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Data Structure Review

List, Tuple, Set and Dictionary

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PhD in Computer Science

Outline

- Review: Tuples vs. Lists, 2D Lists
- IoU Calculation using Tuples
- NMS Using List and Tuples
- Review: Set and Dictionary
- One-Hot Encoding Using Set and Dictionary
- Review: Tree & K-DTree
- K-D Tree Implementation

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1D List Review

❖ A container that can contain elements

list_name = [element-1, …, element-n]

```
// create a list
data = [6, 5, 7, 1, 9, 2]
```

❑ Imputable

```
1.  # danh sách trống
2.  emty_list = []
3.
4.  # danh sách số tự nhiên nhỏ hơn 10
5.  my_list = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
6.
7.  # danh sách kết hợp nhiều kiểu dữ liệu
8.  mixedList = [True, 5, 'some string', 123.45]
9.  n_list = ["Happy", [2,0,1,5]]
10.
11. #danh sách các loại hoa quả
12. shoppingList = ['táo', 'chuối', 'cherries', 'dâu', 'mận']
```

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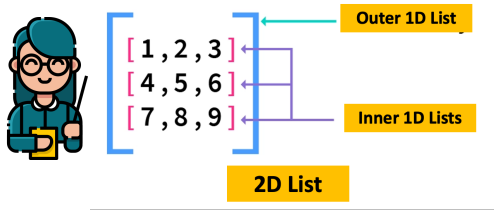
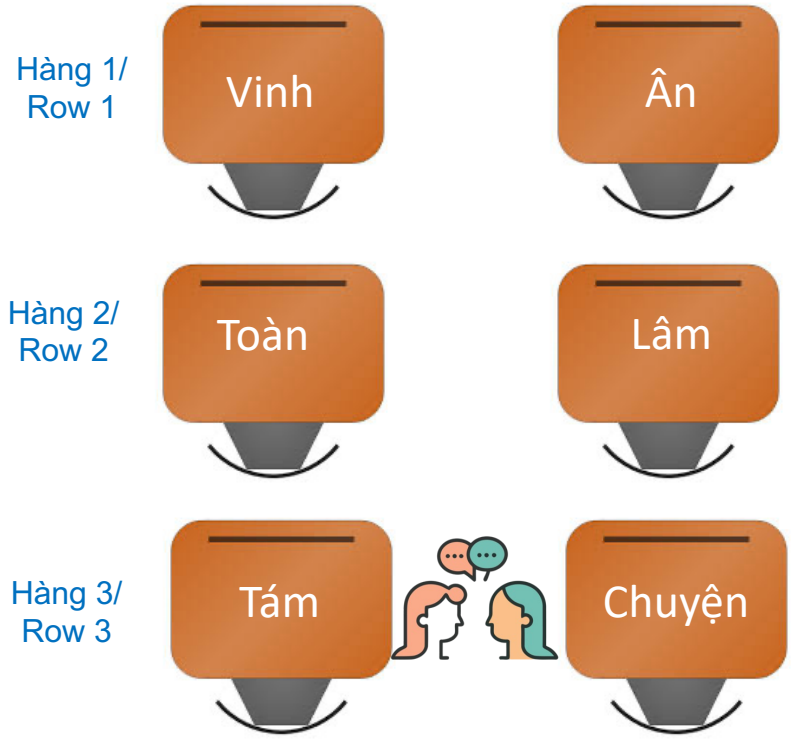
From 1D to 2D List





Given that the teacher cannot remember students' names, please develop a program to help her find a student's name based on his/her seat location in the class.

"Cô mời 2 bạn: ngồi ở vị trí hàng thứ 3, dãy thứ 1, và ngồi ở vị trí hàng thứ 3, dãy thứ 2" lên bảng giải thích về 2D List

"Cô mời bạn Tám và bạn Chuyện" lên bảng giải thích về 2D List

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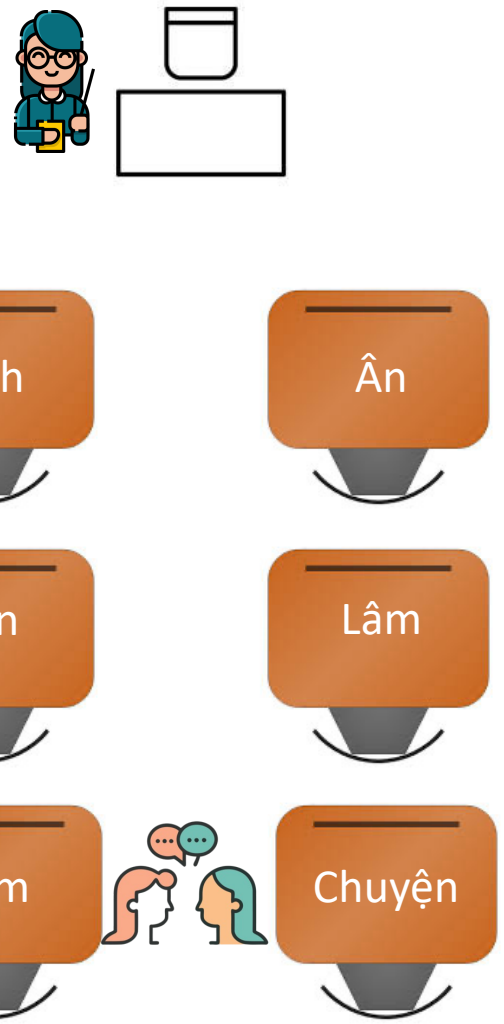
From 1D to 2D List




```python
student_list = ["Vinh", "An", "Toan", "Lam", "Tam", "Chuyen"]
row_class = 3
col_class = 2
def find_student(student_list, r, c):
    index = (r-1)*col_class + (c-1)
    return student_list[index]

#Find student a location (3, 1)
print(find_student(student_list, 3, 1))

#Find student a location (3, 2)
print(find_student(student_list, 3, 2))
```

```
Tam
Chuyen
```

Are there any easier solutions? This one is really difficult for newcomers

From 1D to 2D List

Progrogramer View

	Column index 0	Column index 1
Row index 0	Vinh	An
Row index 1	Toan	Lam
Row index 2	Tam	Chuyen

Teacher View

	Column 1	Column 2
Row 1	Vinh	An
Row 2	Toan	Lam
Row 3	Tam	Chuyen

Use 1D List	Vinh	An
Use 1D List	Toan	Lam
Use 1D List	Tam	Chuyen

student_list = [element1, element2, element3)

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From 1D to 2D List

Teacher View

	Column 1	Column 2
Row 1	Vinh	An
Row 2	Toan	Lam
Row 3	Tam	Chuyen

	Column index 0	Column index 1
Row index 0	Vinh	An
Row index 1	Toan	Lam
Row index 2	Tam	Chuyen

