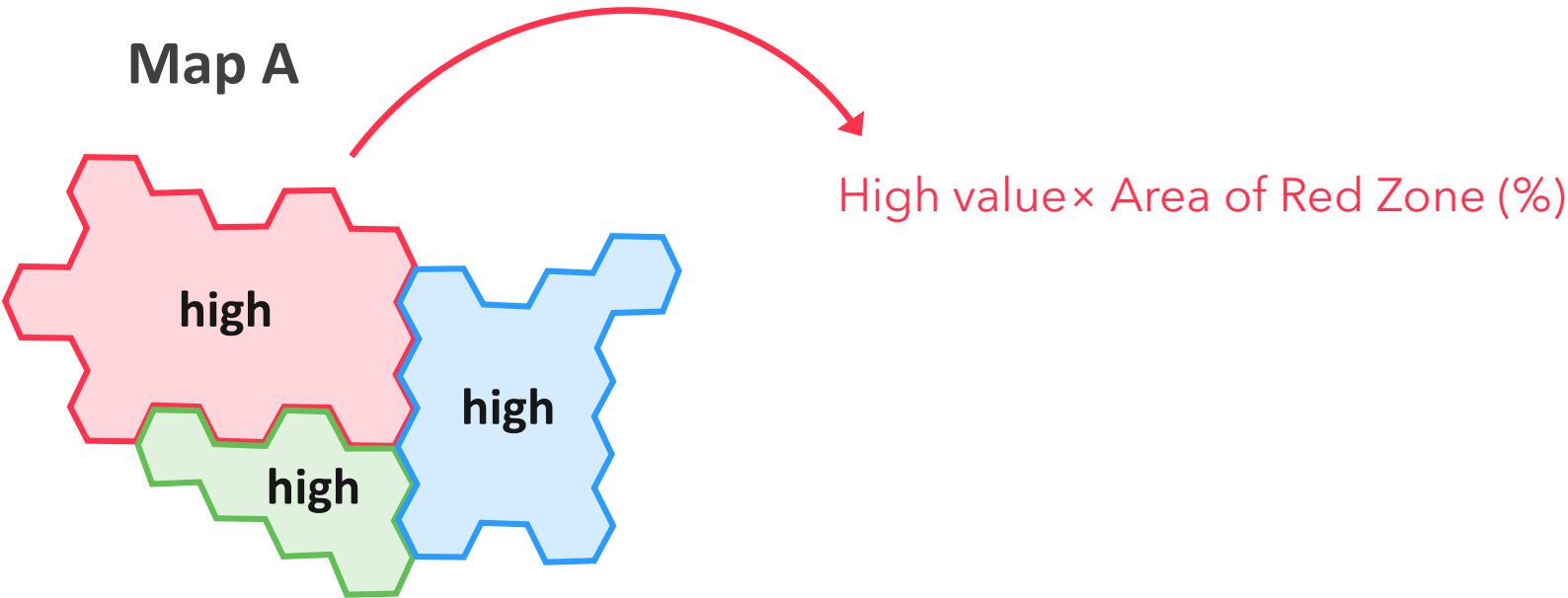
Map A + Map B



Local Correspondence

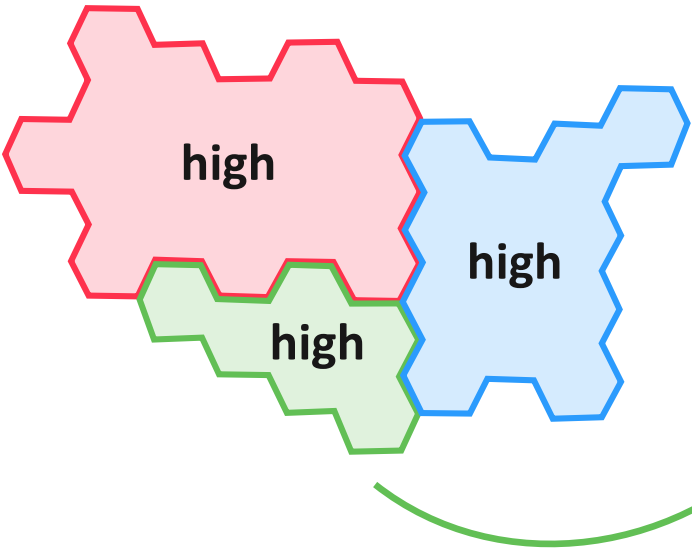


Global Correspondence



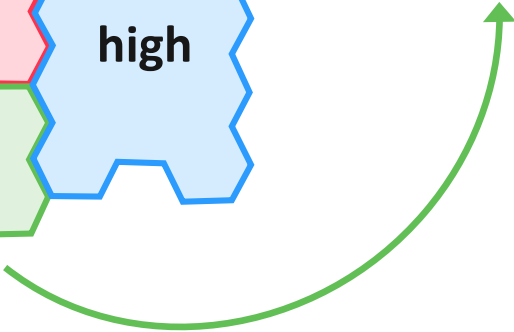
Global Correspondence

Map A



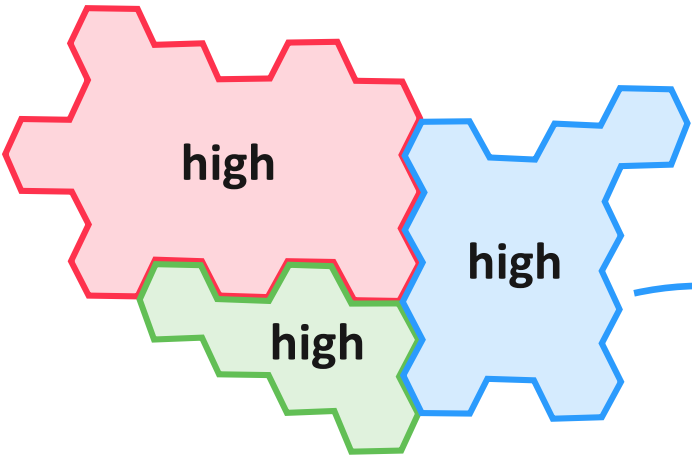
