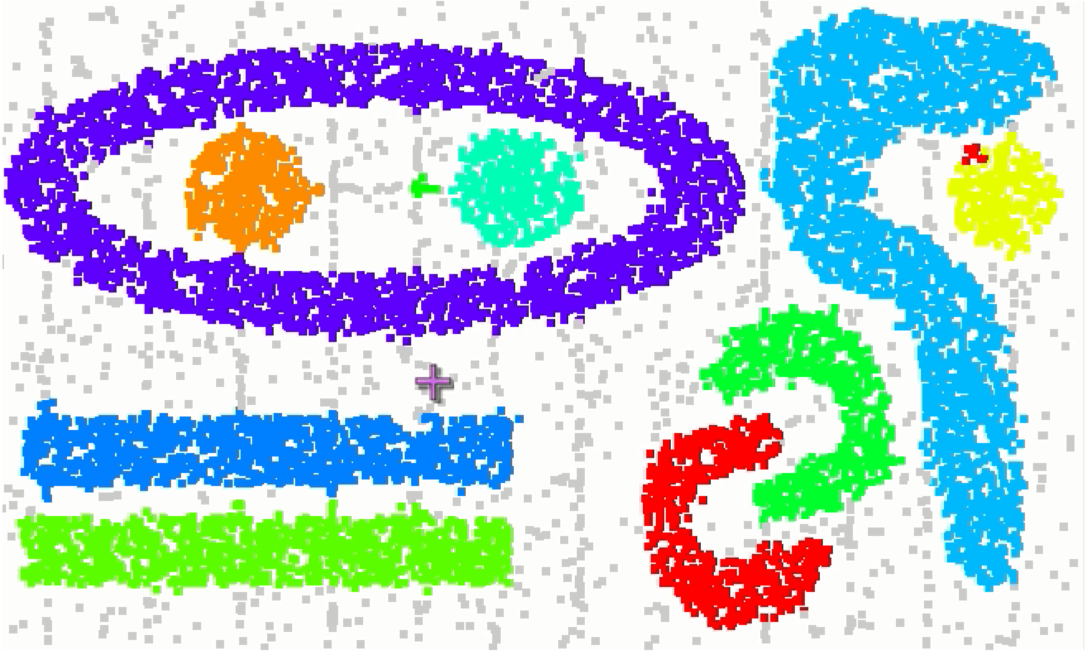
430.217
Introduction to Data Structures

Project

Seoul National University
Advanced Computing Laboratory

DBSCAN

- Density based spatial clustering of applications with noise
  - 밀도가 높으면 하나의 cluster로 간주



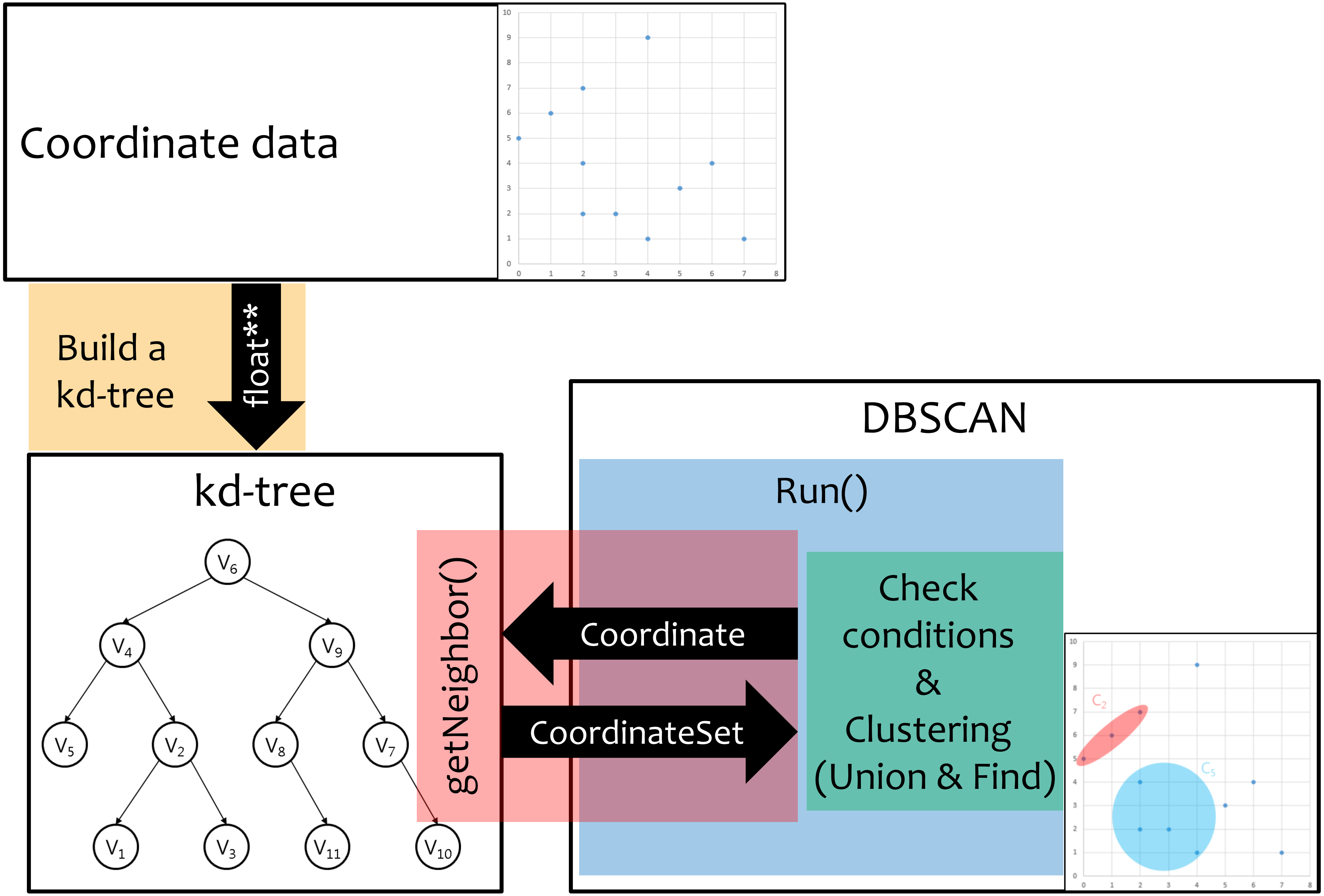
- 구현에 필요한 자료구조
  - kd-tree
  - Disjoint set
  - Container (array / linked list / stack / queue / heap 등)

Project Details

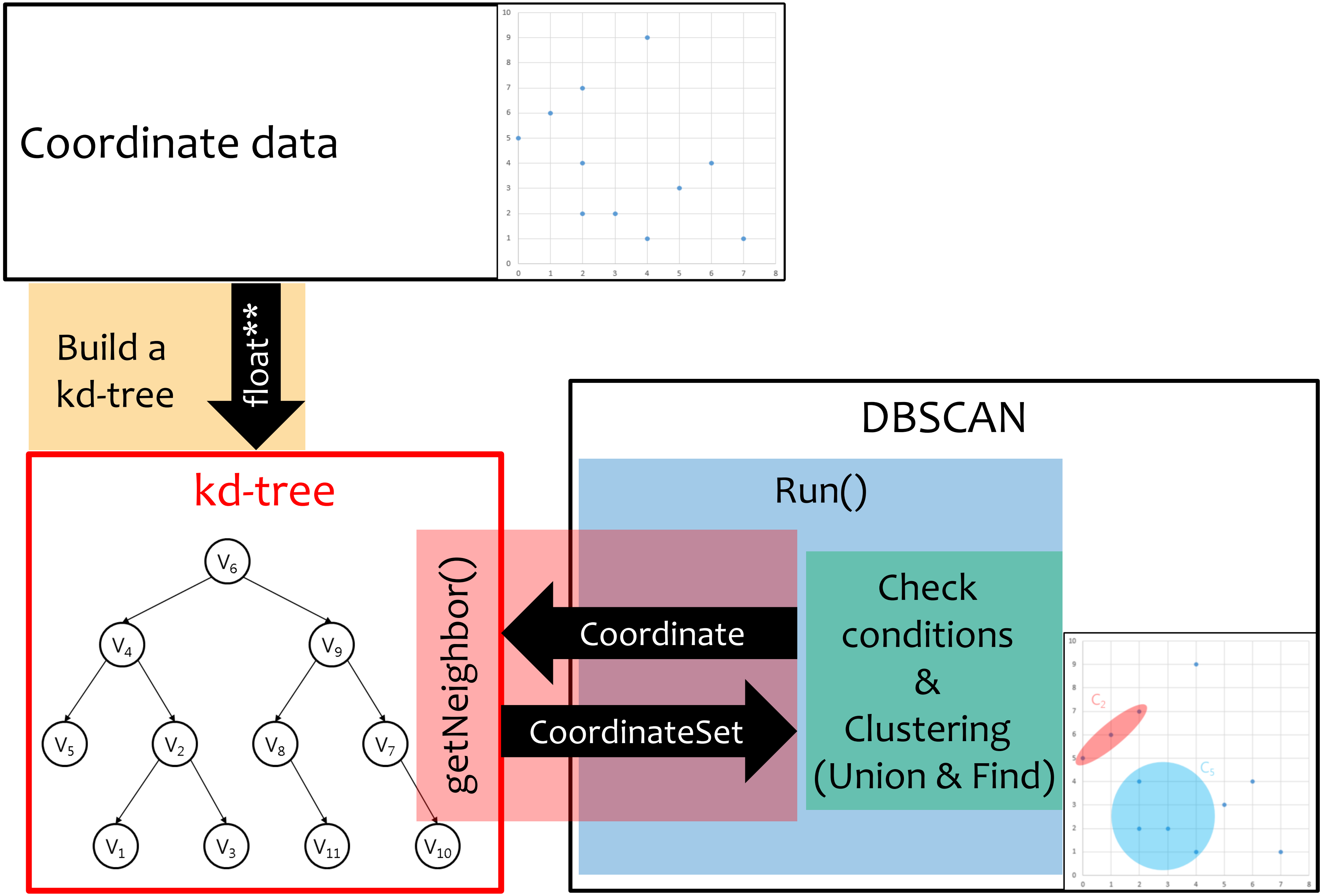
kd-tree

DBSCAN (union-find)

DBSCAN Overview

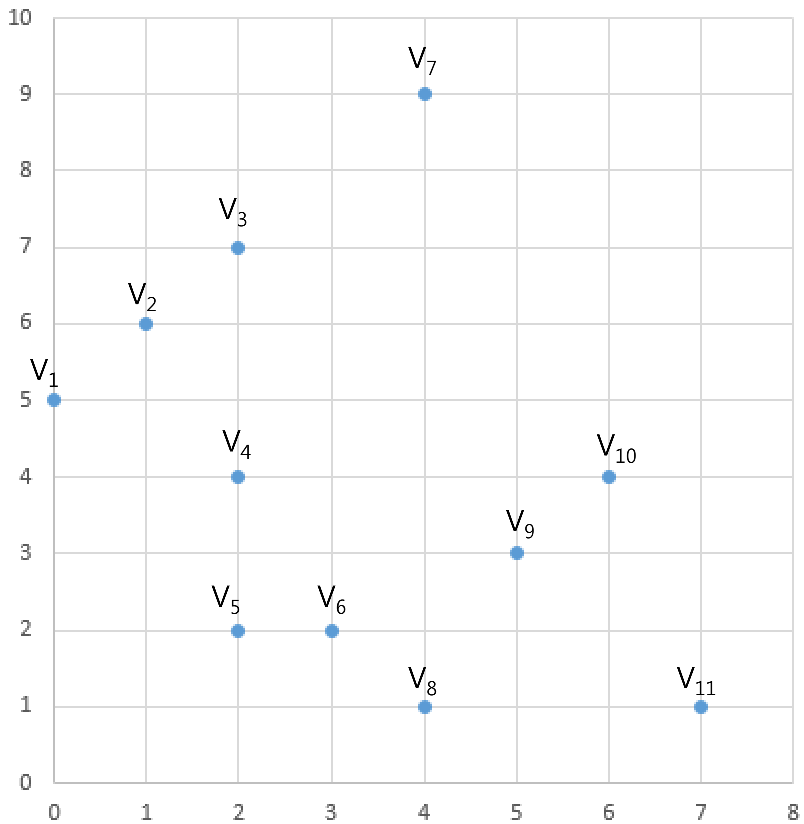


DBSCAN Overview: kd-tree



kd-tree

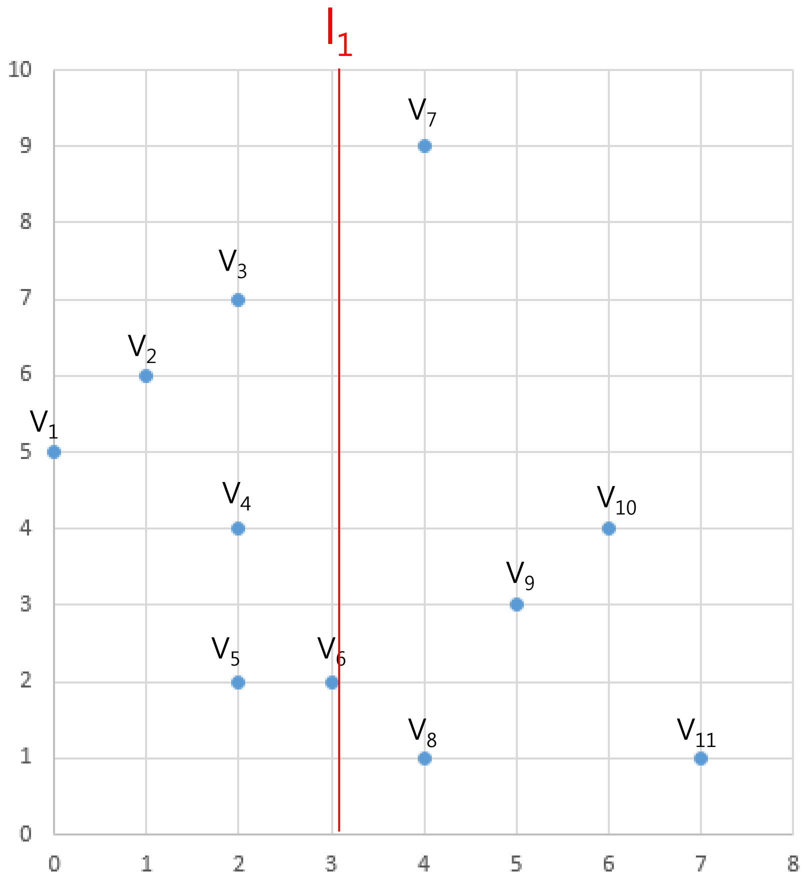
- k-dimensional tree
  - A general version of a BST (BST = 1D tree)
  - Stores k-dimension coordinates data (same dimension in a kd-tree)
  - Fast region search