Progrogramer View

```
row1_student = ["Vinh", "An"] #1D List
row2_student = ["Toan", "Lam"] #1D List
row3_student = ["Tam", "Chuyen"] #1D List

student_list = [row1_student, row2_student, row3_student] # 2D List
```

How to access element:
row 0 and column 1
row 0 and column 2

row1_retrieve = student_list[0] → Vinh | An

row1_retrieve[0] → Vinh

row1_retrieve[1] → An

student_list[0][0] → Vinh

student_list[0]1] → An

From 1D to 2D List

	Column 1	Column 2
Row 1	Vinh	An
Row 2	Toan	Lam
Row 3	Tam	Chuyen

Teacher View

	Column index 0	Column index 1
Row index 0	Vinh	An
Row index 1	Toan	Lam
Row index 2	Tam	Chuyen

Progrogramer View

```python
row1_student = ["Vinh", "An"] #1D List
row2_student = ["Toan", "Lam"] #1D List
row3_student = ["Tam", "Chuyen"] #1D List

student_list = [row1_student, row2_student, row3_student] # 2D List

num_row = len(student_list)
num_col = len(student_list[0])

def find_student(student_list, r, c):
    return student_list[r-1][c-1]

#Find student a location (3, 1)
print(find_student(student_list, 3, 1))

#Find student a location (3, 2)
print(find_student(student_list, 3, 2))
```

```
Tam
Chuyen
```

Thanks! This one is easy to understand

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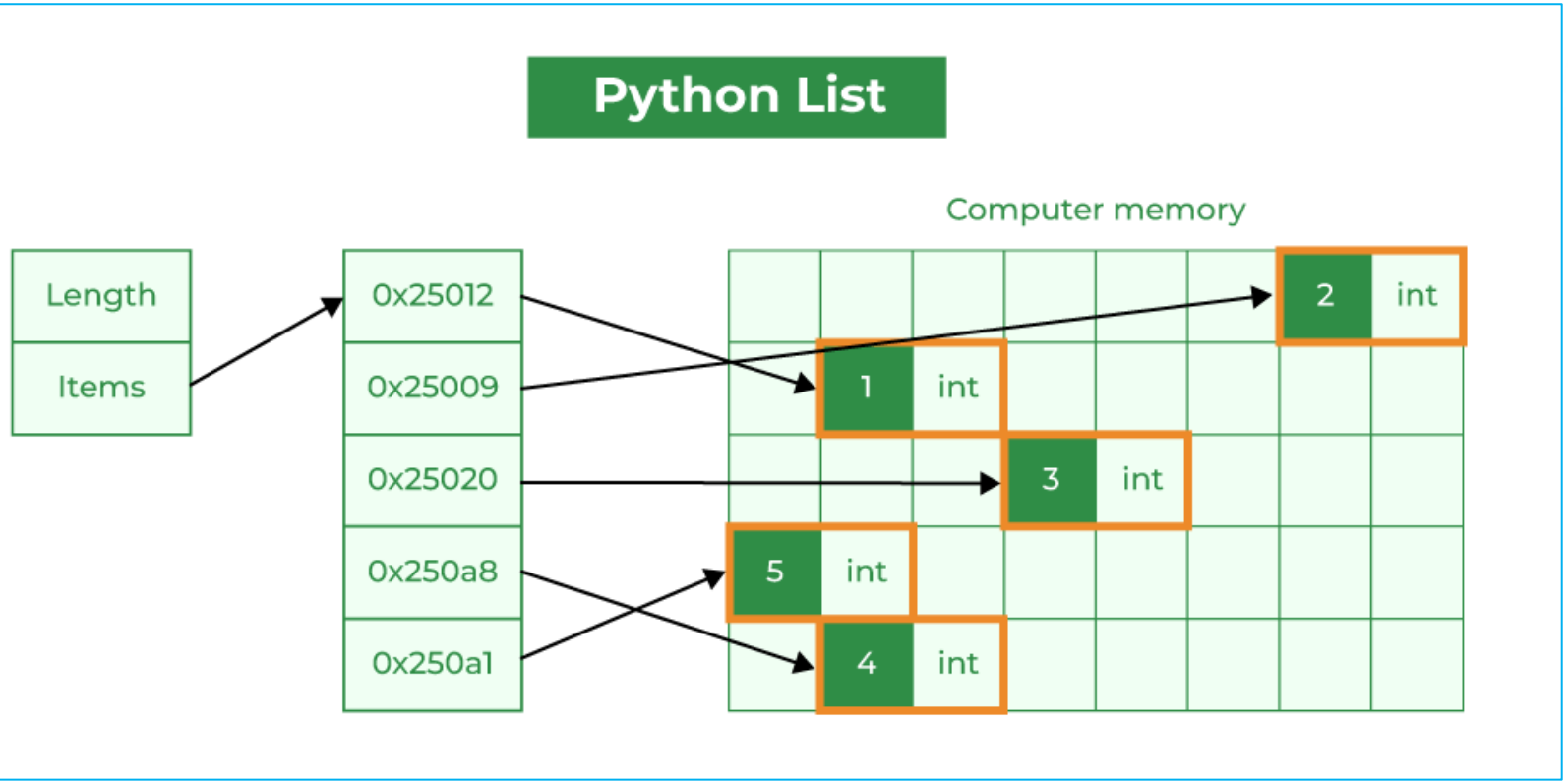
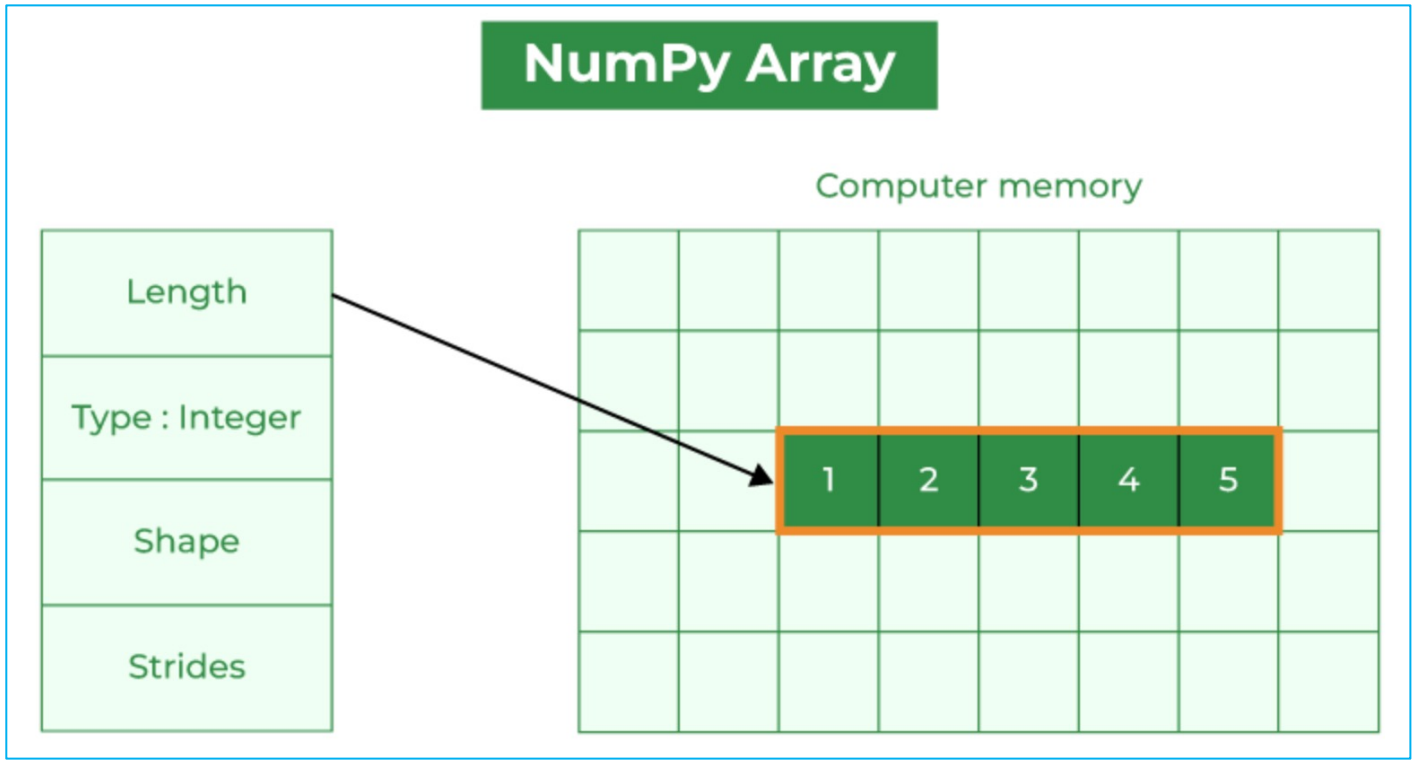
Python List Limitations



