Data Mining Cluster Analysis

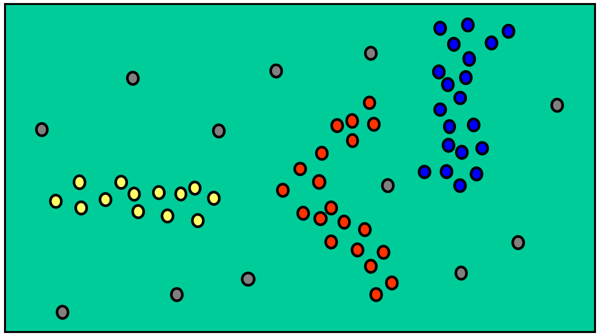
Density-based clustering: DBSCAN

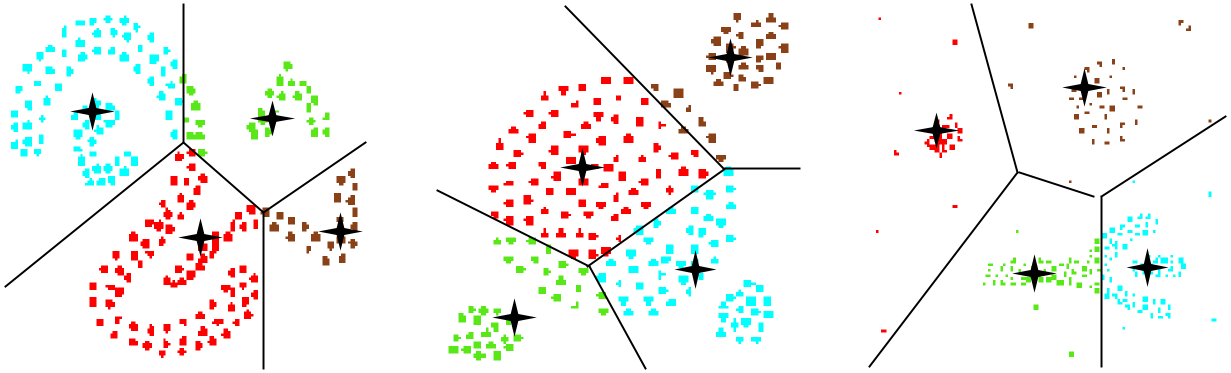
Main source: slides from "Lecture Notes for Chapter 7 -- Introduction to Data Mining, 2nd Edition", by Tan, Steinbach, Karpatne, Kumar

Density Based Clustering

- ***Basic Idea*:**

  Clusters are dense regions in the data space, separated by regions of lower object density