High value × Area of Red Zone (%)

High value × Area of Green Zone (%)



Global Correspondence

Map A



High value × Area of Red Zone (%)

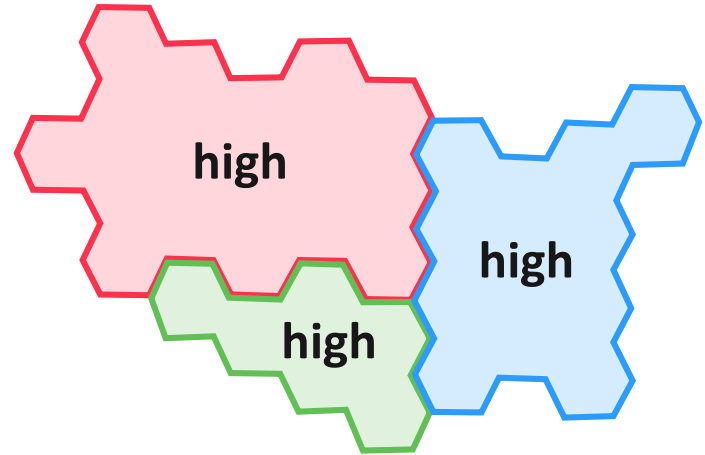
High value × Area of Green Zone (%)

High value × Area of Blue Zone (%)