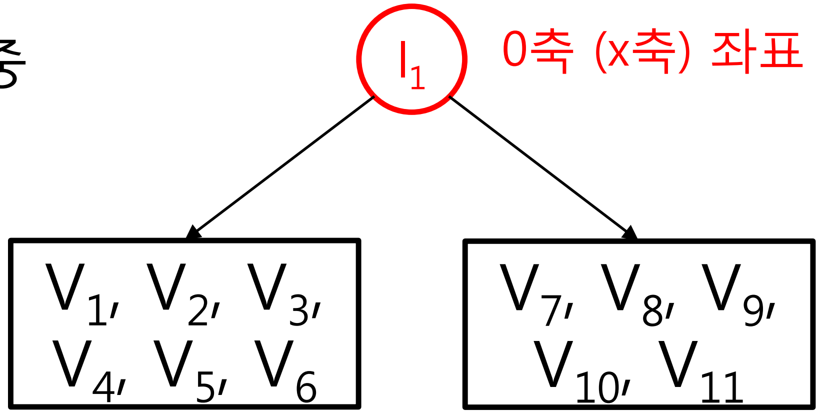


Build a kd-tree

l_i = hyperplane

- Example: 2D
  - Parent node는 hyperplane 정보 저장 (기준 point는 (depth % k) 축의 좌표 중 median 값을 가지는 point이다.)





기준 point의 해당 축의 좌표보다
작거나 같으면 left subtree
크면 right subtree

Build a kd-tree

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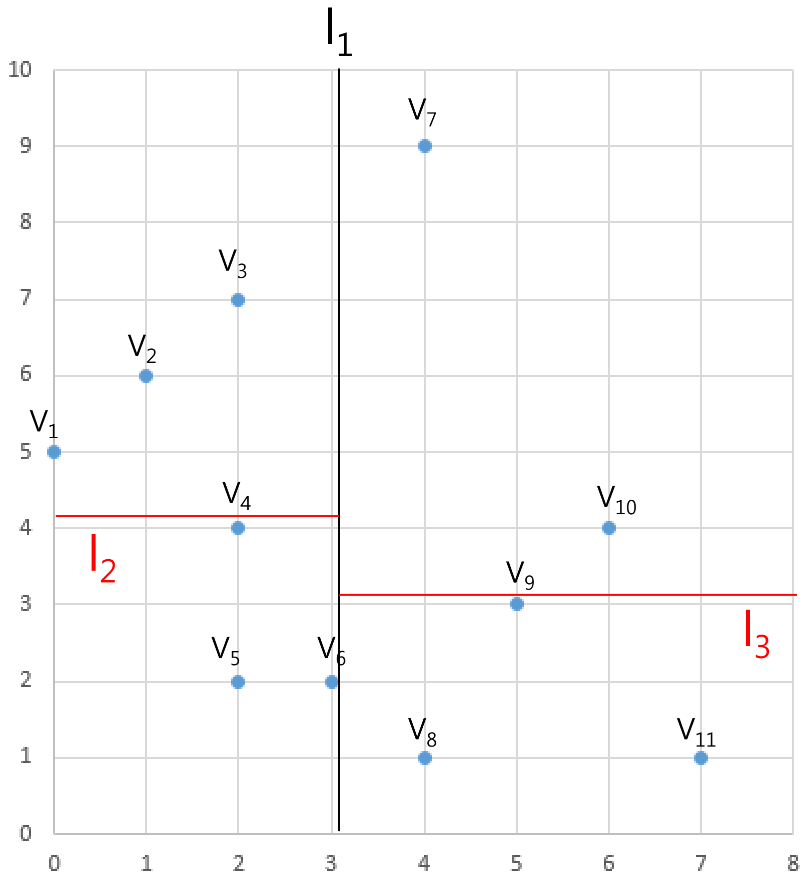

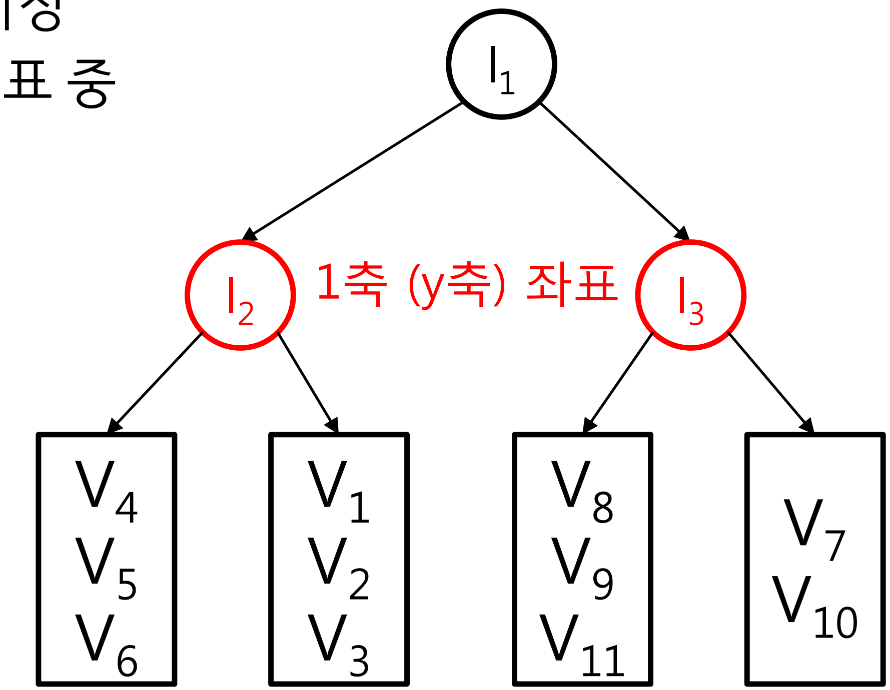

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Build a kd-tree

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  - point가 1개 되면 leaf node가 됨: 데이터 저장

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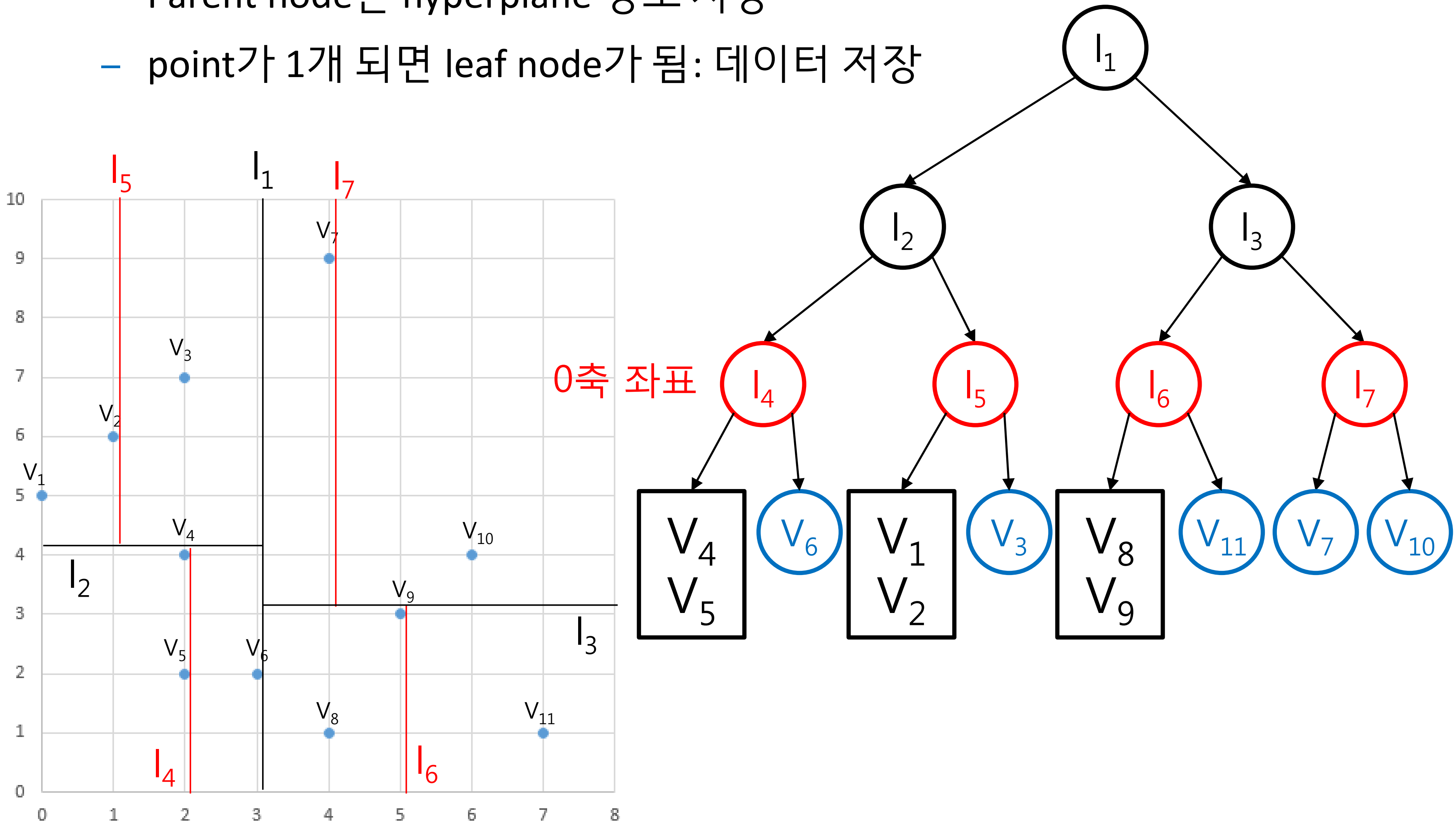