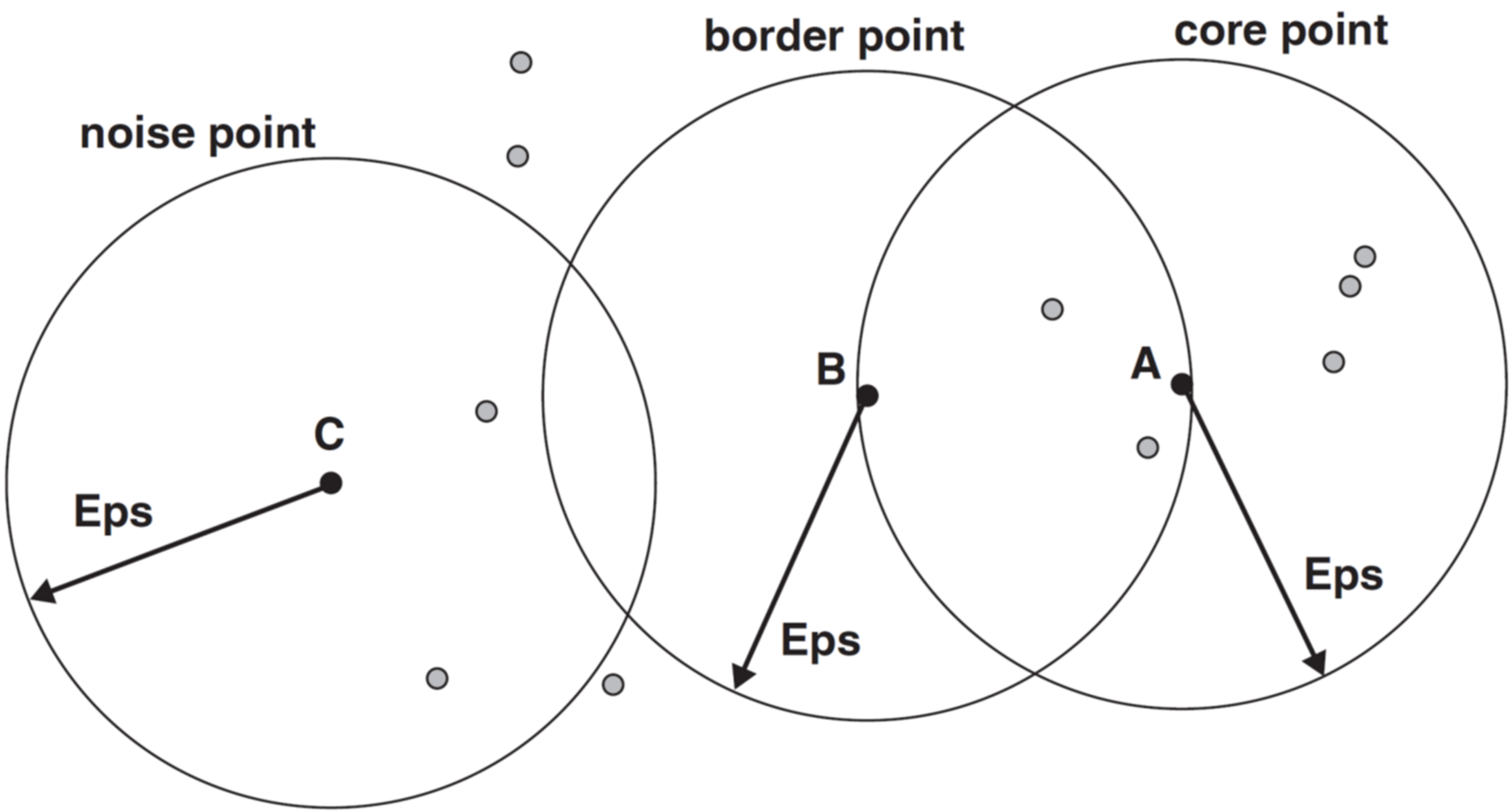
Results of a *k*-medoid algorithm for *k*=4

DBSCAN

- DBSCAN is a density-based algorithm.
  - Density = number of points within a specified radius (Eps)
  - A point is a core point if it has at least a specified number of points (MinPts) within Eps
    - These are points that are at the interior of a cluster
    - Counts the point itself
  - A border point is not a core point, but is in the neighborhood of a core point
  - A noise point is any point that is not a core point or a border point

