- Density-based clustering (DBScan)
  - Reference: Martin Ester, Hans-Peter Kriegel, Jorg Sander, Xiaowei Xu: A Density-Based Algorithm for Discovering Clusters in Large Spatial Databases with Noise. KDD 2006

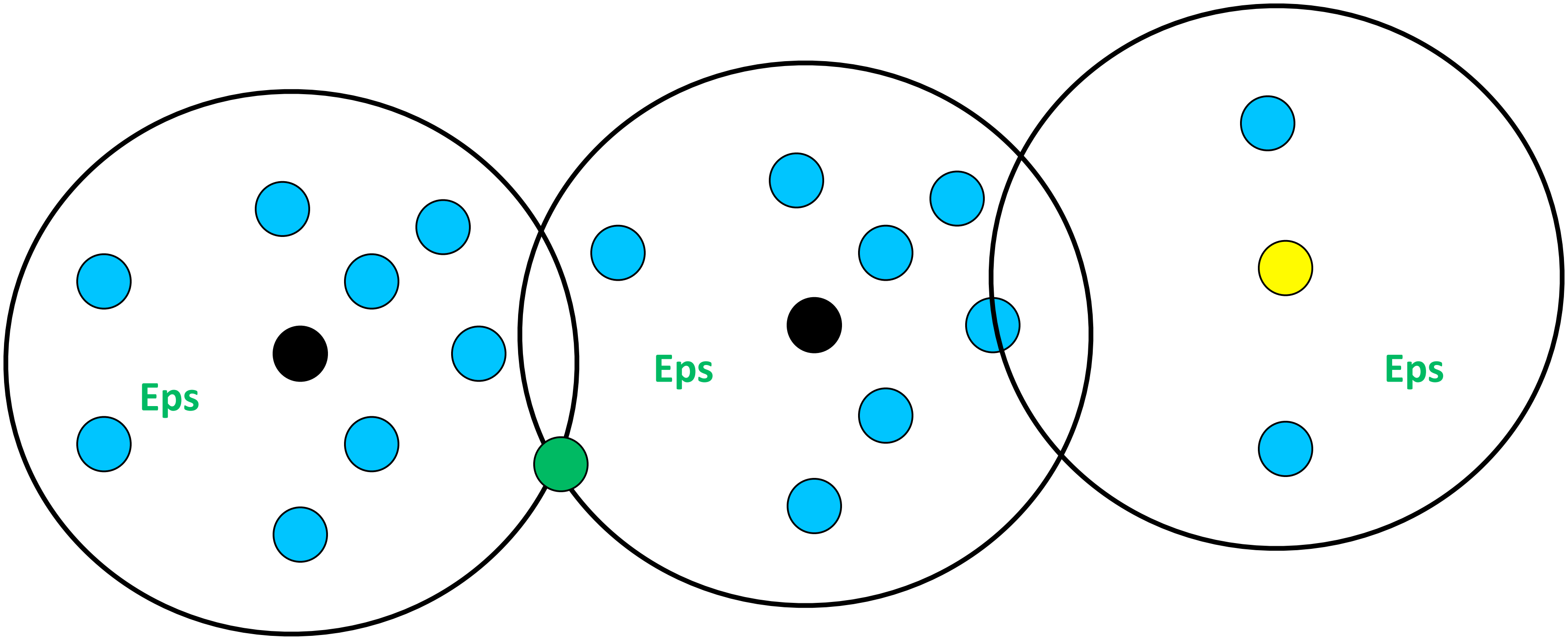
Density-Based Clustering Methods

- Clustering based on density (local cluster criterion), such as density-connected points
- Major features:
  - Discover clusters of arbitrary shape
  - Handle noise

Types of points in density-based clustering

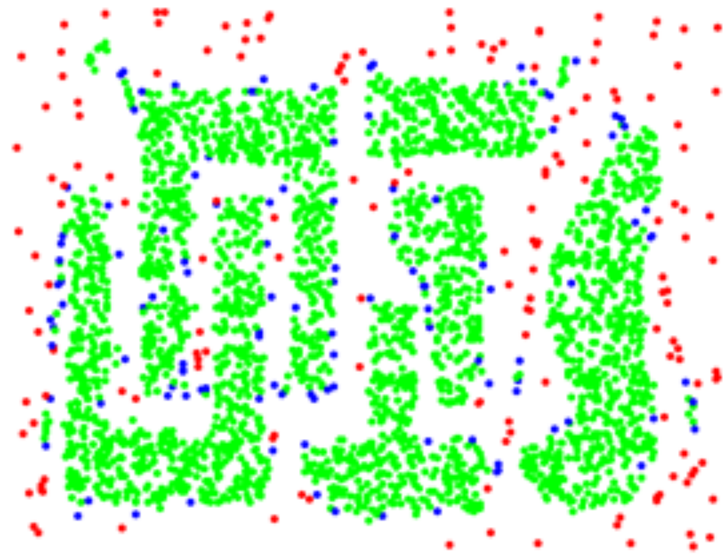
- **Core points**: Interior points of a density-based cluster. A point **p** is a core point if for distance **Eps** :
  - $|N_{Eps}(p)=\{q \mid dist(p,q) <= \varepsilon \}| \geq MinPts$
- **Border points:** Not a core point but within the neighborhood of a core point (it can be in the neighborhoods of many core points)
- **Noise points:** Not a core or a border point