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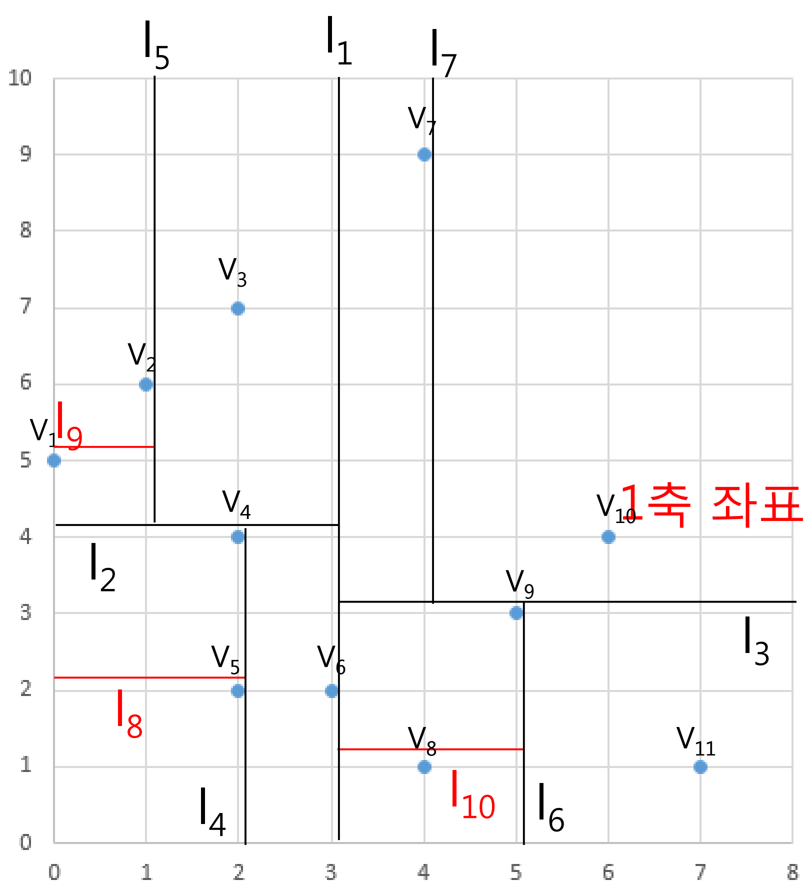
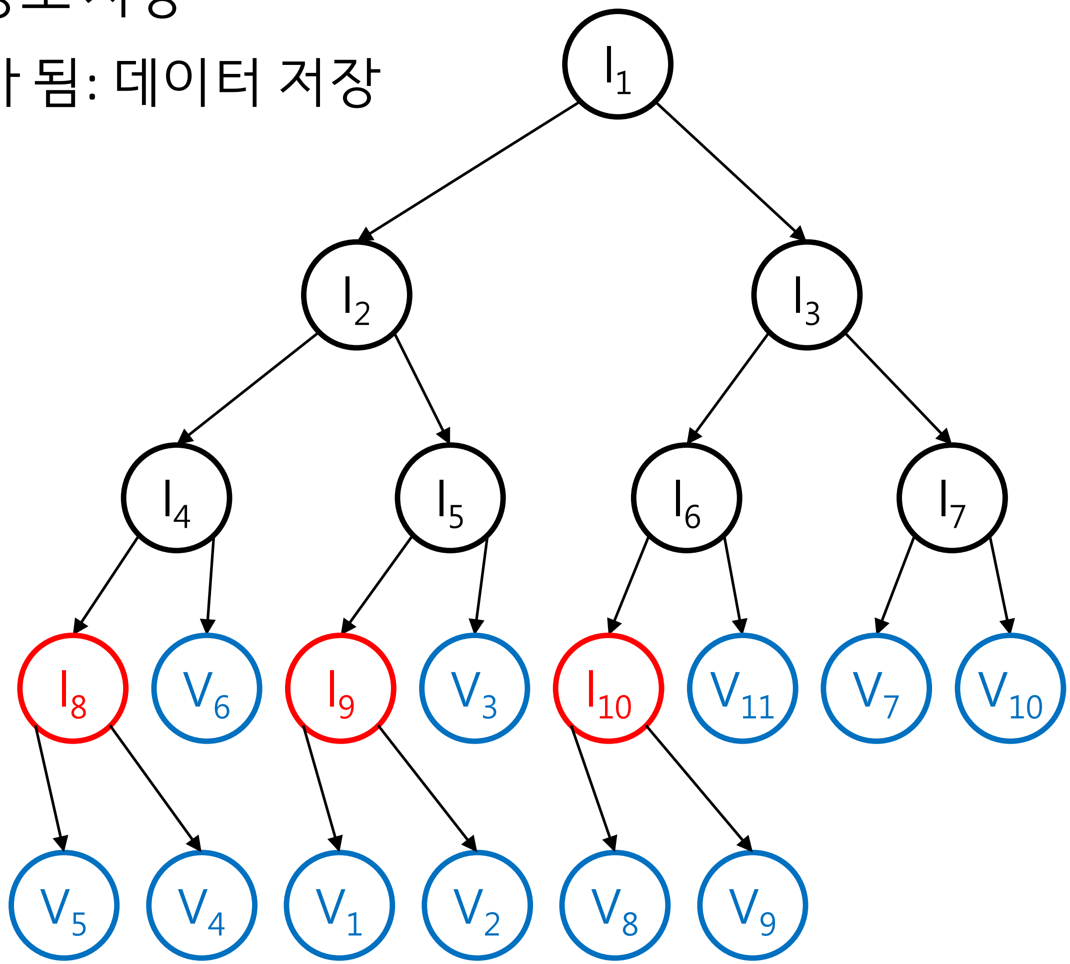
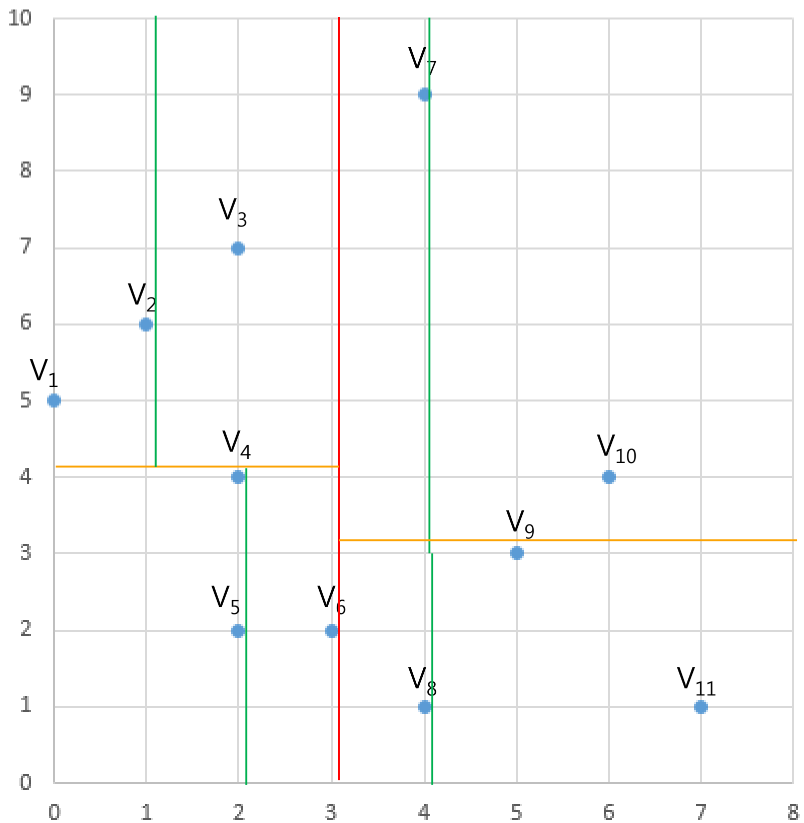
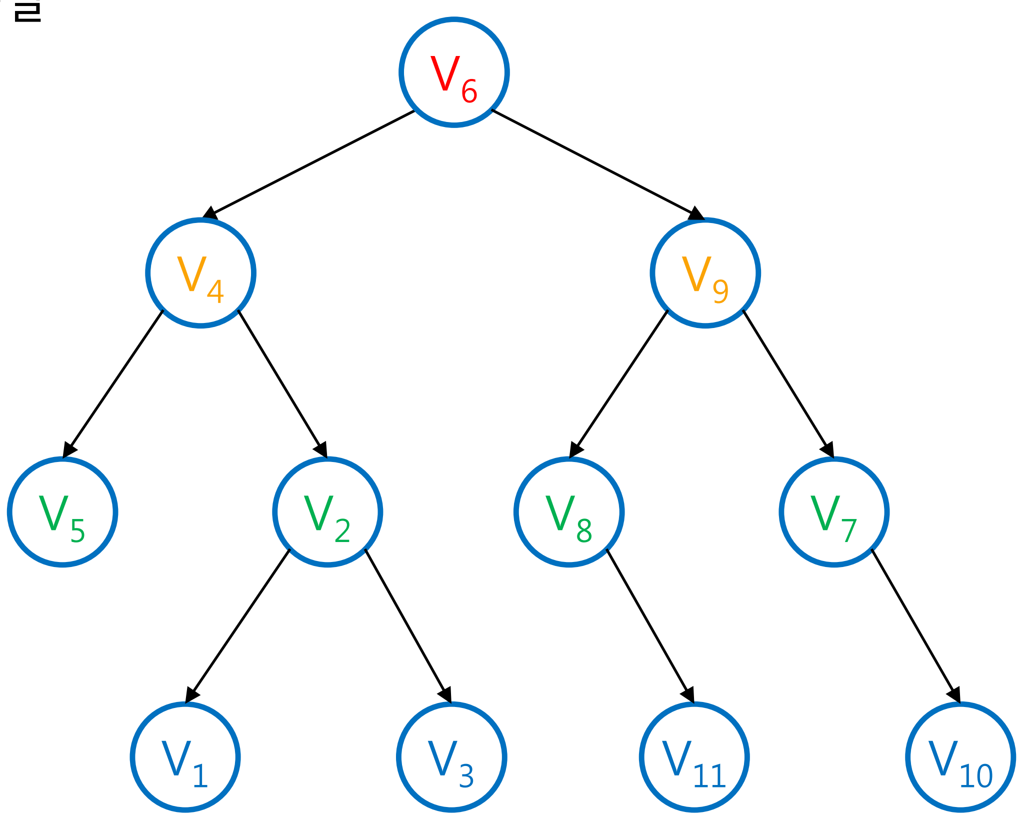




Another Way to Build a kd-tree

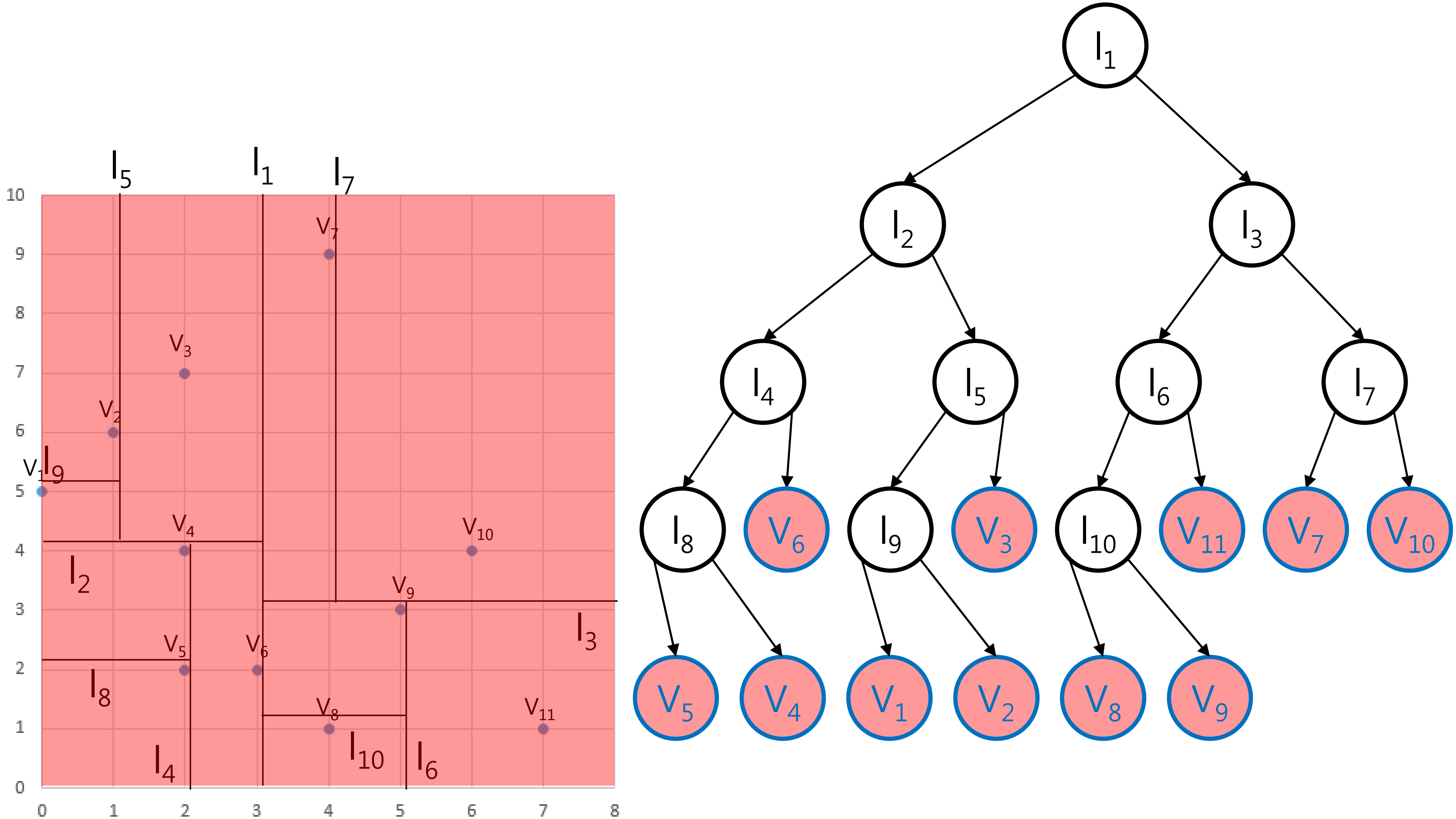
- Build a kd-tree 다른 방법 (기존의 BST에서 배운 방법대로)
  - 모든 노드가 좌표 데이터 저장
    - Subtree 설정은 앞 방법과 동일