DBSCAN: Core, Border, and Noise Points

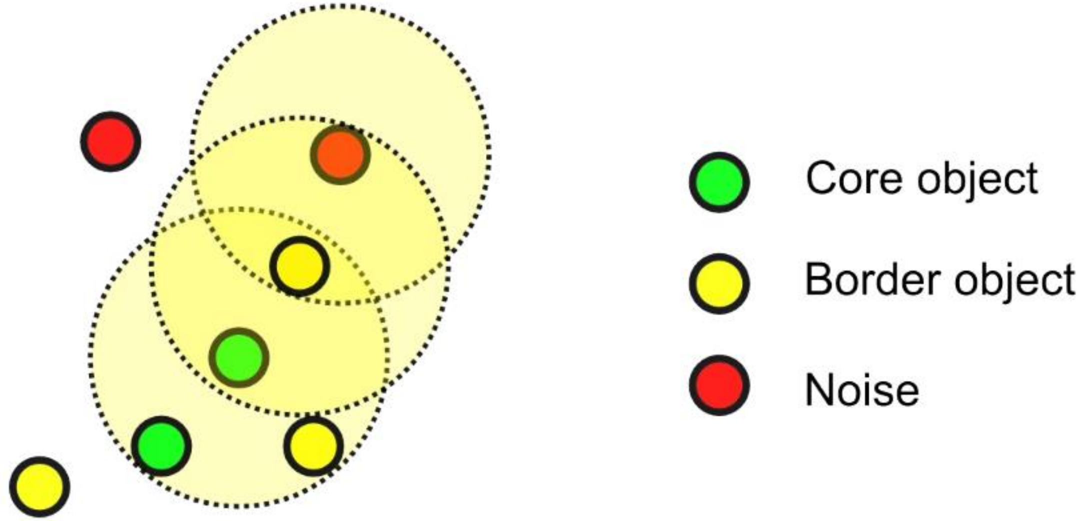
MinPts = 7



Density Based Clustering

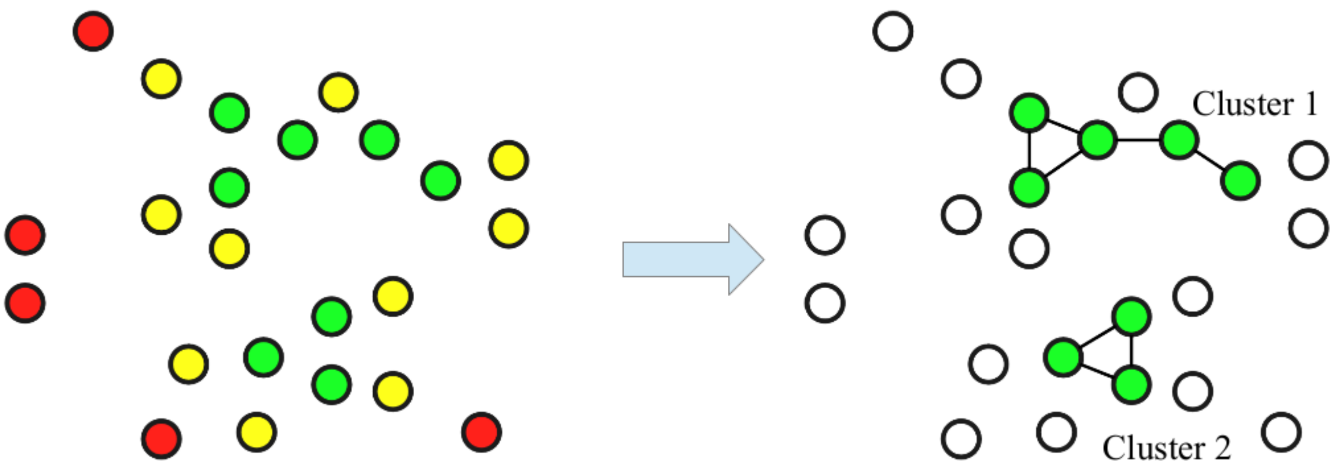
Step 1: label points as core (dense), border and noise

- Based on thresholds R (radius of neighborhood) and min_pts (min number of neighbors)