1.Element Overhead
2.Datatype
3.Memory Fragmentation
4.Performance
5.Functionality

NumPy Array Motivation



1.Homogeneous Data
2.Fixed Data Type
3.Contiguous Memory
4.Performance

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1D List/Array Multiplication

array_name = **np.array**[element-1, …, element-n]

list_name = [element-1, …, element-n]

```python
def multiplizeList(size=1000):
  # declaring lists
  list1 = range(size)
  list2 = range(size)

  # capturing time before the multiplication of Python lists
  initialTime = time.time()

  # multiplying elements of both the lists and stored in another list
  resultantList = [(a * b) for a, b in zip(list1, list2)]

  # calculating execution time
  print("Time taken by Lists to perform multiplication:",
    (time.time() - initialTime),
    "seconds")
```

```python
def multiplizeArray(size=1000):
  # declaring arrays
  array1 = numpy.arange(size)
  array2 = numpy.arange(size)

  # capturing time before the multiplication of Numpy arrays
  initialTime = time.time()

# multiplying elements of both the Numpy arrays and stored in another Numpy array
  resultantArray = array1 * array2

# calculating execution time
  print("Time taken by NumPy Arrays to perform multiplication:",
    (time.time() - initialTime),
    "seconds")
```

```
multiplizeList(100000)
multiplizeArray(100000)
```

```
Time taken by Lists to perform multiplication: 0.025510549545288086 seconds
Time taken by NumPy Arrays to perform multiplication: 0.0005364418029785156 seconds
```

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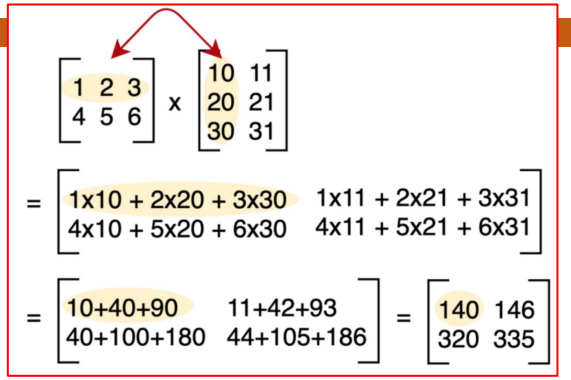
2D List/Array Multiplication



❖ Python List Solution

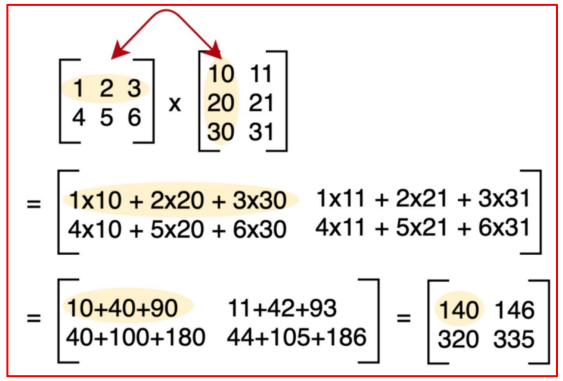
```python
def matrix_multiply(A, B):
    # Get the number of rows and columns for the input matrices
    rows_A, cols_A = len(A), len(A[0])
    rows_B, cols_B = len(B), len(B[0])

    # Ensure the number of columns in A is equal to the number of rows in B
    if cols_A != rows_B:
        raise ValueError("Number of columns in A must be equal to number of rows in B")

    # Initialize the result matrix with zeros
    result = [[0 for _ in range(cols_B)] for _ in range(rows_A)]

    # Perform the matrix multiplication
    for i in range(rows_A):
        for j in range(cols_B):
            for k in range(cols_A):
                result[i][j] += A[i][k] * B[k][j]

    return result
```

```python
# Example matrices
A = [[1, 2, 3],
     [4, 5, 6]]

B = [[7, 8],
     [9, 10],
     [11, 12]]

# Multiply the matrices
result = matrix_multiply(A, B)

# Print the result
for row in result:
    print(row)
```

```
[58, 64]
[139, 154]
```