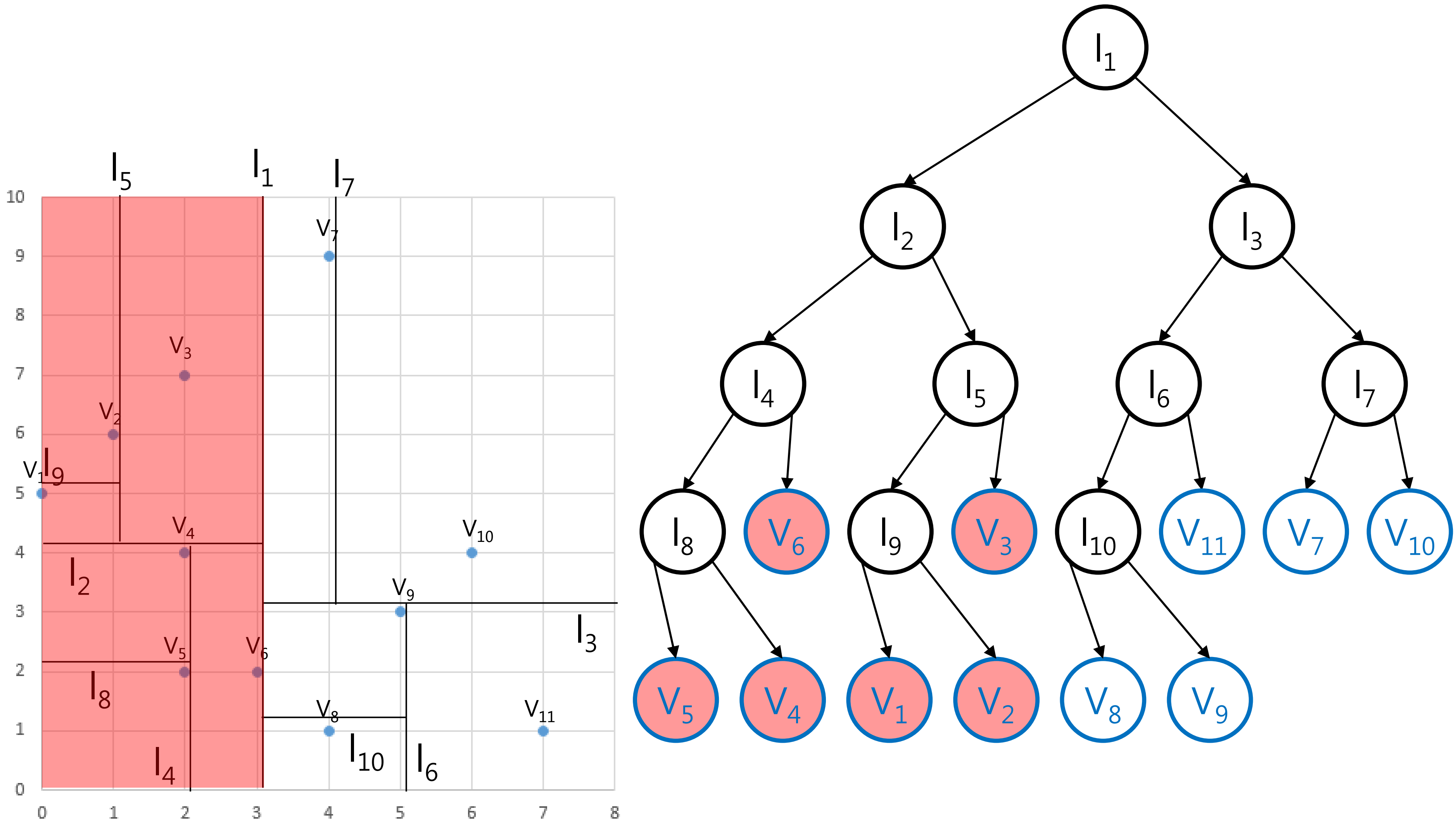
Geometric Meaning

- l_1 노드의 후손들은 모든 data



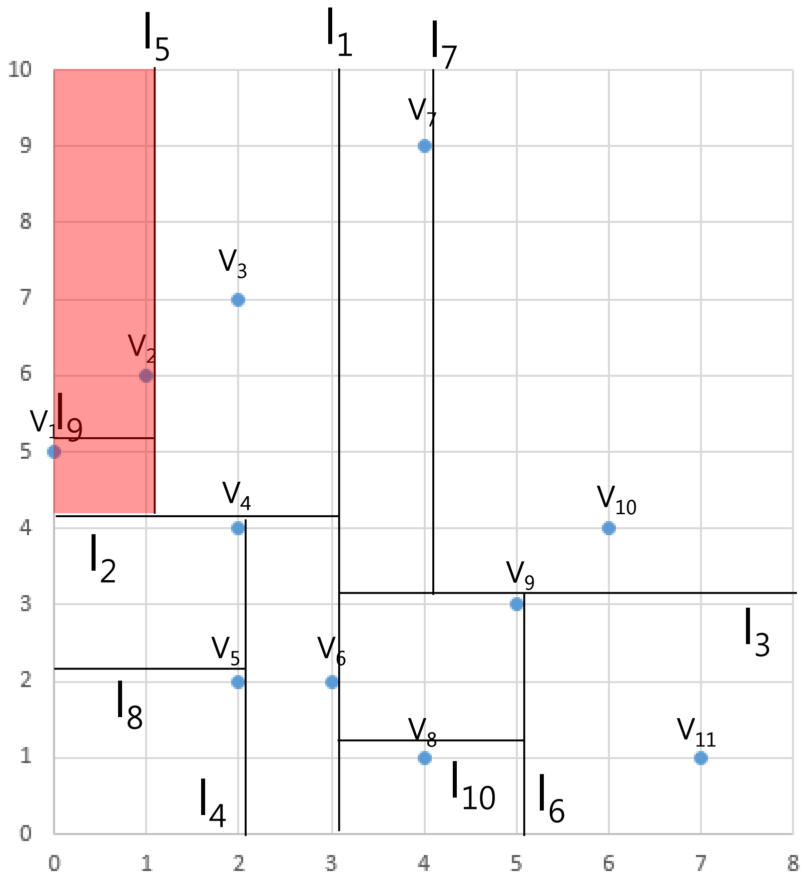
Geometric Meaning

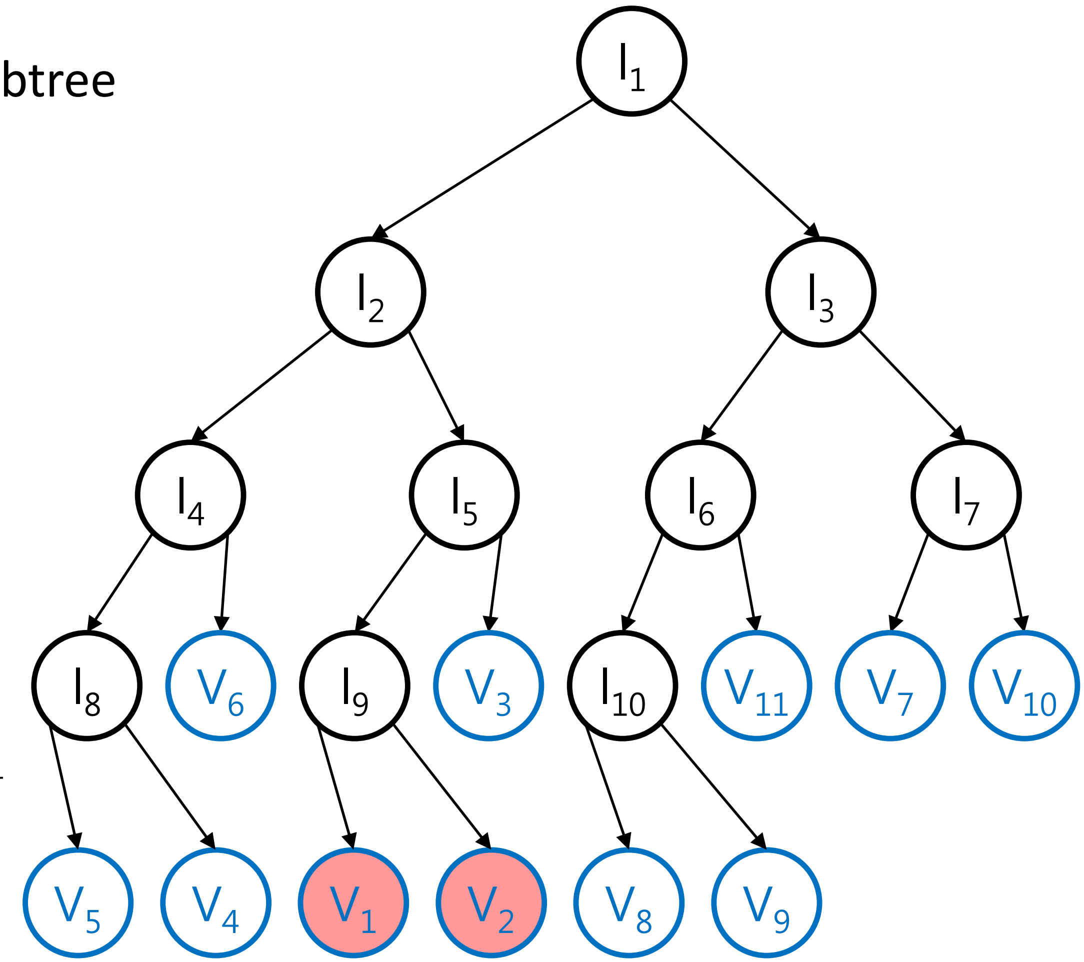
- l_2 노드의 후손들은 0축의 값이 3보다 작거나 같은 data



Geometric Meaning

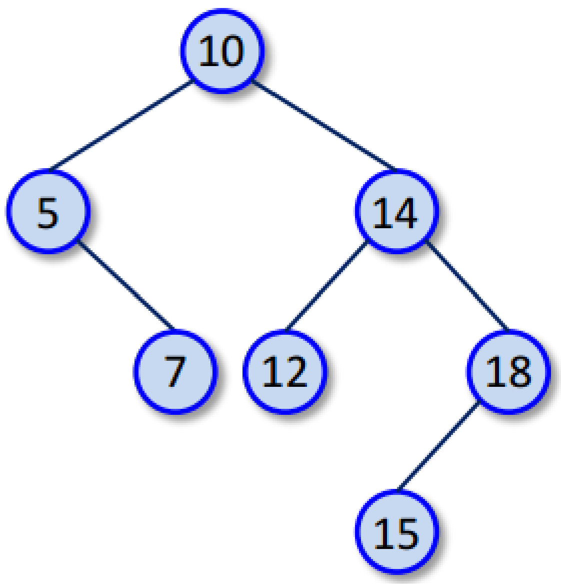
- l_9 노드의 후손들은 …
  - l_5의 left subtree
  - (l_2의 right subtree)의 left subtree





How to Search Region

- 수업시간에 BST는 find만 배웠음 → kd-tree의 find도 쉽고 빠르다!
- 구간 검색은 어떻게 할까.
  - Get data in [9, 15]



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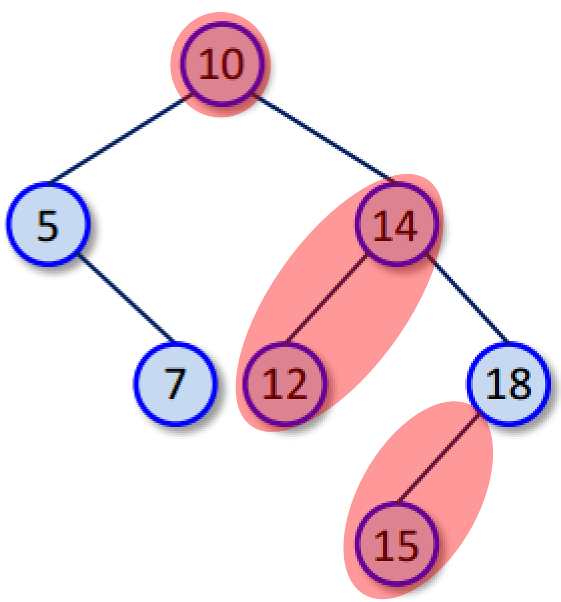
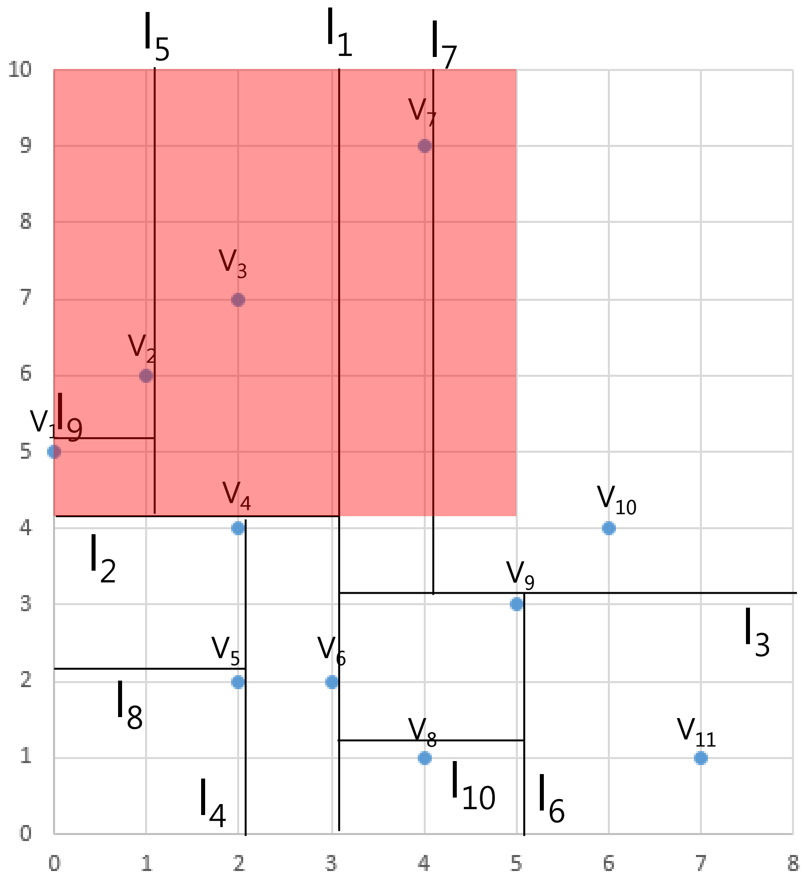