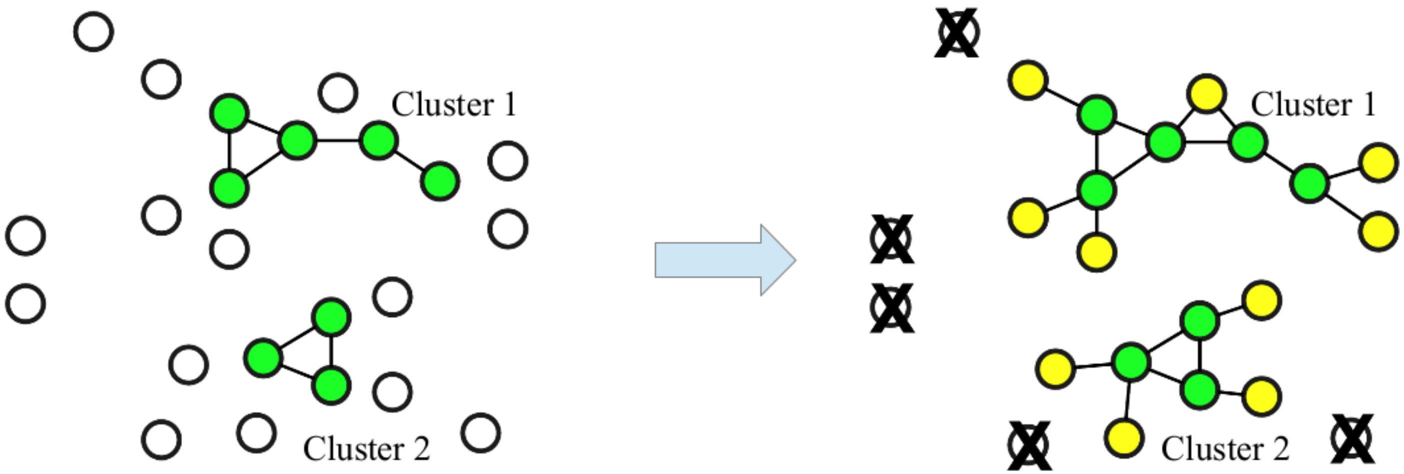
Density Based Clustering

Step 2: connect core objects that are neighbors, and put them in the same cluster



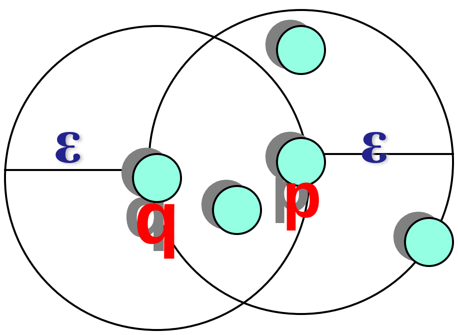
Density Based Clustering

Step 3: associate border objects to (one of) their core(s), and remove noise



Density-Reachability

- **Directly density-reachable**
  - **An object q is directly density-reachable from object p if p is a core object and q is in p's ε-neighborhood.**

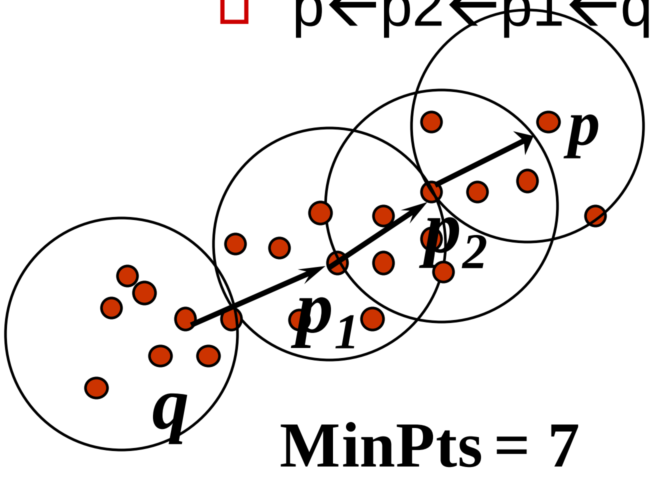


MinPts = 4

- **q is directly density-reachable from p**
- **p is not directly density- reachable from q?**
- **Density-reachability is asymmetric.**

Density-Reachability

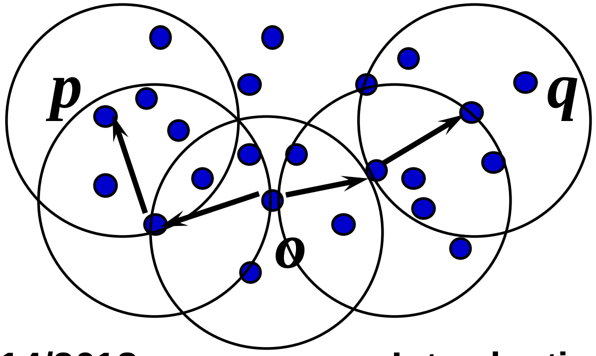
- Density-Reachable (directly and indirectly):
  - A point p is directly density-reachable from p2;
  - p2 is directly density-reachable from p1;
  - p1 is directly density-reachable from q;
  - p←p2←p1←q form a chain.



- **p is (indirectly) density-reachable from q**
- **q is not density- reachable from p?**

Density-Reachability

- Density-reachable is not symmetric
  - not good enough to describe clusters
- Density-Connected
  - A pair of points p and q are density-connected if they are commonly density-reachable from a point o.