2D List/Array Multiplication

❖ NumPy Array Solution




```python
import numpy as np

# Define the matrices
A = np.array([
    [1, 2, 3],
    [4, 5, 6]
])

B = np.array([
    [7, 8],
    [9, 10],
    [11, 12]
])

# Multiply the matrices using np.dot
result = np.dot(A, B)

# Alternatively, you can use the @ operator
# result = A @ B

# Print the result
print(result)
```

Tuple Review

- Immutability
- Performance
- Multiple Return Values
- Unpacking

❖ Structure

tuple_name = (element-1, …, element-n)

( ) can be removed

```
1.  t = 1, 2
2.  print(t)
```

```
(1, 2)
```

Tuple with one element

```
1  var1 = (1 + 2) * 5
2  print(type(var1), ' ', var1)
3
4  var2 = (1)
5  print(type(var2), ' ', var2)
6
7  var3 = (1,)
8  print(type(var3), ' ', var3)
```

```
<class 'int'>   15
<class 'int'>   1
<class 'tuple'>   (1,)
```

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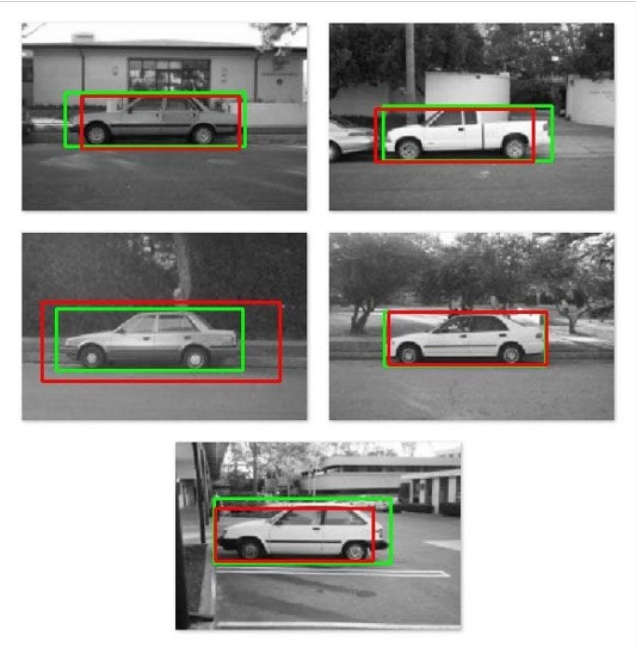
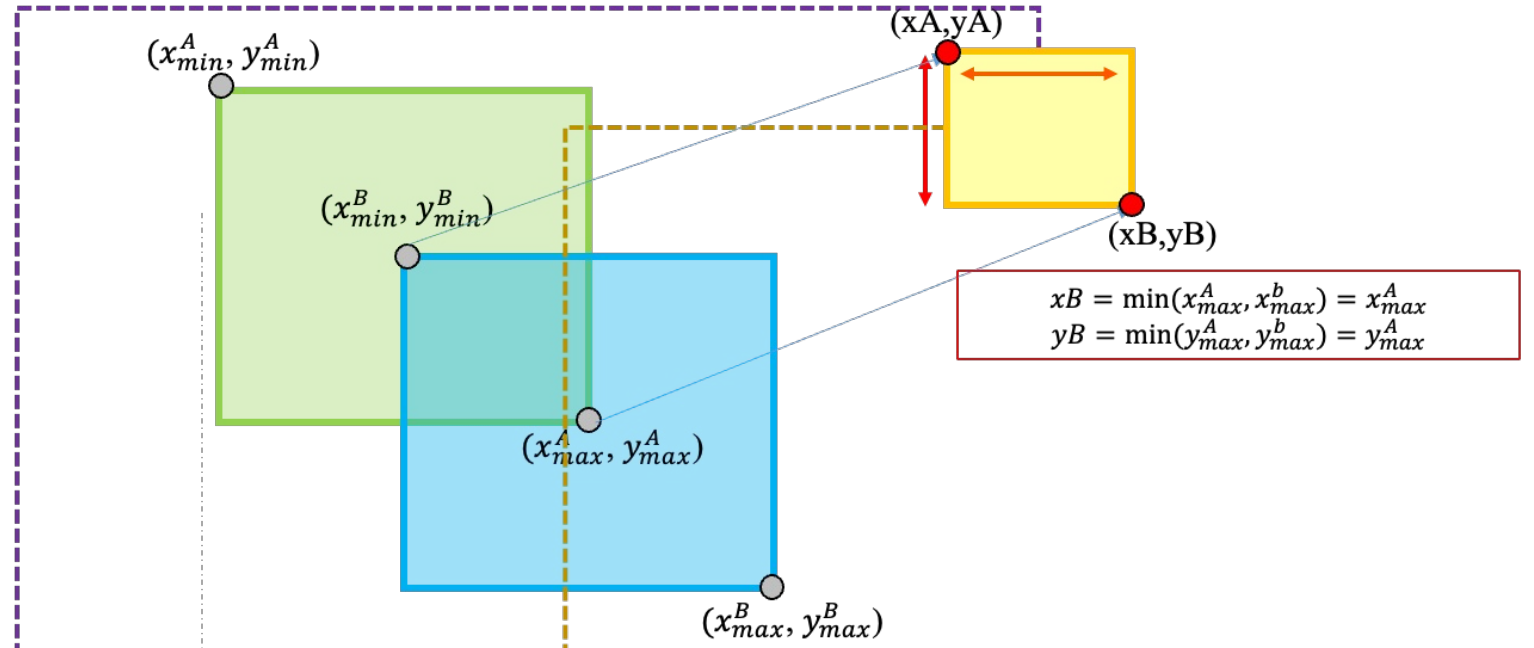
IOU Calculation Using Tuple



$$xA = \max(x^A_{min}, x^b_{min}) = x^b_{min}$$
$$yA = \max(y^A_{min}, y^b_{min}) = y^b_{min}$$

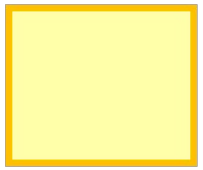


$$xB = \min(x^A_{max}, x^b_{max}) = x^A_{max}$$
$$yB = \min(y^A_{max}, y^b_{max}) = y^A_{max}$$