Global Correspondence

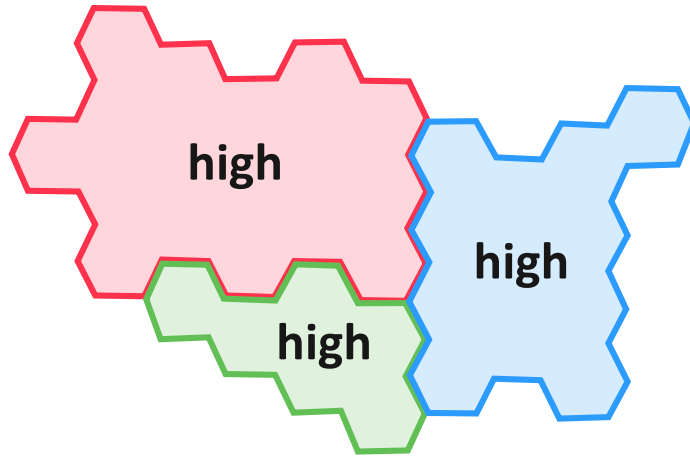
Map A



$$\left(\text{High value} \times \text{Area of Red Zone (\%)} + \text{High value} \times \text{Area of Green Zone (\%)} + \text{High value} \times \text{Area of Blue Zone (\%)} \right)$$

Global Correspondence

Map A

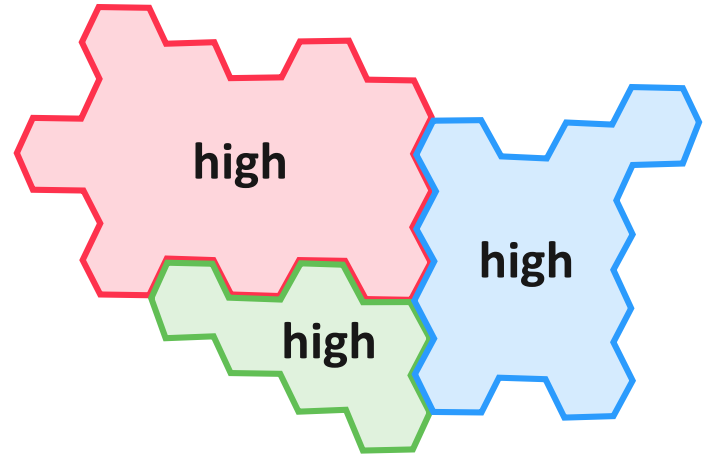


$$\left(\text{High value} \times \text{Area of Red Zone (\%)} + \text{High value} \times \text{Area of Green Zone (\%)} + \text{High value} \times \text{Area of Blue Zone (\%)} \right) = 1$$

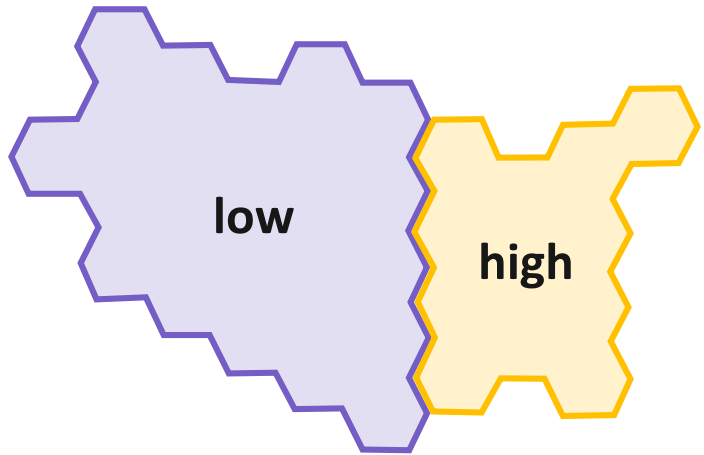
Global Correspondence of Map B zones Within Map A zones