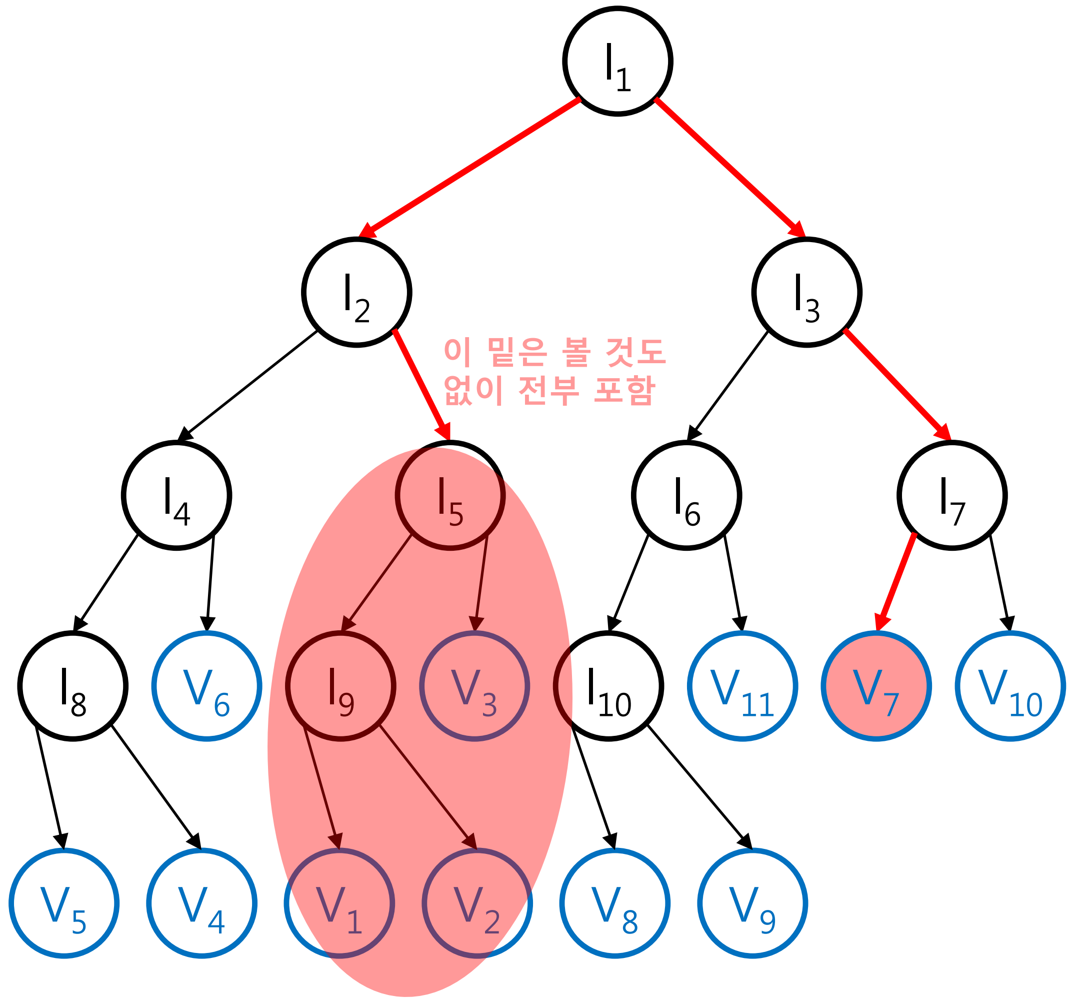
정렬할 필요 없음

10	12	14	15

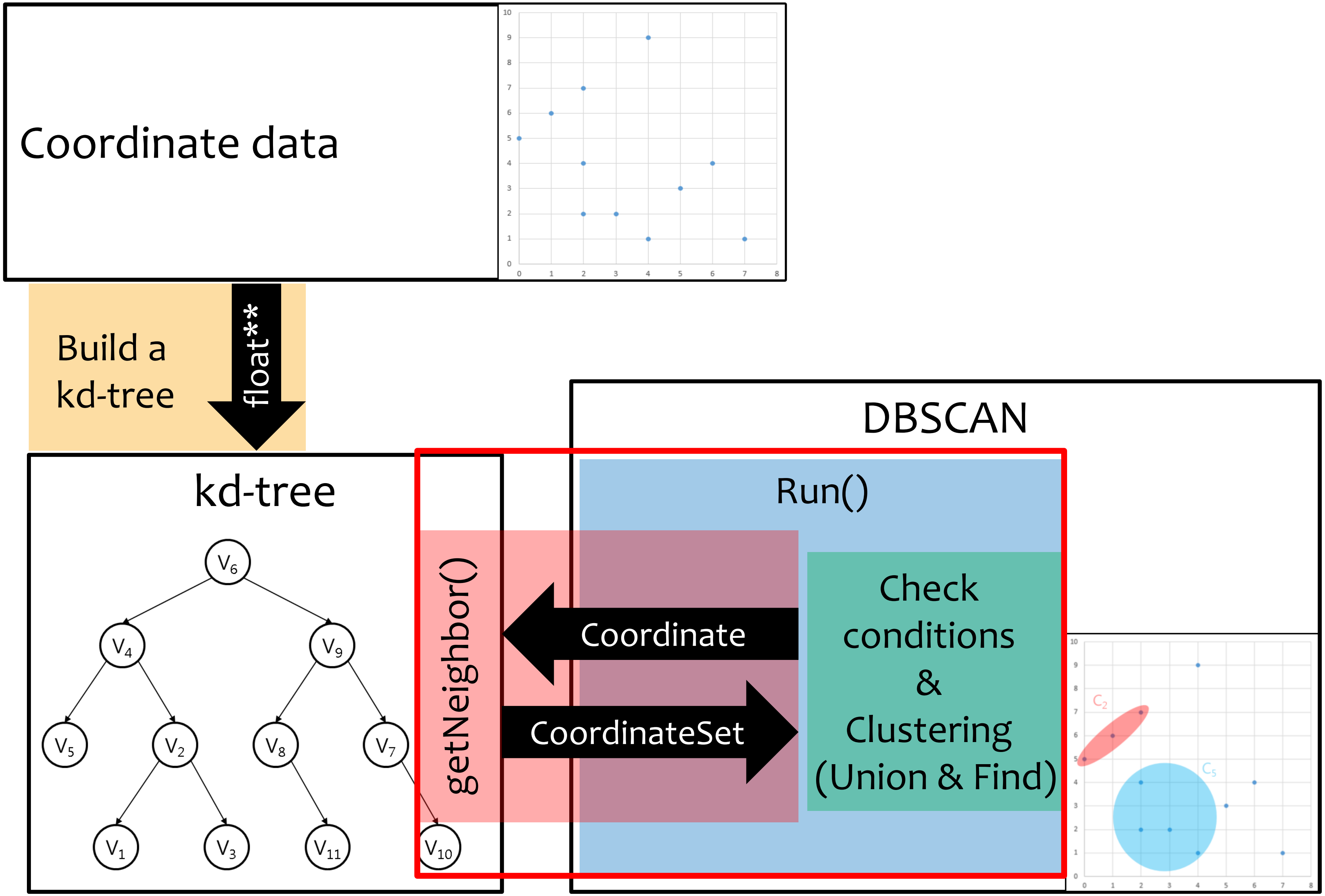
How to Search Region

- Get data in (0축 = [- ∞, 5] , 1축 = (4, ∞])





DBSCAN Overview: DBSCAN



DBSCAN: Project Algorithm

- Disjoint set 사용
  - Union & Find operation을 사용해 DBSCAN 알고리즘 진행

Algorithm 2 The disjoint-set data structure based DBSCAN Algorithm (DSDBSCAN). Input: A set of points X, distance eps, and the minimum number of points required to form a cluster, $minpts$. Output: A set of clusters.

procedure DSDBSCAN($X, eps, minpts$)
    for each point $x \in X$ **do**
        $p(x) \leftarrow x$
    for each point $x \in X$ **do**
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        if $|N| \geq minpts$ **then**
            mark x as core point
            for each point $x' \in N$ **do**
                if x' is a core point **then**
                    UNION(x, x')
                else if x' is not yet member of any cluster **then**
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※ input point 순서대로
for문이 진행되도록 하면,
구현에 따라 결과 달라지지 않음.

DBSCAN: Project Algorithm

- 먼저 모든 point의 parent를 자기 자신으로
  - 수업시간의 Make-Set(x)와 동일한 역할

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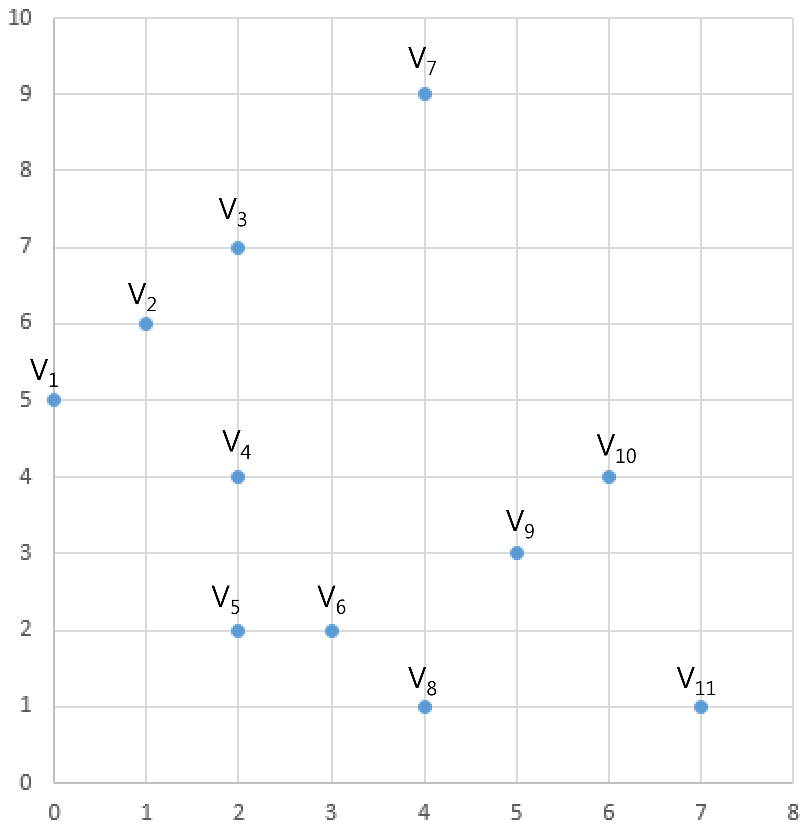

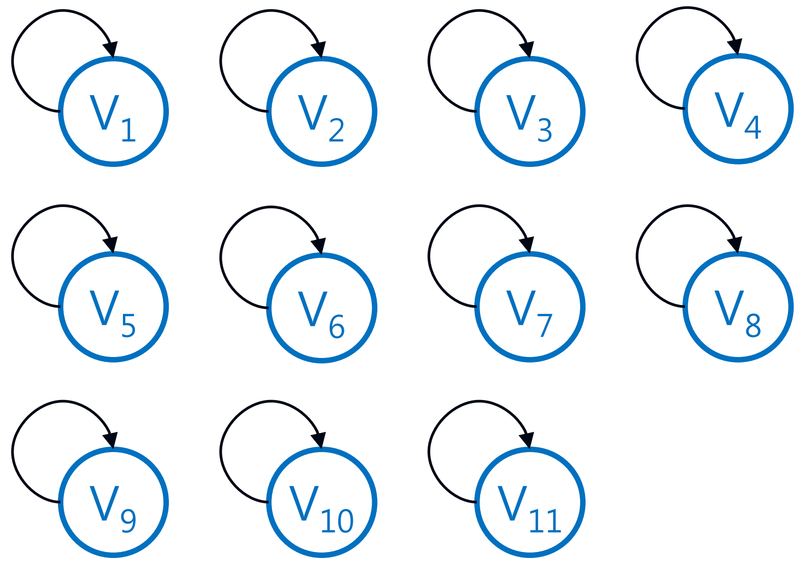

DBSCAN: Project Algorithm

- 각 point들의 ε-neighbor를 검색
  - kd-tree 로부터 얻을 수 있음

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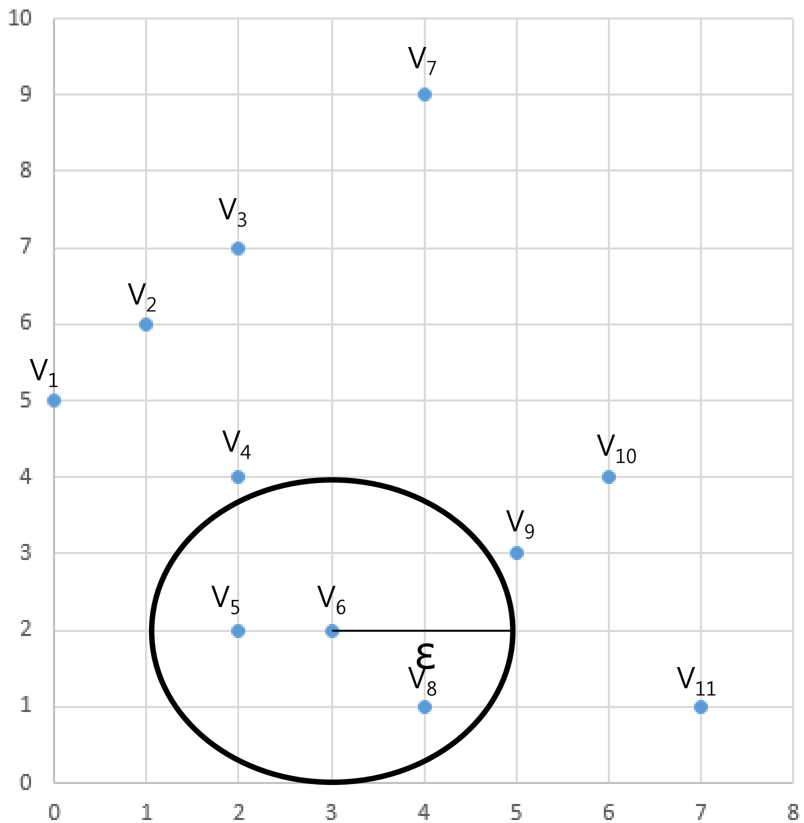

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V_2: V_1, V_3
V_3: V_2
V_4: V_5
V_5: V_4, V_6
V_6: V_5, V_8
V_7:
V_8: V_6
V_9: V_{10}
V_{10}: V_9
V_{11}:

DBSCAN: Project Algorithm

- Core point 조건 (if문) 을 만족하는 point들에 대해서 알고리즘 진행
  - Core point 만족조건 예시: neighbor가 2개 이상

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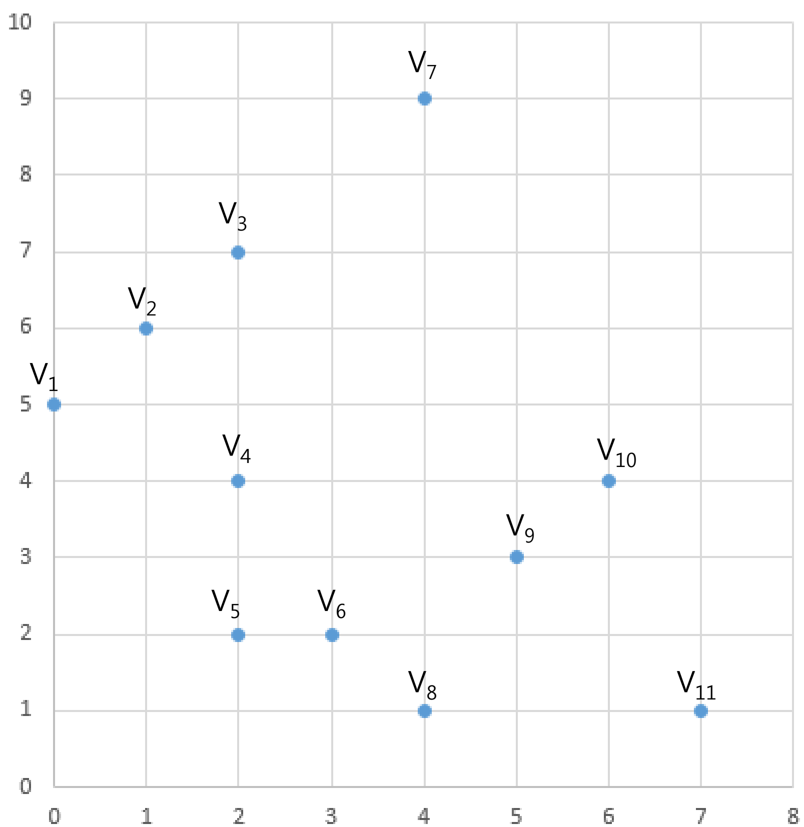