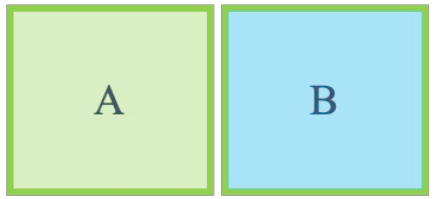
$$W = xB - xA$$

$$H = yB - yA$$

$$A \cap B = W * H$$



Area



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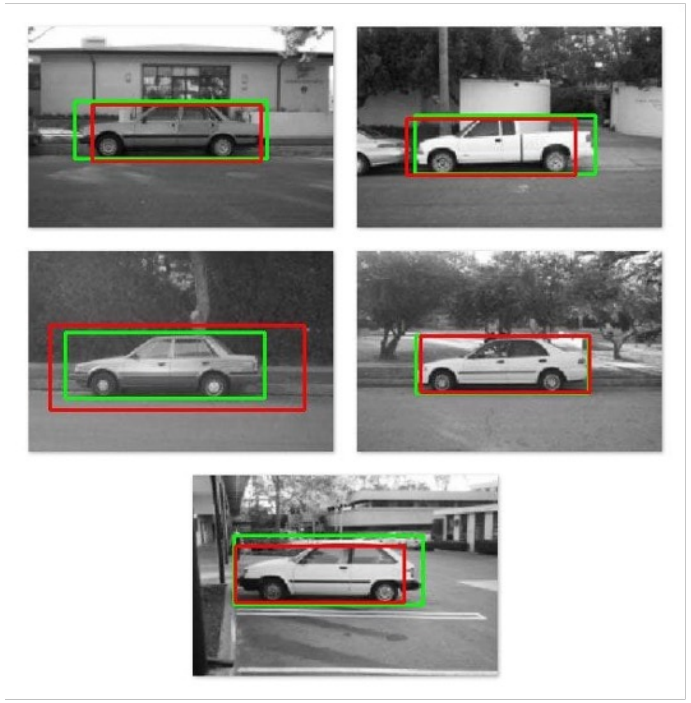
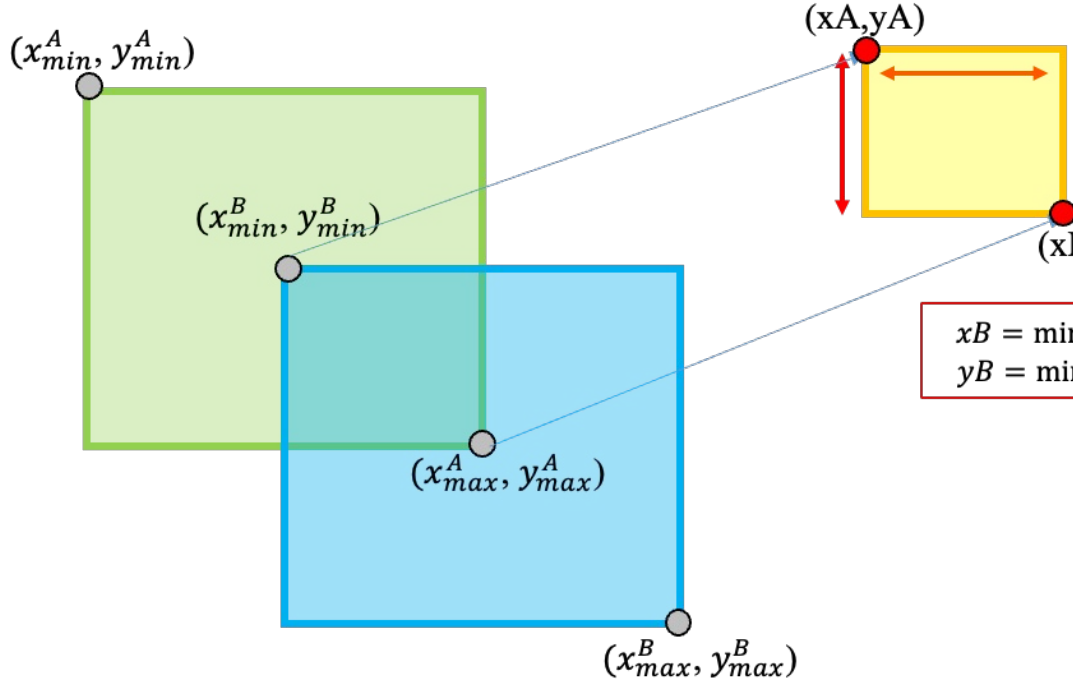
IOU Calculation Using Tuple



Giả sử ta có 2 boxes với thông tin như sau:

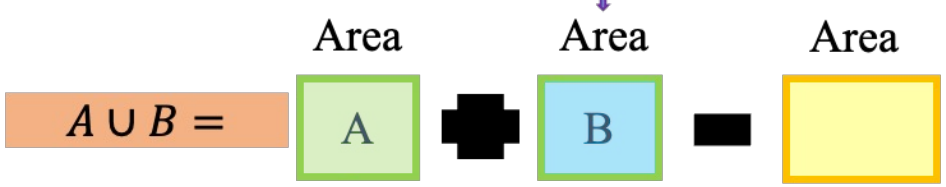
- **Box A** có tọa độ $(x^A_{min}, y^A_{min}, x^A_{max}, y^A_{max})$ => Tuple
- **Box B** có tọa độ $(x^B_{min}, y^B_{min}, x^B_{max}, y^B_{max})$ => Tuple

$$xA = \max(x^A_{min}, x^b_{min}) = x^b_{min}$$
$$yA = \max(y^A_{min}, y^b_{min}) = y^b_{min}$$



$$xB = \min(x^A_{max}, x^b_{max}) = x^A_{max}$$
$$yB = \min(y^A_{max}, y^b_{max}) = y^A_{max}$$

$$(x^B_{max} - x^B_{min}) * (y^B_{max} - y^B_{min})$$



$$(x^A_{max} - x^A_{min}) * (y^A_{max} - y^A_{min})$$

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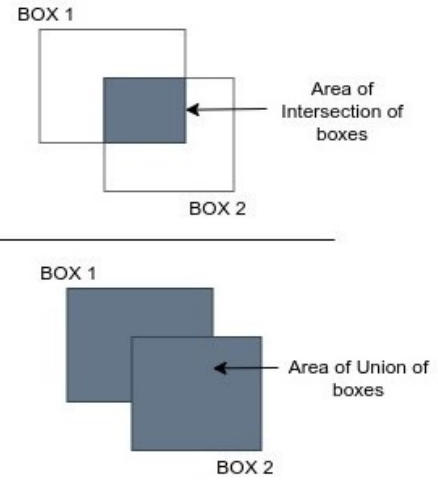
IOU Calculation Using Tuple

IOU =



$$\frac{|A \cap B|}{|A \cup B|}$$

Tính diện tích của 2 box A, B

area1 = $(x^A_{max} - x^A_{min}) * (y^A_{max} - y^A_{min})$

area2 = $(x^B_{max} - x^B_{min}) * (y^B_{max} - y^B_{min})$

Tìm tọa đọ của vùng giao nhau (Intersection)

$$xA = \max(x^A_{min}, x^b_{min}) = x^b_{min}$$
$$yA = \max(y^A_{min}, y^b_{min}) = y^b_{min}$$

$$xB = \min(x^A_{max}, x^b_{max}) = x^A_{max}$$
$$yB = \min(y^A_{max}, y^b_{max}) = y^A_{max}$$