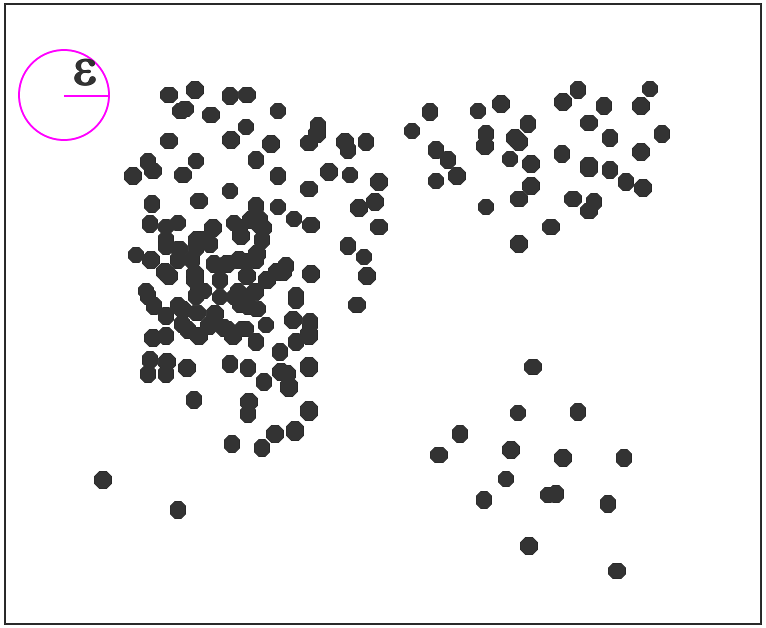
- Density-connectivity is symmetric

DBSCAN Algorithm

```
Input: The data set D

Parameter: ε, MinPts

For each object p in D
    if p is a core object and not processed then
        C = retrieve all objects density-reachable from p
        mark all objects in C as processed
        report C as a cluster
    else mark p as outlier
    end if

End For
```

DBSCAN

- **Example:**
  - **Radius ε as shown below (Euclidean distance).**
  - **Minimum support *m* = 7.**
  - **What are the clusters?**



DBSCAN

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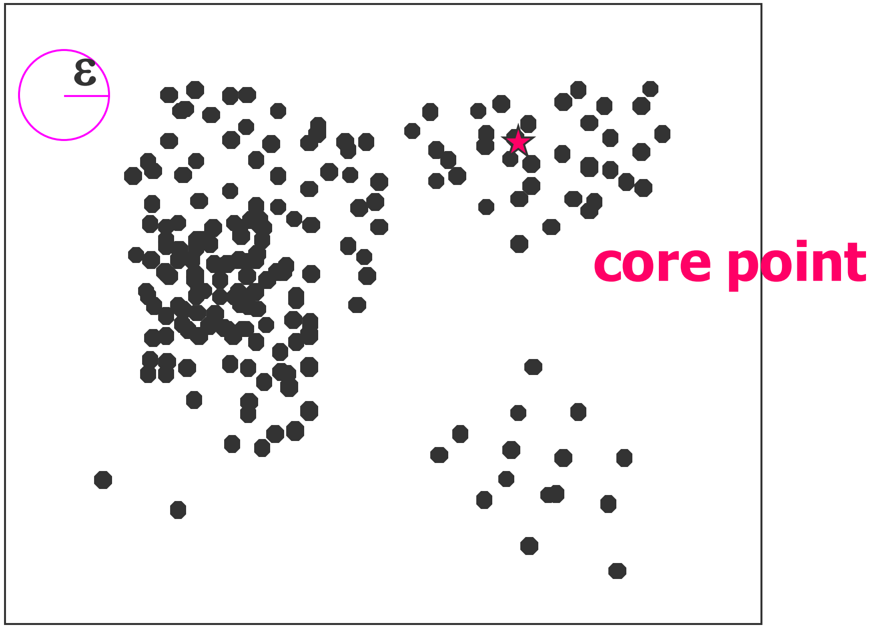