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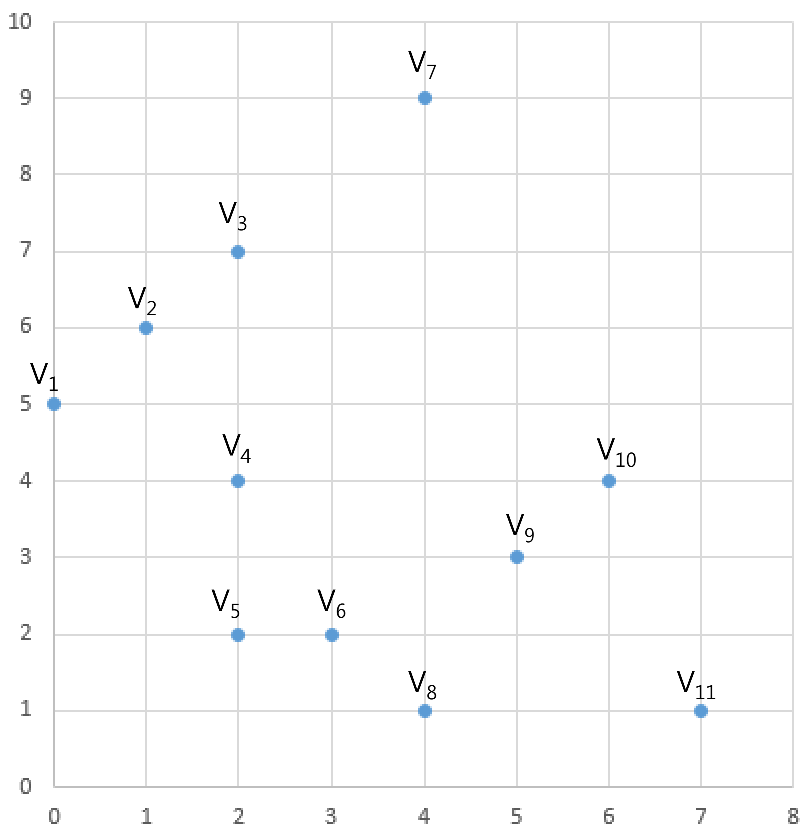

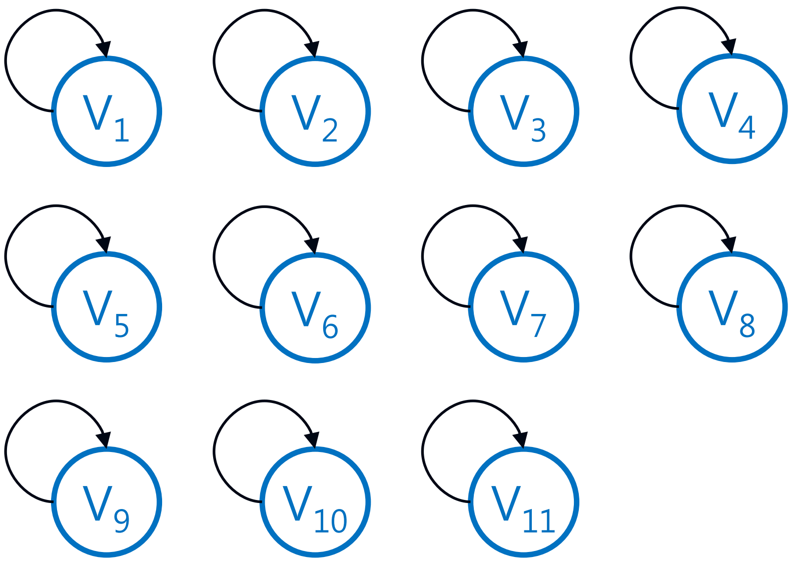

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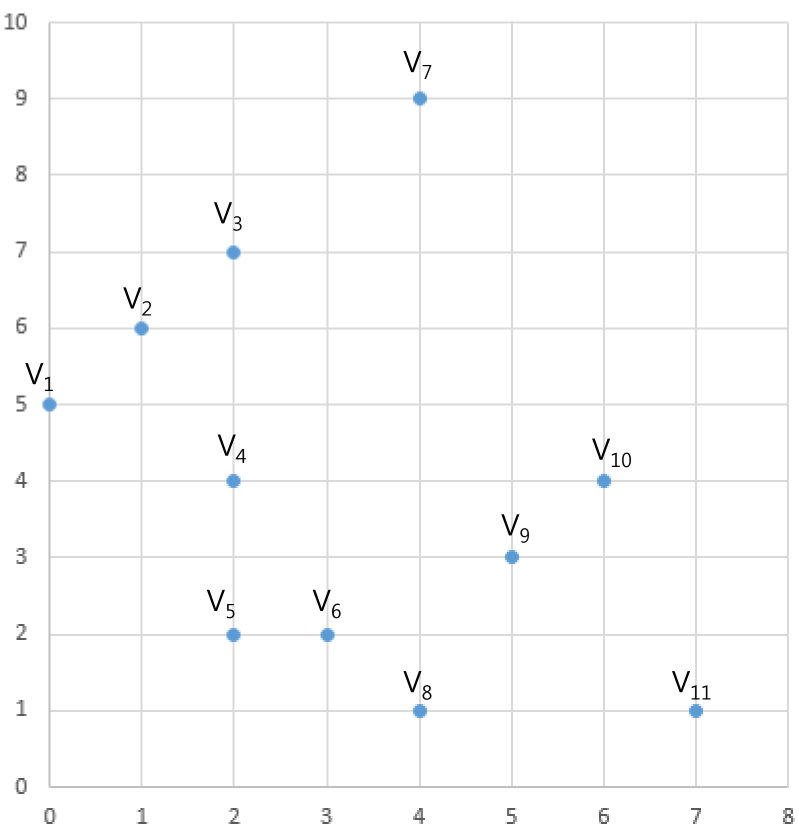

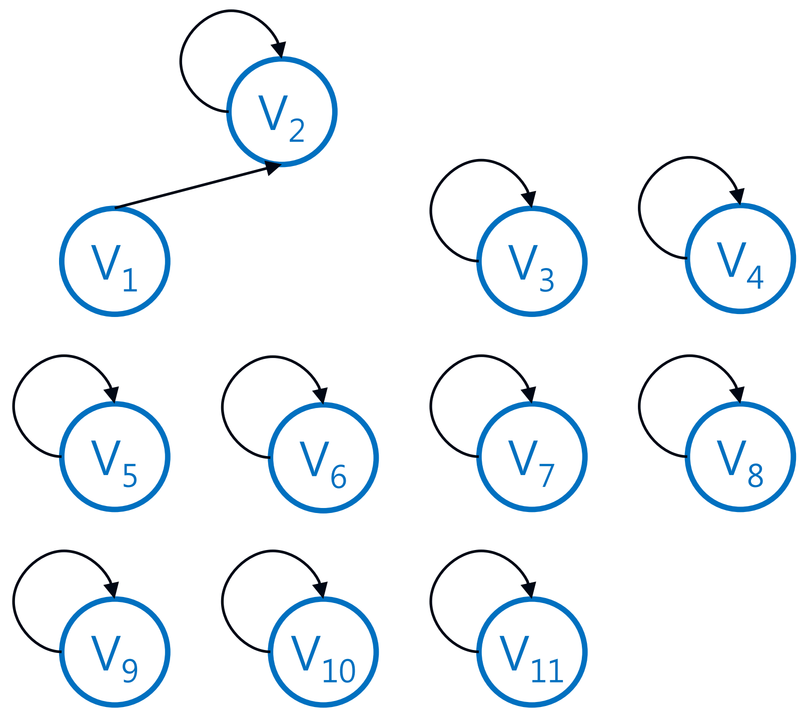

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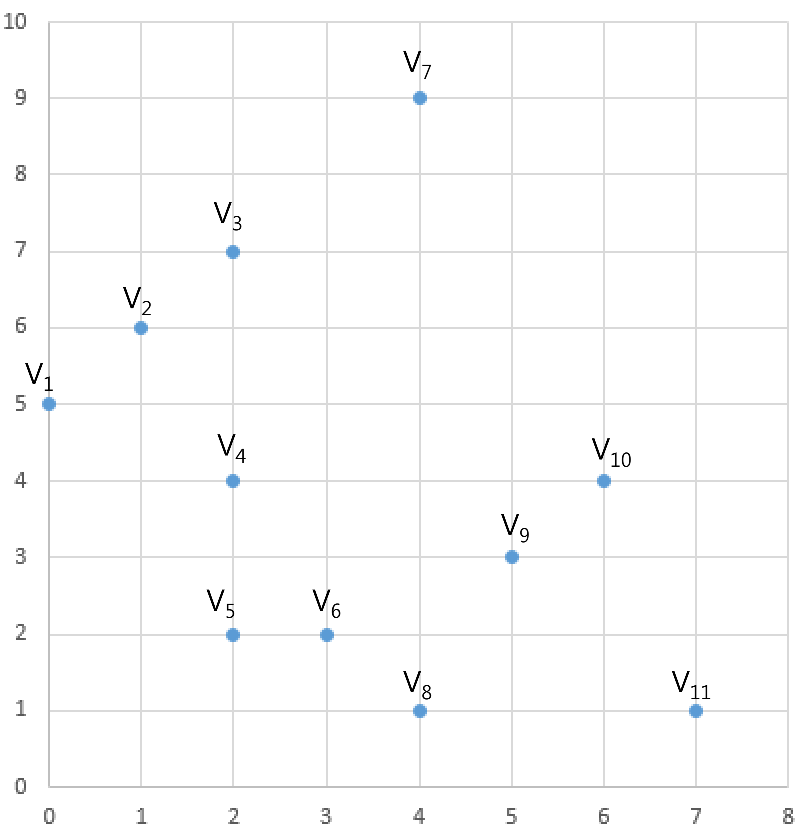

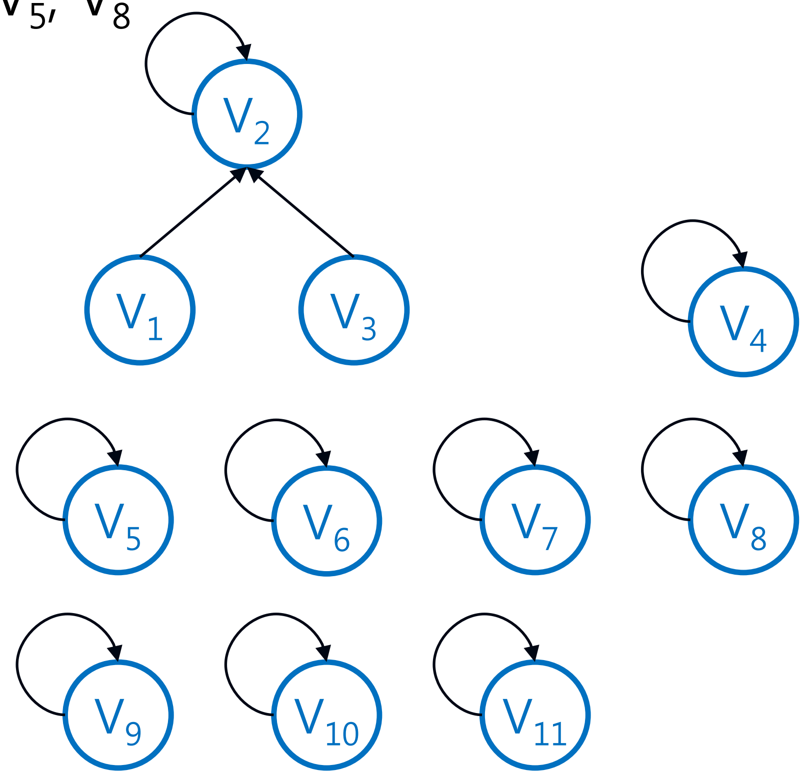

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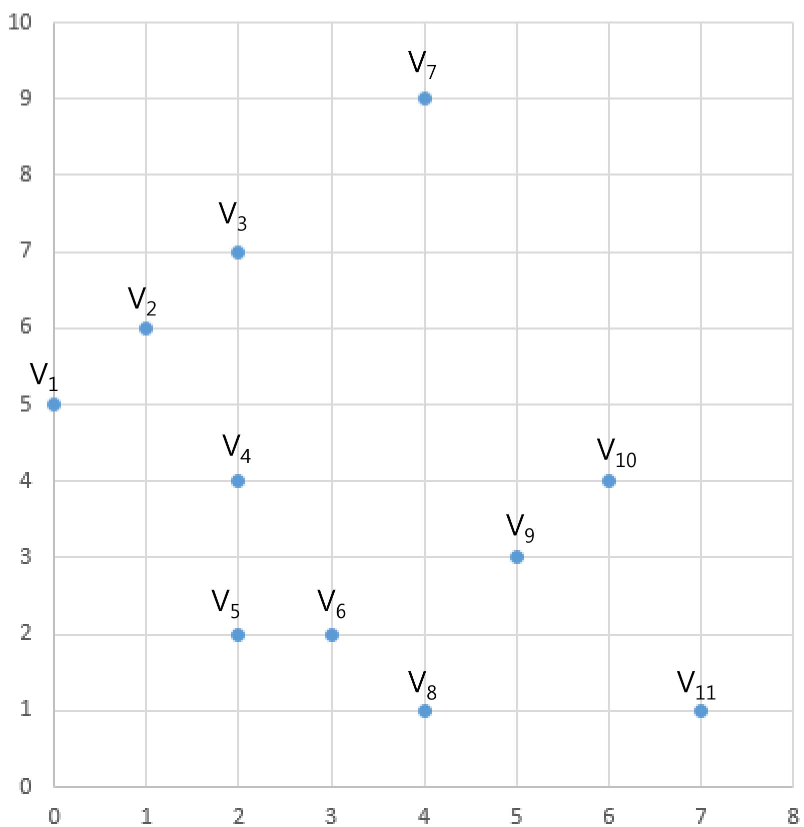