Tính diện tích vùng giao nhau

$W = xB - xA$

H = yB – yA

intersection_area = w*h

Tính diện tích phần hợp nhau

union_area = area1 + area2 - intersection_area

Dựa trên phần giao và phần hợp để tính IoU

IoU = intersection_area / union_area

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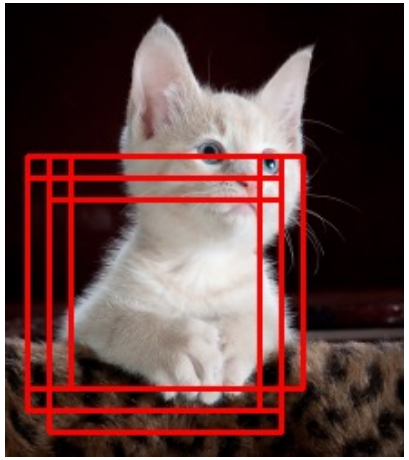
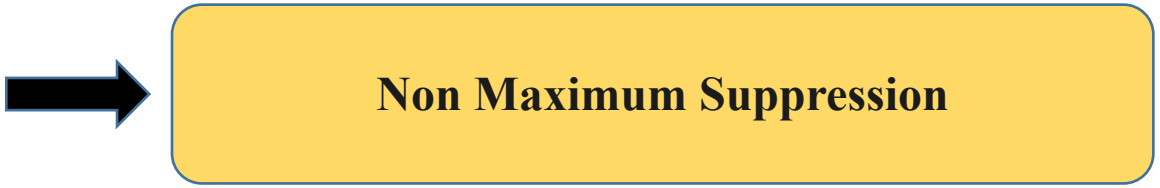
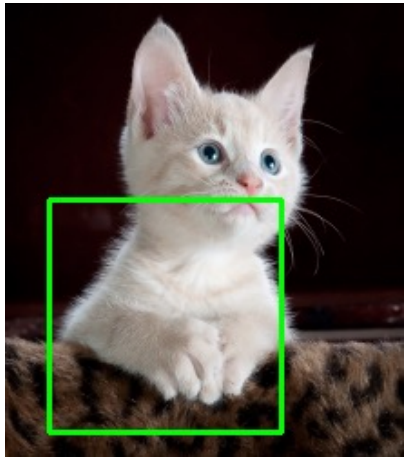
Non-Maxima Suppression: List & Tuple







List

Tuple

```
# import the necessary packages
import numpy as np
import cv2
from google.colab.patches import cv2_imshow

boundingBoxes = np.array([
  (12, 84, 140, 212, 0.3),
  (24, 84, 152, 212, 0.4),
  (36, 84, 164, 212, 0.5),
  (12, 96, 140, 224, 0.6),
  (24, 96, 152, 224, 0.7),
  (24, 108, 152, 236, 0.8)])
```

Algorithm

Step 1 : Select the prediction **S** with highest confidence score and remove it from **P** and add it to the final prediction list **keep**. (**keep** is empty initially).

Step 2 : Now compare this prediction **S** with all the predictions present in **P**. Calculate the IoU of this prediction **S** with every other predictions in **P**. If the IoU is greater than the threshold **thresh_iou** for any prediction **T** present in **P**, remove prediction **T** from **P**.

Step 3 : If there are still predictions left in **P**, then go to **Step 1** again, else return the list **keep** containing the filtered predictions.

Q&A Time

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Set Review

❖ Create a set

Using curly brackets

```
1  # create a set
2  animals = {"cat", "dog", "tiger"}
3
4  print(type(animals))
5  print(animals)
```

```
<class 'set'>
{'dog', 'cat', 'tiger'}
```

Items with different data types

```
1  # create a set
2  a_set = {"cat", 5, True, 40.0}
3
4  print(type(a_set))
5  print(a_set)
```

```
<class 'set'>
{40.0, 'cat', 5, True}
```

Set comprehension

```
1  # set comprehension
2
3  a_set = {i*i for i in range(10)}
4  print(a_set)
```

```
{0, 1, 64, 4, 36, 9, 16, 49, 81, 25}
```

Dictionary Review

number_list = [11, 15, 35, 20, 18, 9]

11	15	35	20	18	9
0	1	2	3	4	5

Index

index

value

number_list[0] => 11

It's very hard to remember that the 1st element in a list has index 0, is there an easier way to remember this?