DBSCAN

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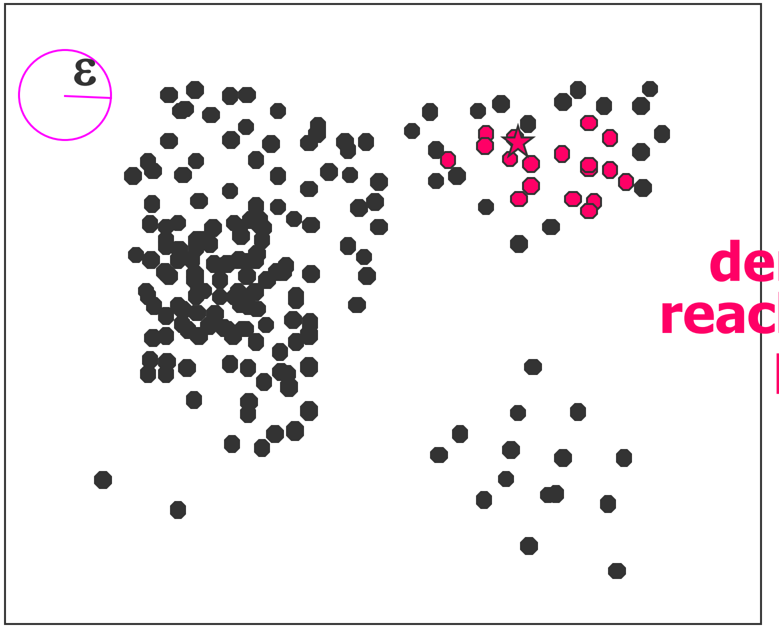

density-reachable core points

DBSCAN

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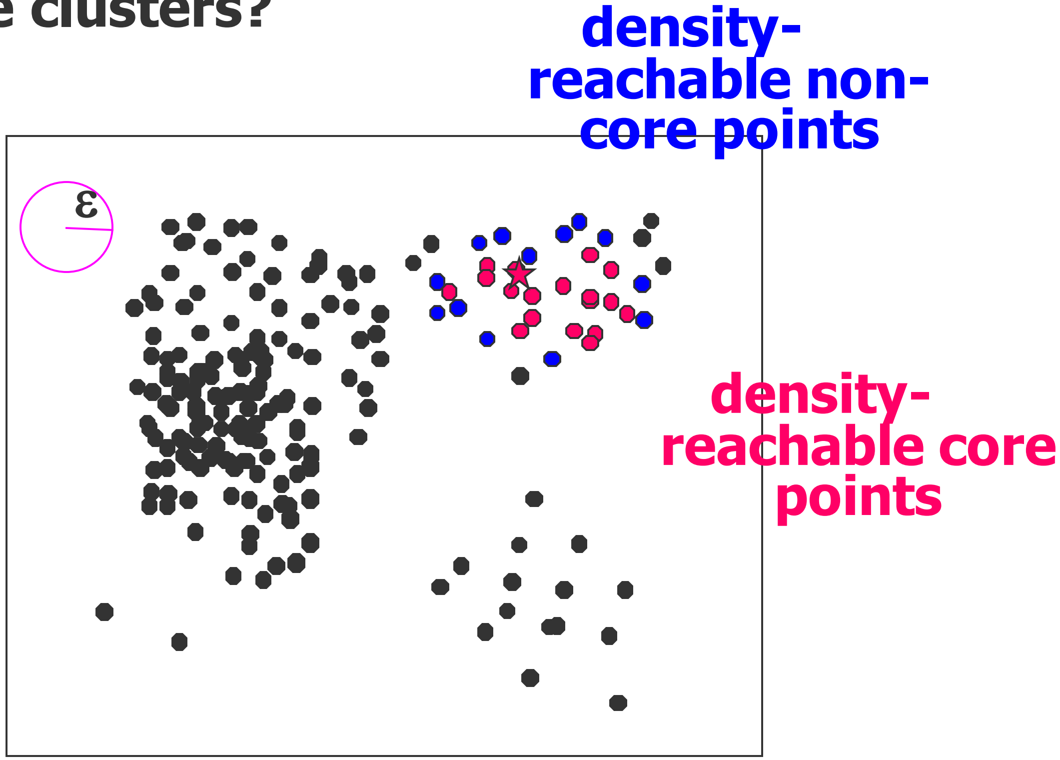
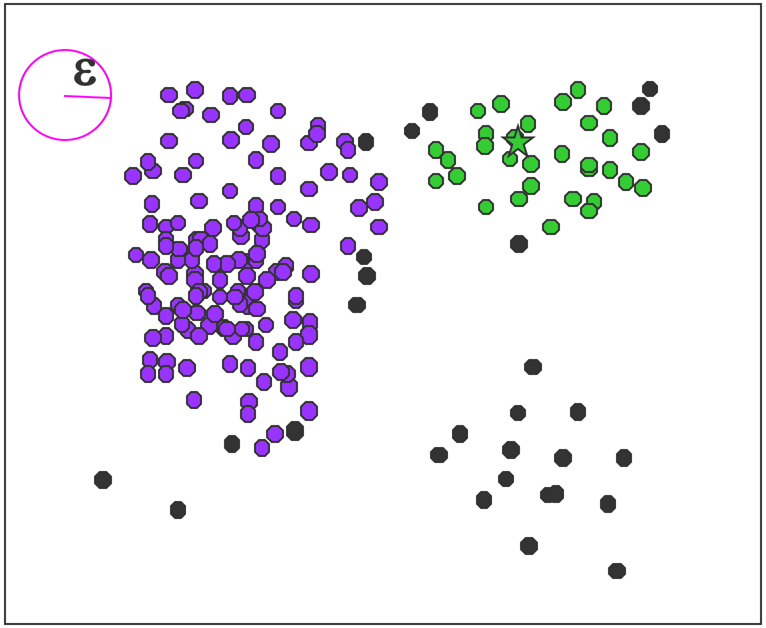