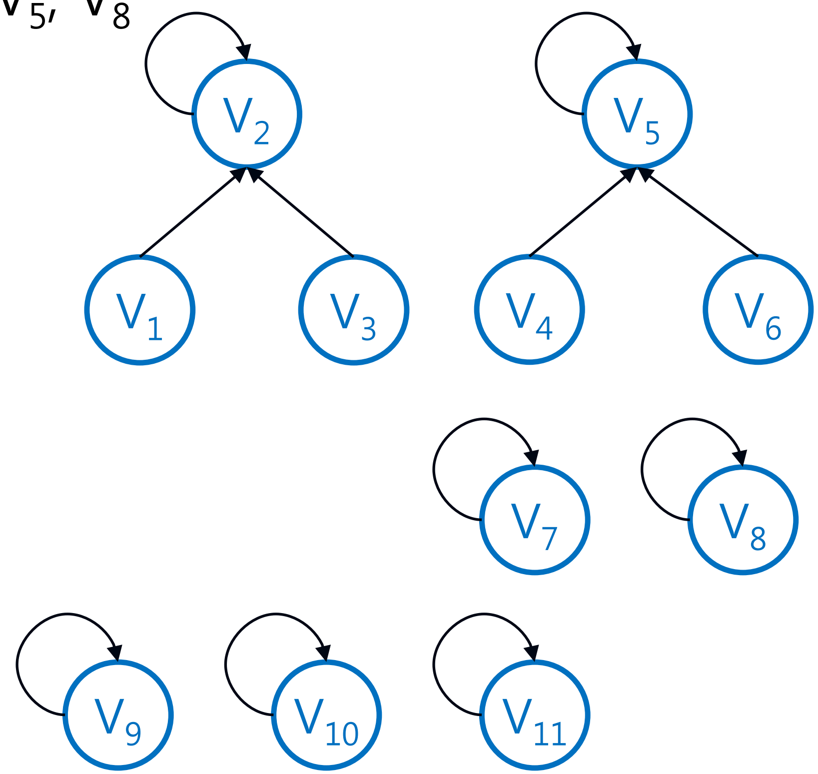

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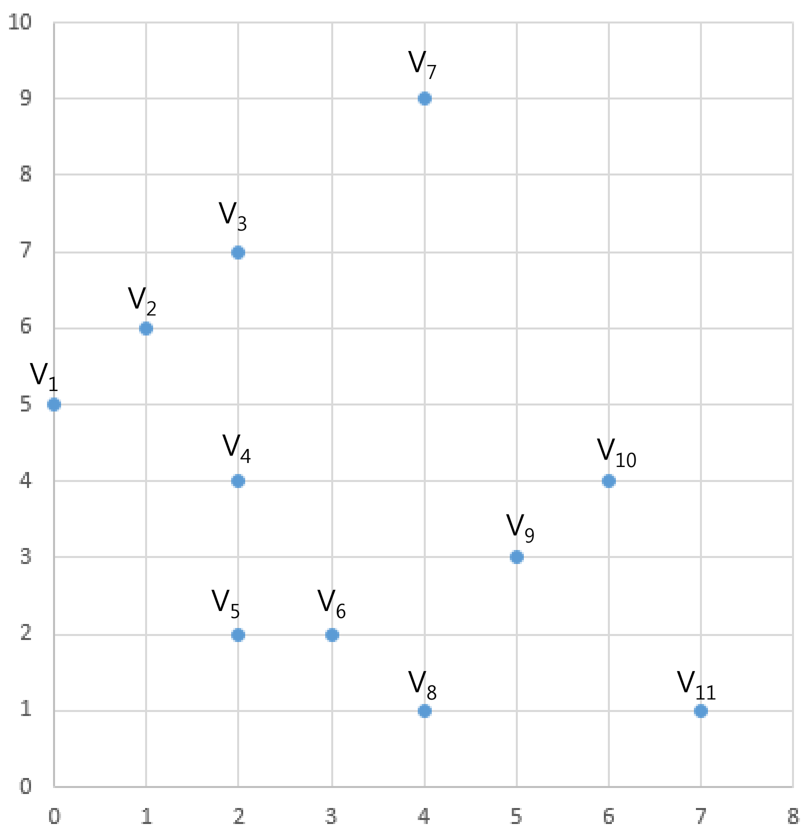

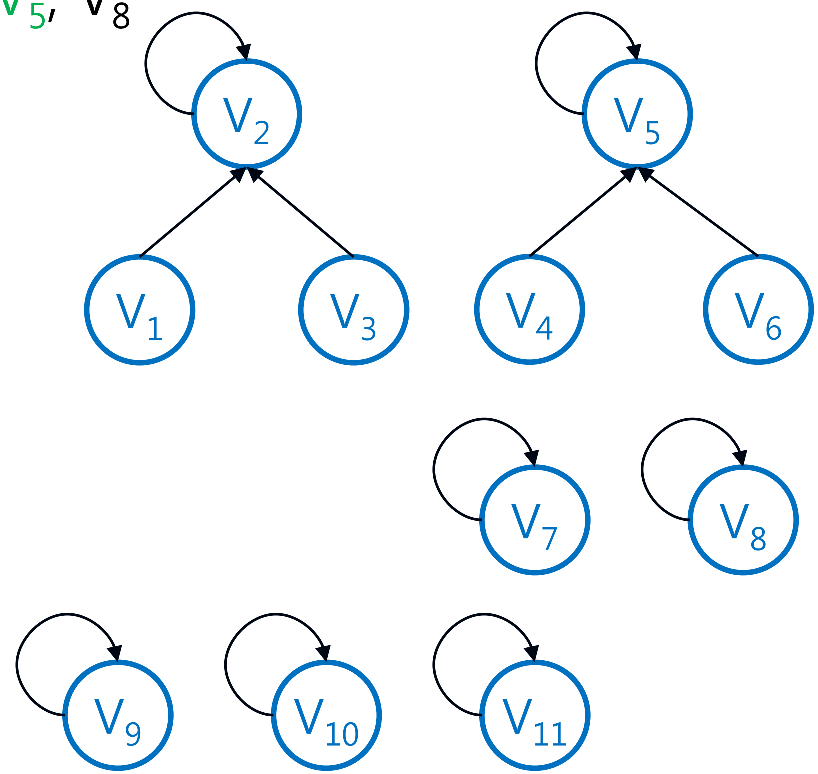

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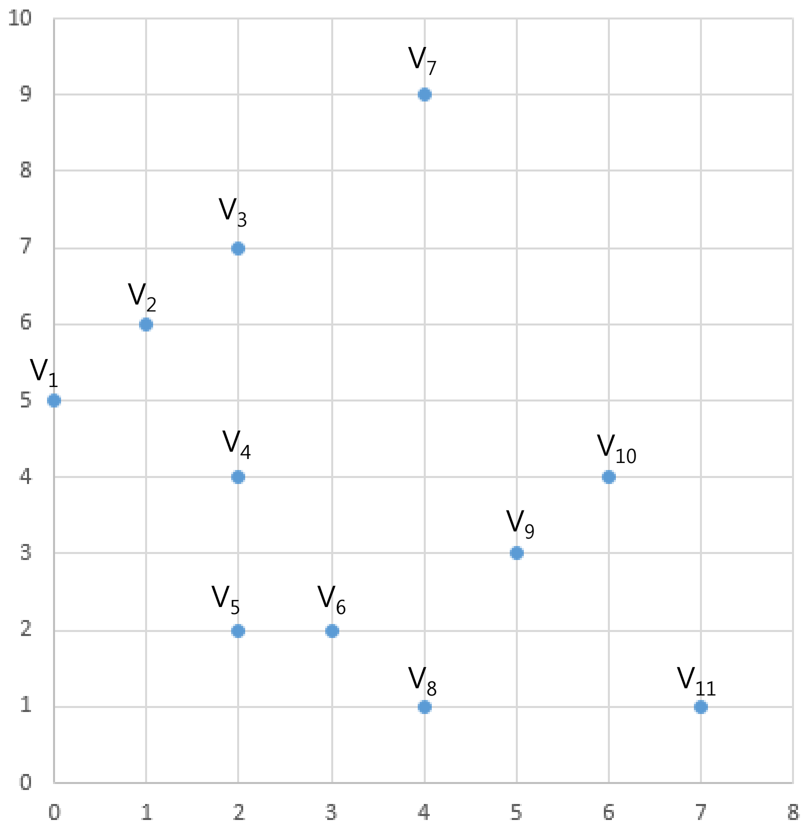
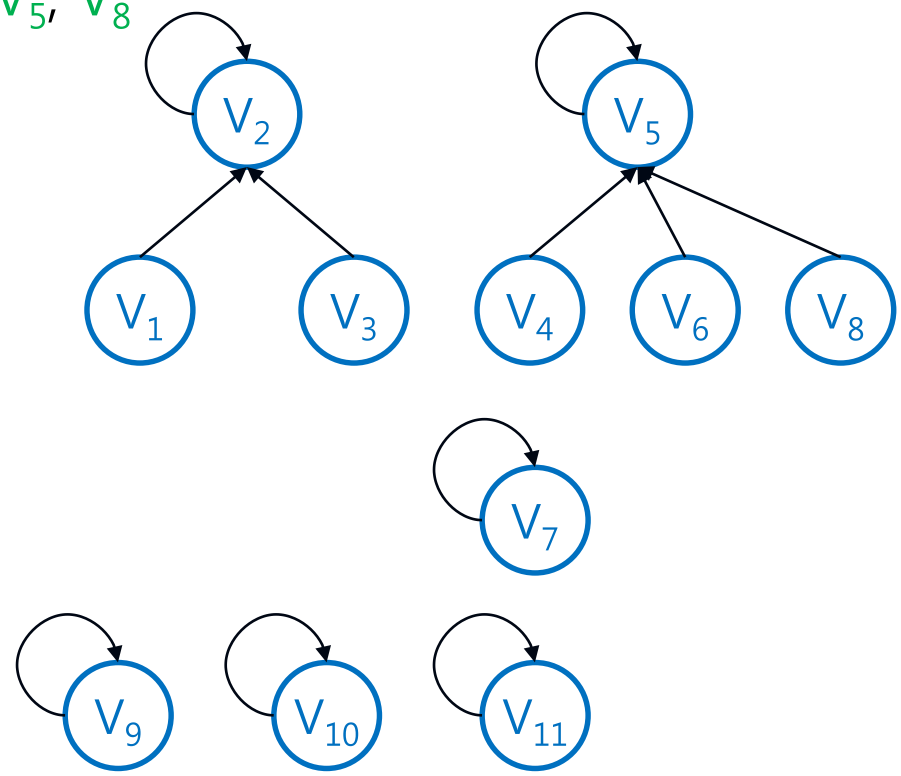
V_5: V_4, V_6

V_6: V_5, V_8



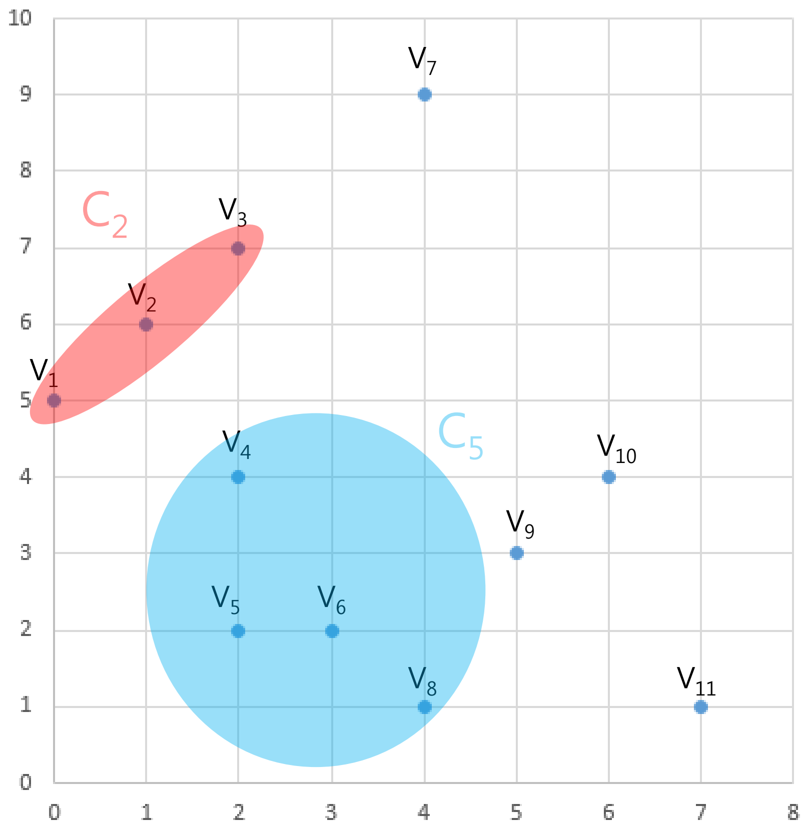


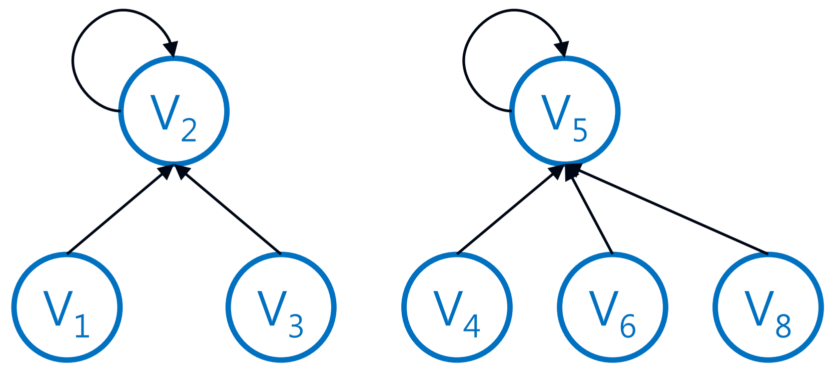
DBSCAN: Project Algorithm

- Output은 각 point가 어떤 cluster에 속하는지 출력 (cout 이용)
  - Cluster id는 root point id로 출력
  - Noise는 -1로 출력