Global Correspondence

Map A

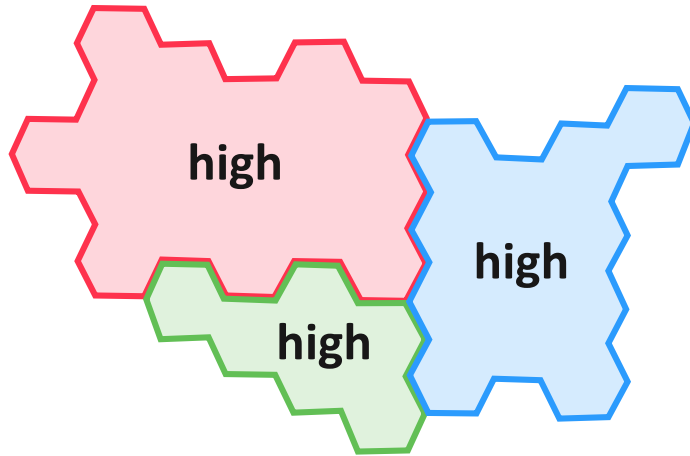


Map B

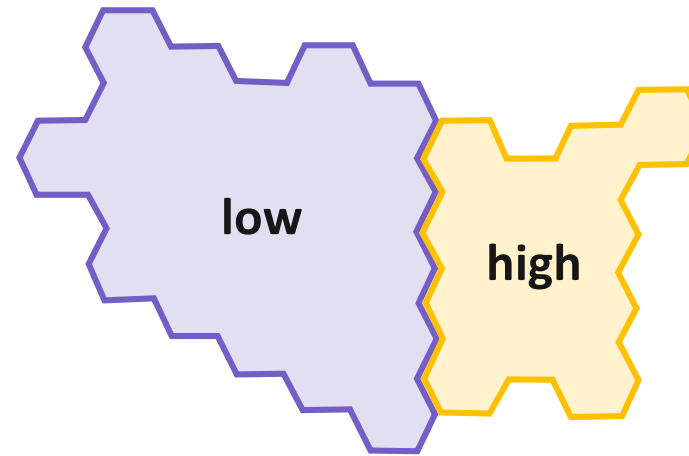


Global Correspondence

Map A



Map B

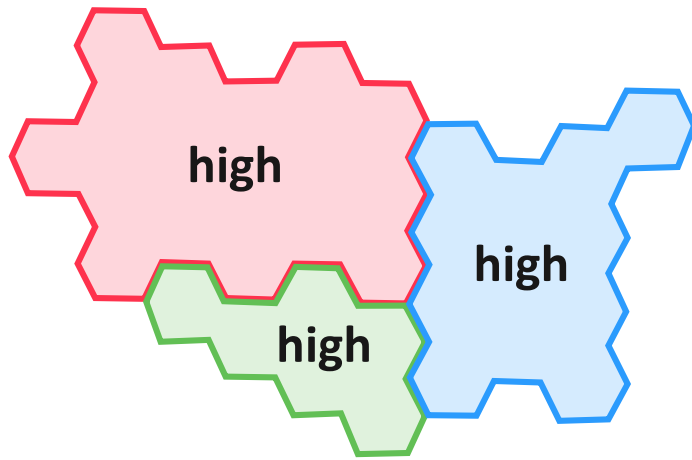


$$\left(\begin{array}{l} \text{Low value} \times \text{Area} \\ \text{of Purple Zone (\%)} \end{array} + \begin{array}{l} \text{High value} \times \text{Area of} \\ \text{Yellow Zone (\%)} \end{array} \right) = 0.67$$

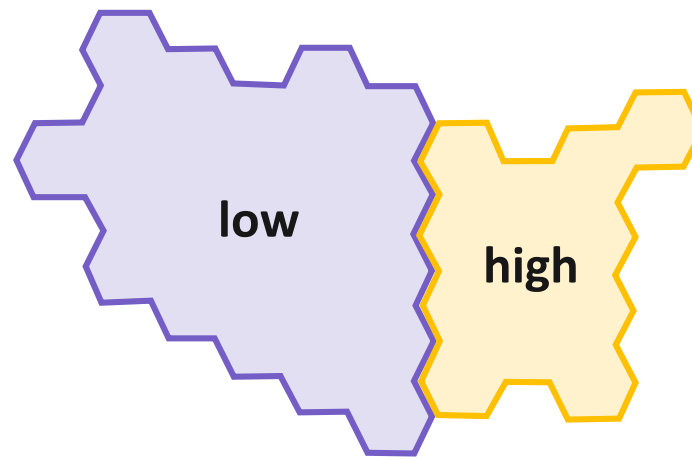
Global Correspondence of Map A zones Within Map B zones

Global Measure of Association

Map A



Map B



$$\frac{2 \times 0.67}{1 + 0.67} = 0.8$$

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