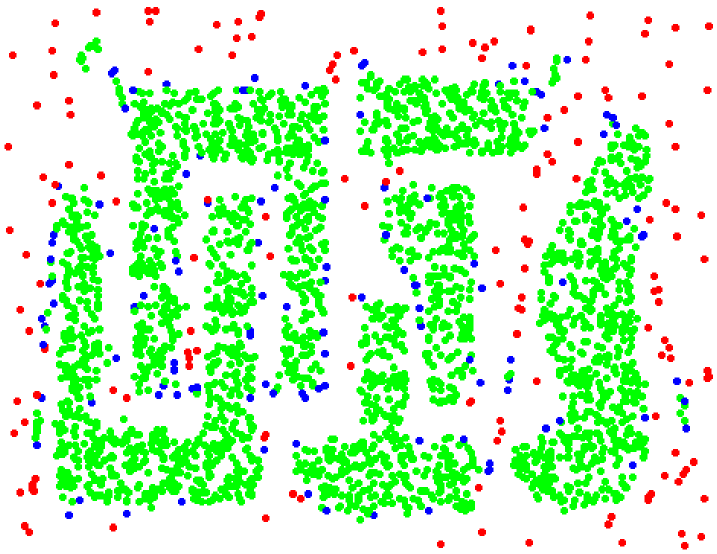
DBSCAN

- **Example:**
  - **Radius ε** as shown below (Euclidean distance).
  - Minimum support *m* = 7.
  - 2 clusters in this example.
  - Lower-right grouping not dense enough to form a cluster.