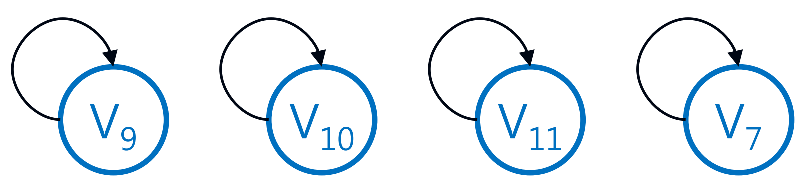
Algorithm 2 The disjoint-set data structure based DBSCAN Algorithm (DSDBSCAN). Input: A set of points X, distance eps, and the minimum number of points required to form a cluster, $minpts$. Output: A set of clusters.

procedure DSDBSCAN($X, eps, minpts$)
  for each point $x \in X$ **do**
    $p(x) \leftarrow x$
  for each point $x \in X$ **do**
    $N \leftarrow$ GETNEIGHBORS(x, eps)
    if $|N| \geq minpts$ **then**
      mark x as core point
      for each point $x' \in N$ **do**
        if x' is a core point **then**
          UNION(x, x')
        else if x' is not yet member of any cluster **then**
          mark x' as member of a cluster
          UNION(x, x')

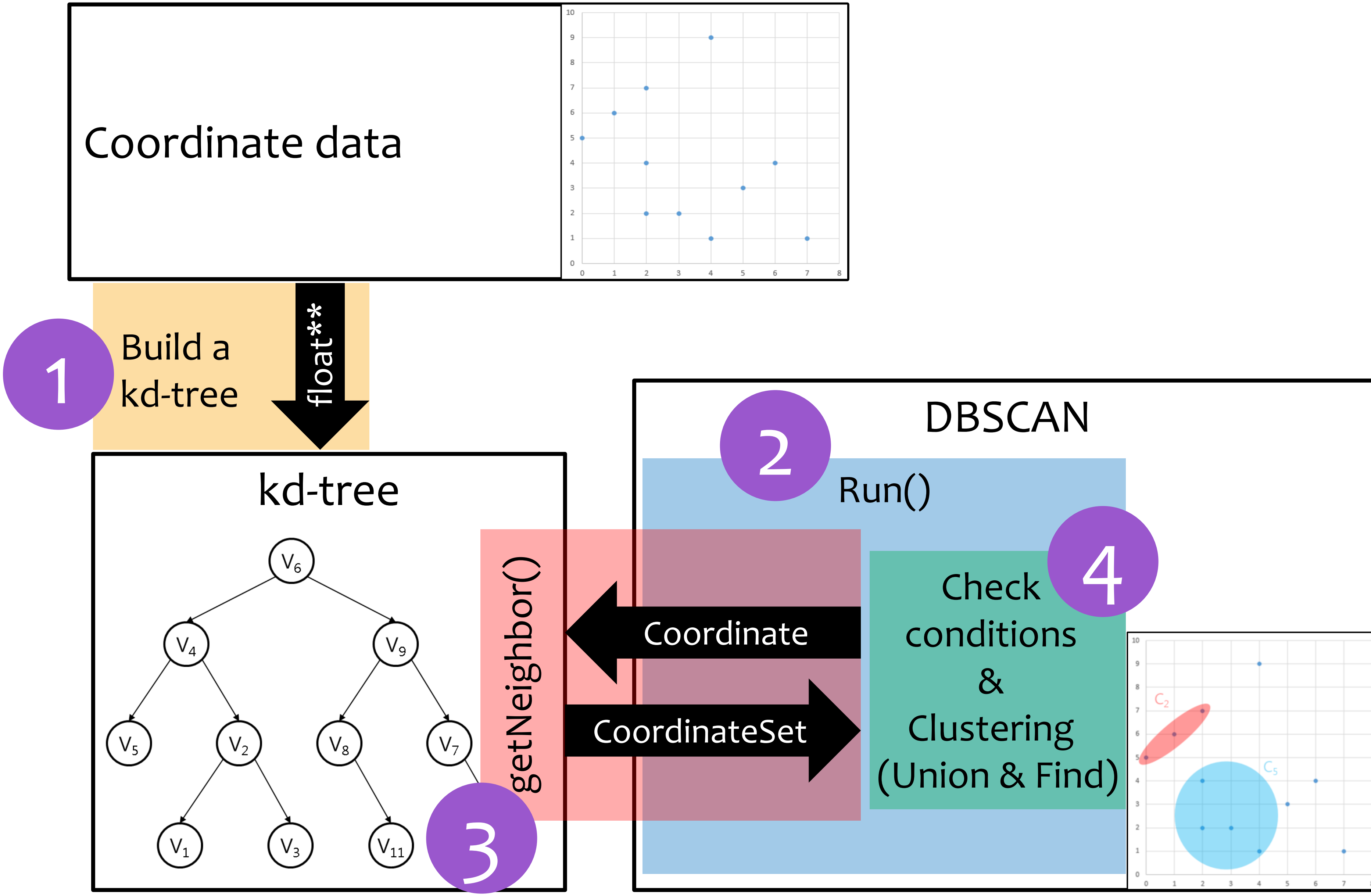




나머지는 noise



DBSCAN Overview



Project Information

Project

- 최소 필요 class
  - Coordinate
  - CoordinateSet
  - KDtree
  - DBSCAN
  - Class들의 디자인 (member variables, functions) 은 직접 생각할 것.
  - 이 외 class 추가해도 된다. (disjoint set class, container class)

각 class들의 제시된 함수들 반드시 구현

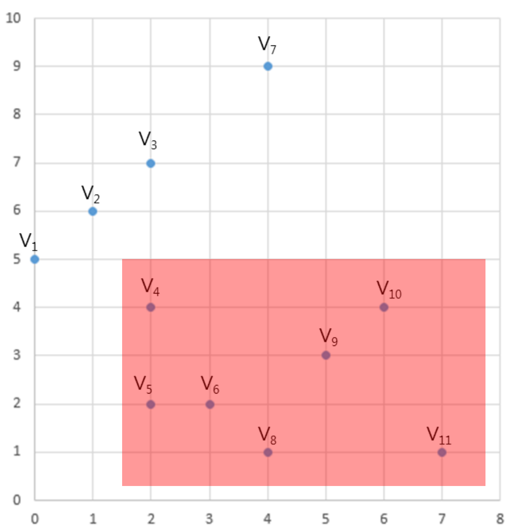
- Member function들 input/output 예시

예: foo()
    Input: int a, float b
    Output: CoordinateSet cset

1. CoordinateSet foo(int a, float b)
2. CoordinateSet* foo(int a, float b)
3. CoordinateSet& foo(int& a, float* b)
4. void foo(int a, float b, CoordinateSet* cset)
5. void foo(int a, float b, CoordinateSet& cset)
6. ...

Project

- Coordinate class
  - 좌표 데이터를 저장하는 저장 class
- CoordinateSet class
  - 여러 Coordinate object (좌표데이터) 들을 저장하는 저장 class
  - print()
    - Input과 Output은 없으나, cout을 이용하여 다음과 같이 출력할 것




```
4 (2, 4)
5 (2, 2)
6 (3, 2)
8 (4, 1)
9 (5, 3)
10 (6, 4)
11 (7, 1)
```

Point_id (k dimesion 좌표들)

.

.

.

CoordinateSet 안에 있는
point id 순서대로 출력

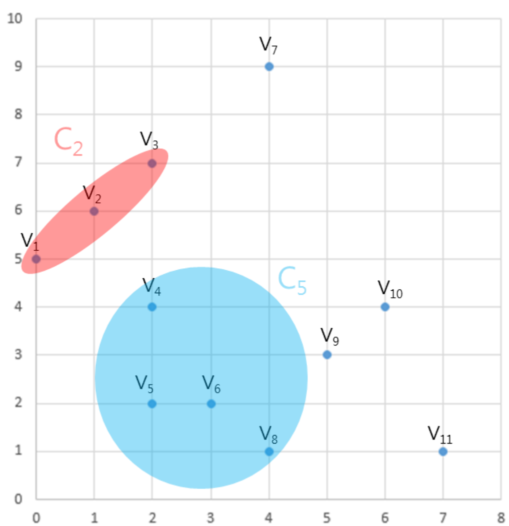
예시에서는 2D이기 때문에 (x, y) 출력
만약 4D라면 (a, b, c, d) 로 출력

Project

- KDtree class
  - Constructor
    - Input: k-dimensional point들의 좌표 (float** points) → n x k 행렬
    - Input: dimension (int dimension)
    - Input: point 개수 (int numOfPoints)
  - getNeighbors()
    - Input: query point 좌표 (Coordinate queryPoint)
    - Input: query radius 길이 (float radius)
    - Output: query 결과 검색된 k-dim point들의 좌표
      (CoordinateSet neighborPoints)

Project

- DBSCAN class (project algorithm 구현)
  - Constructor
    - Input: 만들어둔 KDtree (KDtree& kdtree)
    - Input: DBSCAN parameter ε (float epsilon)
    - Input: core point가 되기 위한 neighbor의 최소 개수 (int minPoints)
      (= cluster를 이루기 위한 최소 개수)
  - run()
    - Input과 Output은 없으나, cout을 이용하여 다음과 같이 출력할 것




```
1 2
2 2
3 2
4 5
5 5
6 5
7 -1
8 5
9 -1
10 -1
11 -1
```

Point_id cluster_id

.

.

.

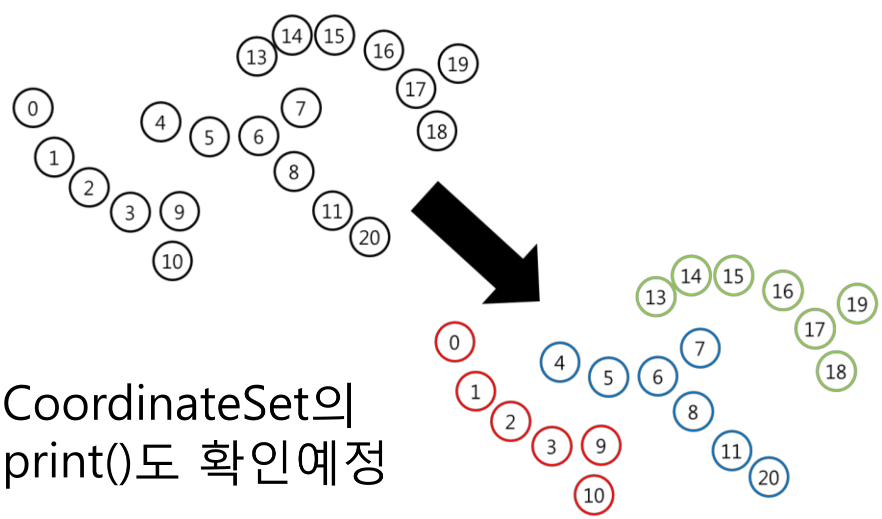
Point id 순서대로 출력

Project 주의사항

- Input 관련
  - Input은 k-dimensional point들의 좌표들이 float** 타입으로 main에서 주어질 것이고, 이는 KDtree를 생성할 때 parameter로 들어갈 것.
  - Point의 index는 input 순서대로 할당하고 **0부터 시작**한다.
    - 예시에서는 이해를 돕기 위해 1부터 시작.

- Test 관련
  - 자신이 구현한 알고리즘을 확인하기 위해 여러 test를 해볼 것.
  - Test 코드는 다음과 같다.

```
void test()
{
    float** data = ...;
    KDtree myTree(data, 2, 20);
    DBSCAN myDBSCAN(myTree, 0.5, 3);
    myDBSCAN.run();
}
```



CoordinateSet의 print()도 확인예정

Project 주의사항

- 제출 관련
  - 제출 압축파일명: 2015-12345.zip
    - visual studio project 폴더 (“빌드 → 솔루션 정리” 후)
    - Project 보고서

- Project 보고서
  - 개발자의 입장에서, 사용자들에게 배포할 문서라 생각
    - 간결하고 명확한 설명
    - Class들의 디자인 및 관계 (overview)
    - 함수들의 설명: 동작원리·역할 / 사용방법 / input과 output
  - 분량은 평가 요인 아님 (되도록 짧게)
  - 예시
    - https://cran.r-project.org/web/packages/gputools/gputools.pdf
    - http://kr.mathworks.com/help/matlab/ref/plot.html

Project 주의사항

- 채점 관련
  - 채점 방식: On/Off
    - 코드 정확도
      - 주어진 테스트셋에서 동작하면 On, 안 하면 Off
    - 코드 효율성
      - 비 효율적 (Time, Memory) → Off
      - 가이드 무시 → Off
    - 코드 도용 및 공유
      - 학칙에 의거 처리
- 기한
  - 제출: 12월 21일 (월) 23:59 까지
  - 질문: 12월 21일 (월) 18:00 까지