number_dict ={"One":11, "Two":15, "Three":35, "Four":20, "Five":18, "Six:9" }

11	15	35	20	18	9
"One	Two	Three	Four	Five	Six

key

key

value

number_dict["One"] => 11

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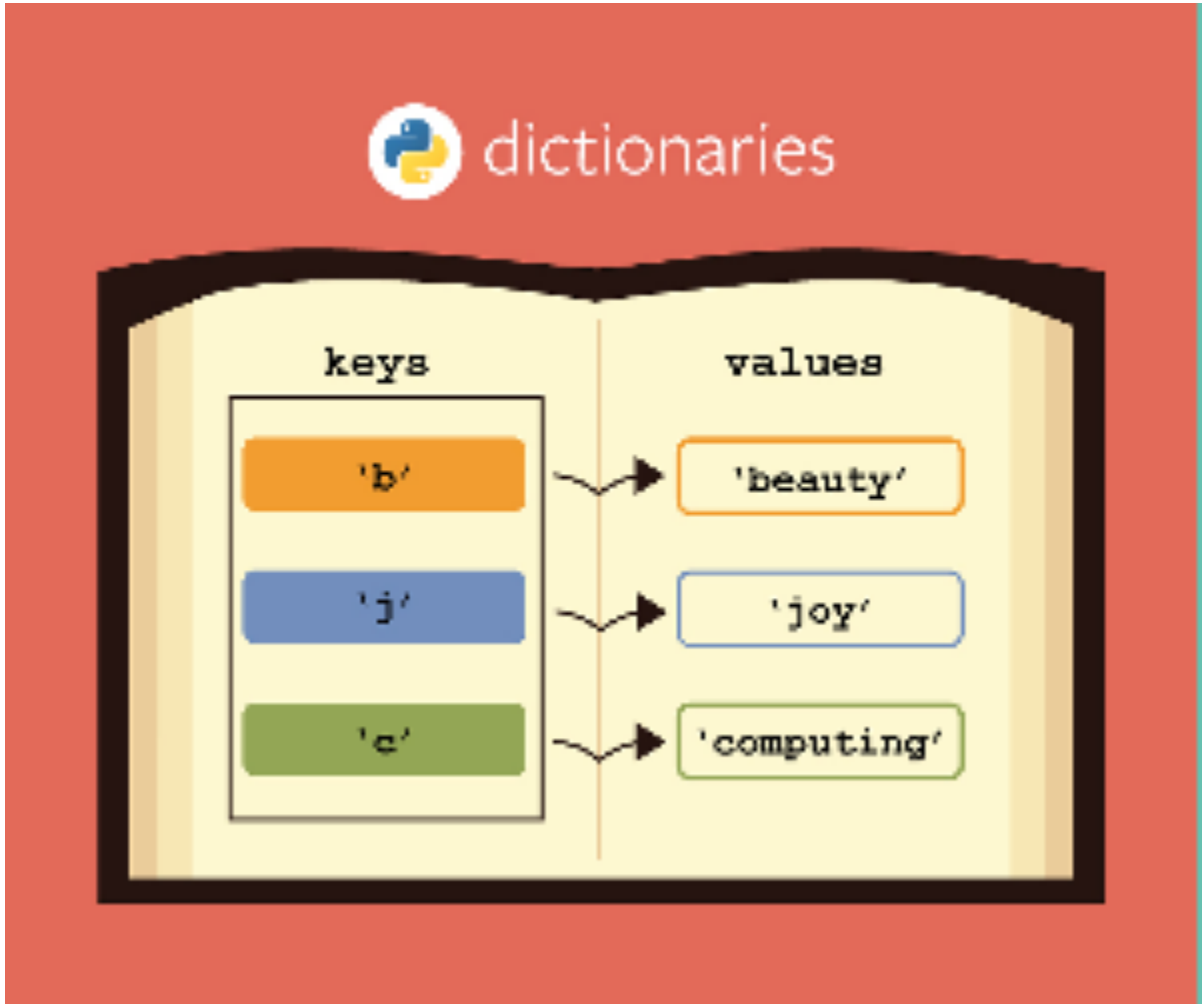
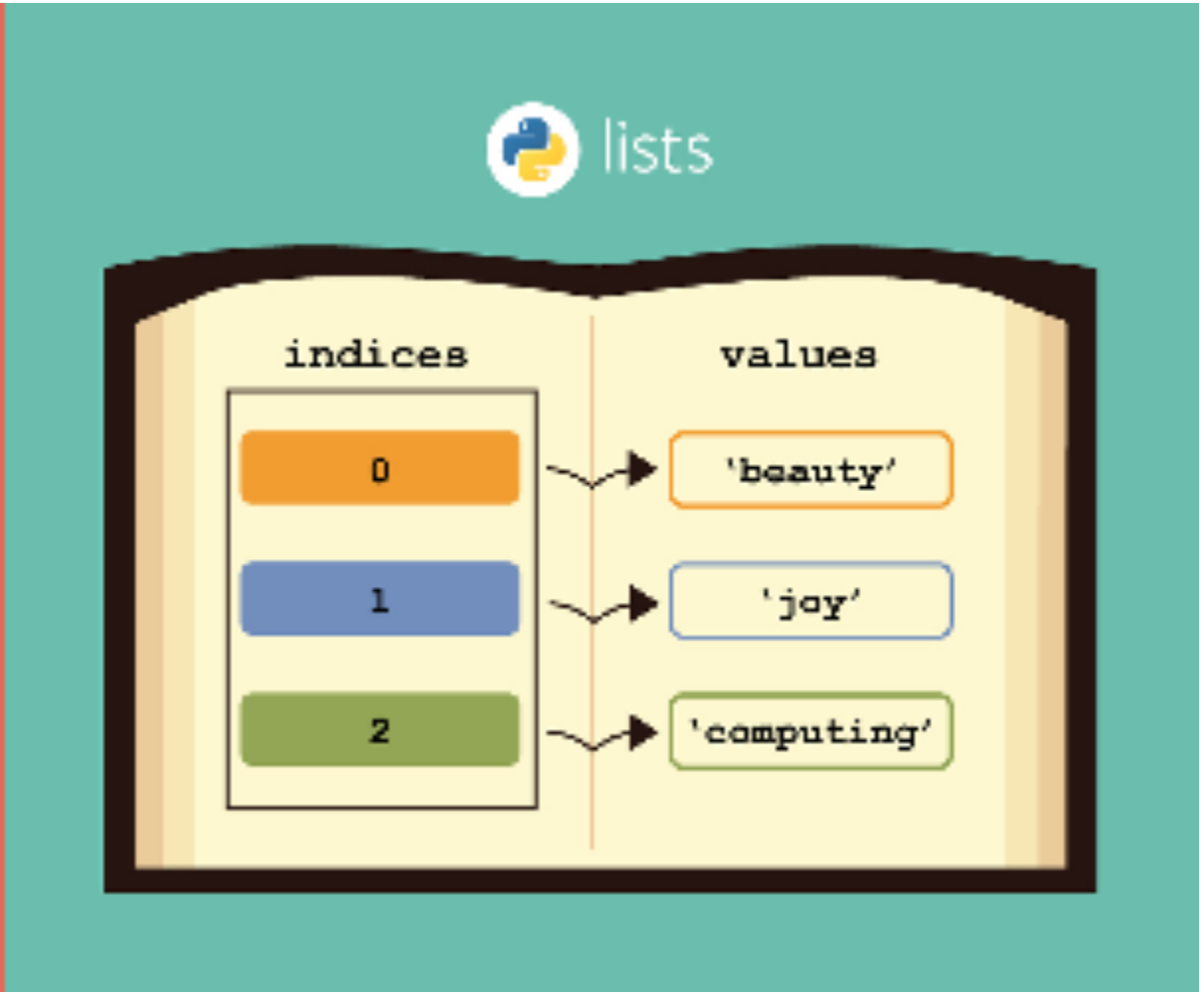
Dictionary Review