Core, border and noise points



Core, Border and Noise points

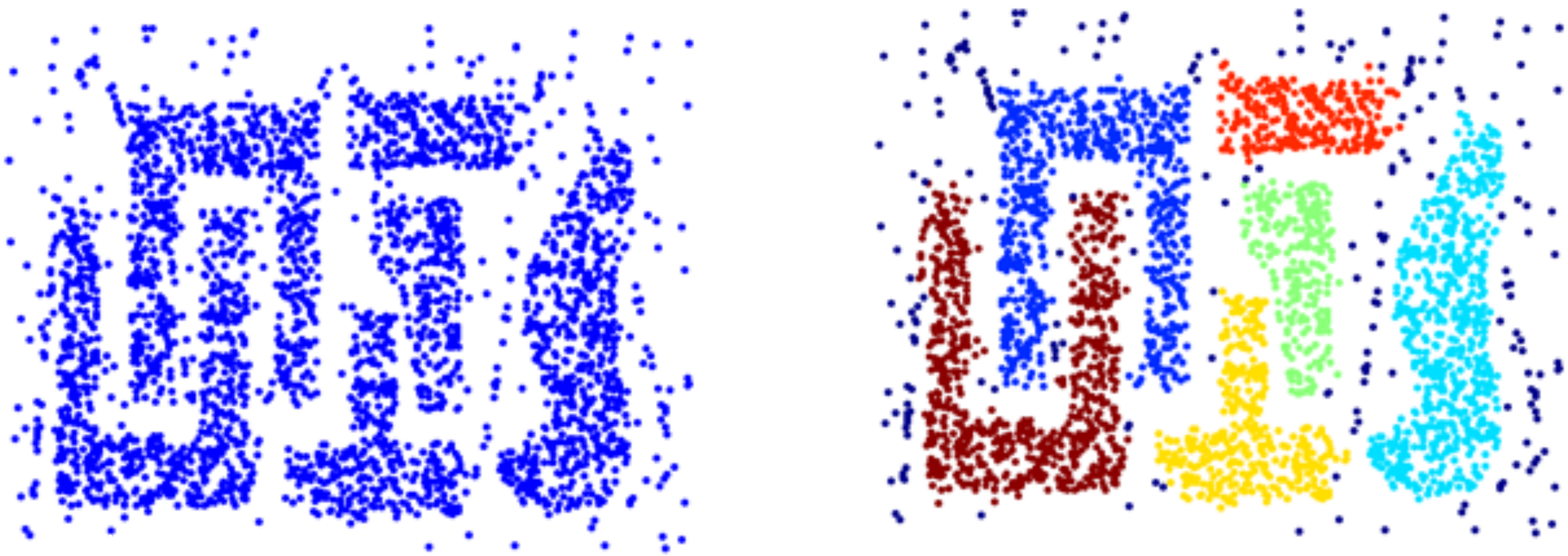
Original Points



Point types: core border and noise

MinPts = 4

Clusters output by DBScan



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

Classification of points in density-based clustering

- **Core points**: Interior points of a density-based cluster. A point **p** is a core point if for distance **Eps** :
  - $|N_{Eps}(p)=\{q \mid dist(p,q) <= \varepsilon \}| \geq MinPts$

- **Border points:** Not a core point but within the neighborhood of a core point (it can be in the neighborhoods of many core points)