DBSCAN: Core, Border and Noise Points

Original Points

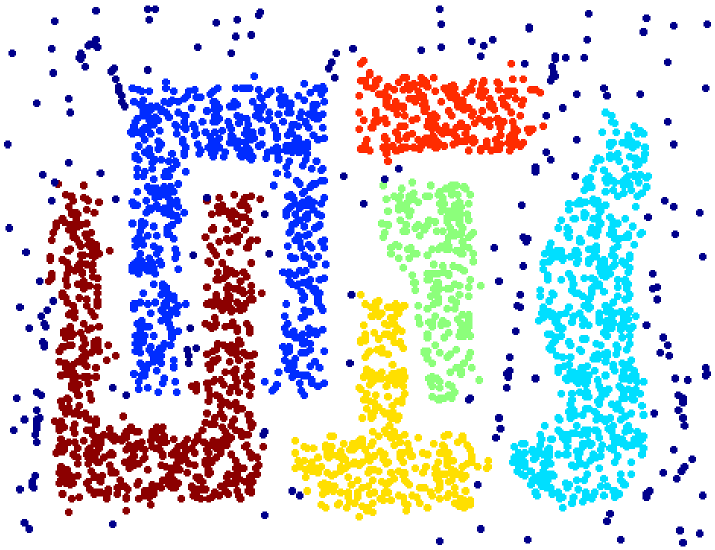


Point types: core, border and noise

Eps = 10, MinPts = 4

When DBSCAN Works Well

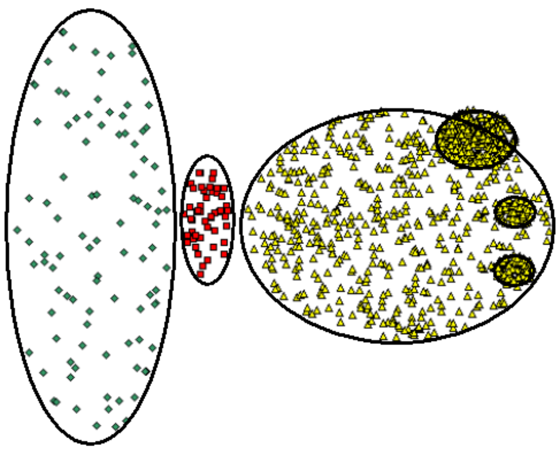
Original Points



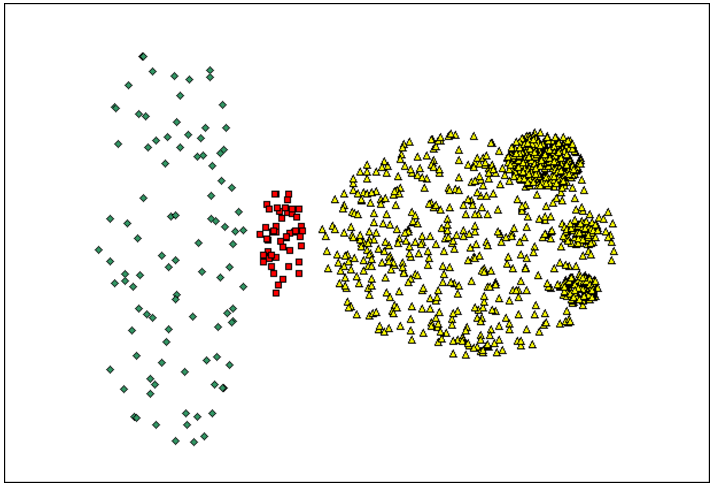
Clusters

- Resistant to Noise
- Can handle clusters of different shapes and sizes

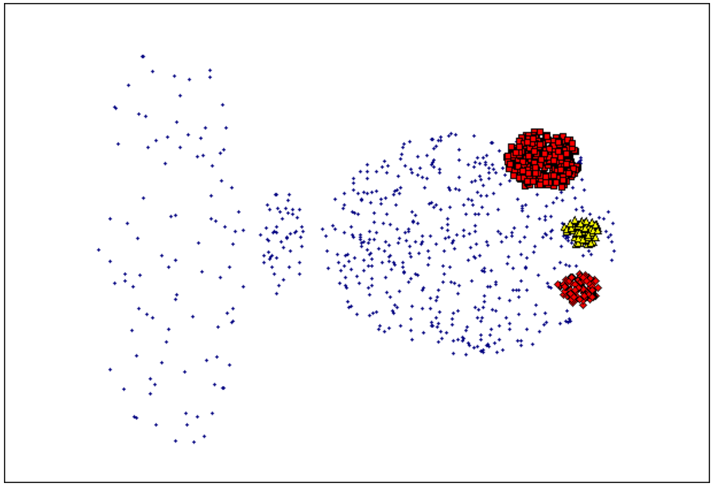
When DBSCAN Does NOT Work Well



Original Points



(MinPts=4, Eps=9.75).



(MinPts=4, Eps=9.92)

- Varying densities
- High-dimensional data

DBSCAN: Determining EPS and MinPts

- Idea is that for points in a cluster, their k^{th} nearest neighbors are at roughly the same distance
- Noise points have the k^{th} nearest neighbor at farther distance
- So, plot sorted distance of every point to its k^{th} nearest neighbor