- **Noise points:** Not a core or a border point

DBSCAN: The Algorithm

– Label all points as ***core***, ***border***, or ***noise*** points

– Eliminate noise points

– Put an edge between all core points that are within ***Eps*** of each other

– Make each group of connected core points into a separate cluster

– Assign each border point to one of the cluster of its associated core points

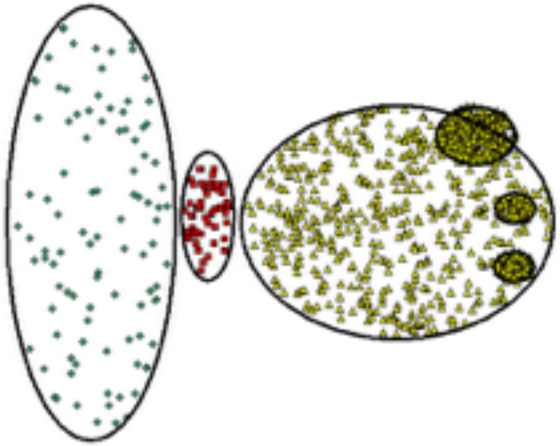
Time and space complexity of DBSCAN

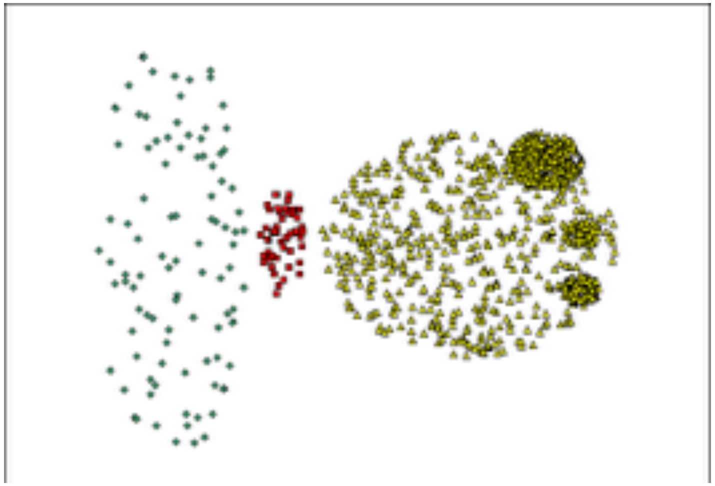
- For a dataset **X** consisting of **n** points, the time complexity of DBSCAN is **O(n x time to find points in the Eps-neighborhood)**

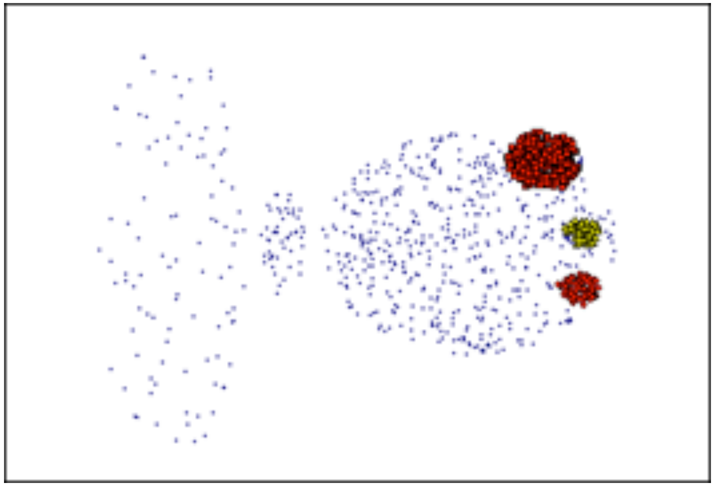
- Worst case **$O(n^2)$**

- In low-dimensional spaces (d=2) can become **O(nlogn)**; (not the original algorithm, an new improved one)
- Efficient data structures (e.g., ***kd-trees***) allow for efficient retrieval of all points within a given distance of a specified point

When DBSCAN Does NOT Work Well

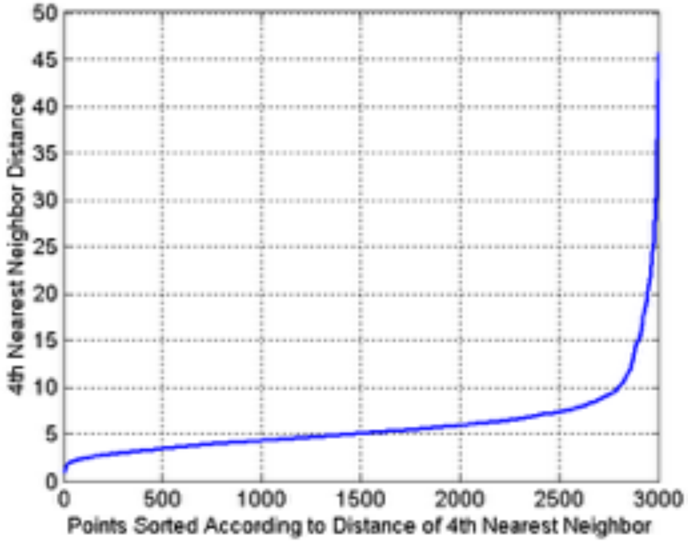






Determining EPS and MinPts

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



Strengths and weaknesses of DBSCAN

- Resistant to noise
- Finds clusters of arbitrary shapes and sizes
- Difficulty in identifying clusters with varying densities
- Problems in high-dimensional spaces; notion of density unclear
- Can be computationally expensive when the computation of nearest neighbors is expensive