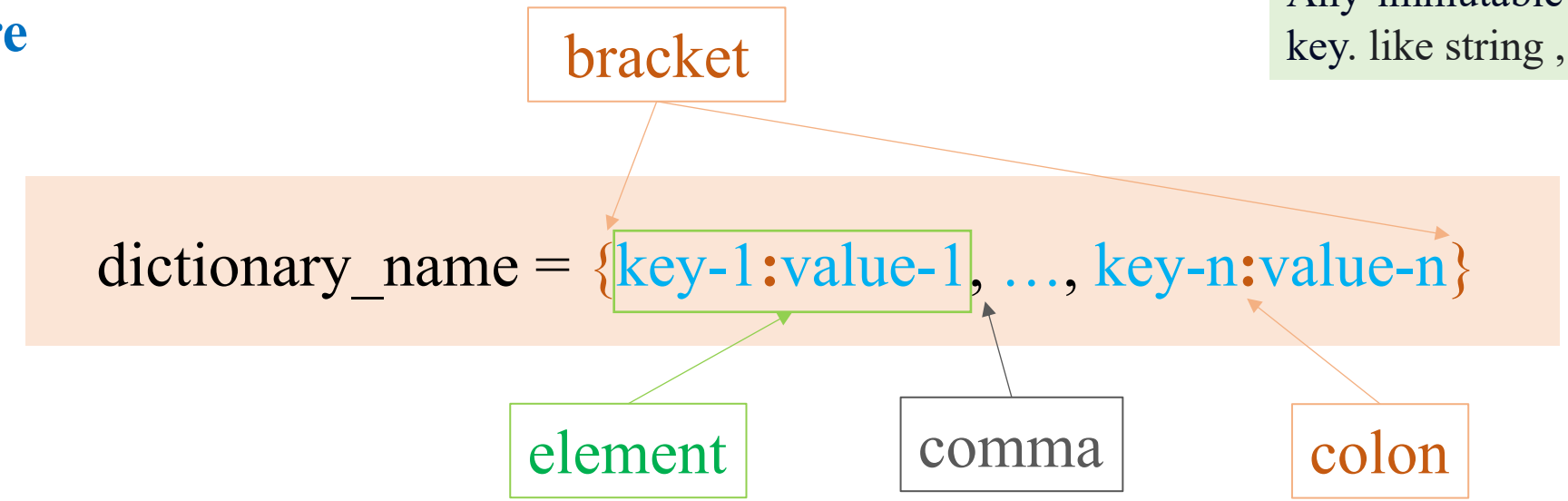




Dictionary Review

❖ Structure

Any immutable can be dictionary key. like string , number, tuple



Create a dictionary

```
1  parameters = {'learning_rate': 0.1,
2                'optimizer': 'Adam',
3                'metric': 'Accuracy'}
4
5  print(parameters)
6  print(type(parameters))
```

```
{'learning_rate': 0.1, 'optimizer': 'Adam', 'metric': 'Accuracy'}
<class 'dict'>
```

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- One-Hot Encoding Using Set and Dictionary
- Review: Tree & K-DTree
- K-D Tree Implementation

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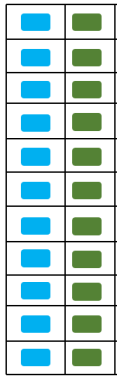
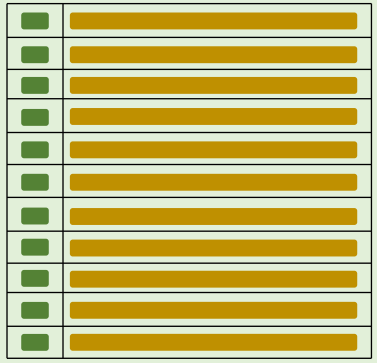
Set/Dictionary in ML Preprocessing

❖ Text classification



Text Sample → Preprocessing (standardization & vectorization) →  → Machine Learning Algorithm → Output

”Make money” → Preprocessing → Embedding → Fully-connected layer

0	1	2	4	5	6	7	4	8

Embedding features → Support Vector Machine → Spam

Set/Dictionary in ML Preprocessing

How to Convert Categorical Data to Numerical Data?

1.Integer Encoding (already discussed in previous modules)

2.One-Hot Encoding

❖Vocabulary Building

Python is a high-level, interpreted, general-purpose programming language. Its design philosophy emphasizes code readability with the use of significant indentation. Python is dynamically-typed and garbage-collected. It supports multiple programming paradigms, including structured, object-oriented and functional programming.

Python Program (using Set structure)

0 its	8 it	16 functional	24 design
1 indentation	9 including	17 readability	25 a
2 collected	10 and	18 general	26 the
3 supports	11 typed	19 with	27 oriented
4 is	12 interpreted	20 philosophy	28 emphasizes
5 programming	13 dynamically	21 object	29 high
6 garbage	14 multiple	22 level	30 significant
7 purpose	15 python	23 paradigms	31 structured
			32 language
			33 code
			34 use
			35 of

Vocabulary

Input

"Python is a high-level"

Text data

Output

15	4	25	29	22

Numerical Data

Set/Dictionary in ML Preprocessing

How to Convert Categorical Data to Numerical Data?

1.Integer Encoding (already discussed in previous modules)

2.One-Hot Encoding

Name
Ho Chi Minh
Da Nang
Ho Chi Minh
Da Nang
Can Tho

Integer Encoding
0
1
0
1
2

Integer Encoding

Can Tho	Da Nang	Ho Chi Minh
0	0	1
0	1	0
0	0	1
0	1	0
1	0	0

One-Hot Encoding

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Set/Dictionary in ML Preprocessing

How to Convert Categorical Data to Numeri

1.Integer Encoding (already discussed in pre

2.One-Hot Encoding

Can Tho	Da Nang	Ho Chi Minh
0	0	1
0	1	0
0	0	1
0	1	0
1	0	0

One-Hot Encoding

```
One-Hot Encoded Features:
 [[0, 0, 1], [0, 1, 0], [0, 0, 1], [0, 1, 0], [1, 0, 0]]
['Can Tho', 'Da Nang', 'Ho Chi Minh']
```

```python
import numpy as np

dataset = np.array(['Ho Chi Minh', 'Da Nang',
                    'Ho Chi Minh', 'Da Nang','Can Tho'])

# Initialize an empty set to store unique categories
unique_categories = set()

# Iterate through the dataset and add categories to the set
for data in dataset:
    unique_categories.add(data)

# Convert the set to a sorted list to maintain order
unique_categories = sorted(list(unique_categories))

# Create a mapping from category to index
category_to_index = {category: idx for idx, category in enumerate(unique_categories)}

# Initialize an empty list to store the one-hot encoded features
one_hot_encoded_features = []

# Perform one-hot encoding
for data in dataset:
    one_hot_vector = [0] * len(unique_categories)
    one_hot_vector[category_to_index[data]] = 1
    one_hot_encoded_features.append(one_hot_vector)

# Print the unique categories and one-hot encoded features
print("One-Hot Encoded Features:\n", one_hot_encoded_features)
print(unique_categories)
```

Q&A Time

Outline

- Review: Tuples vs. Lists, 2D Lists
- IoU Calculation using Tuples
- NMS Using List and Tuples
- Review: Set and Dictionary
- One-Hot Encoding Using Set and Dictionary
- Review: Tree & K-DTree
- K-D Tree Implementation

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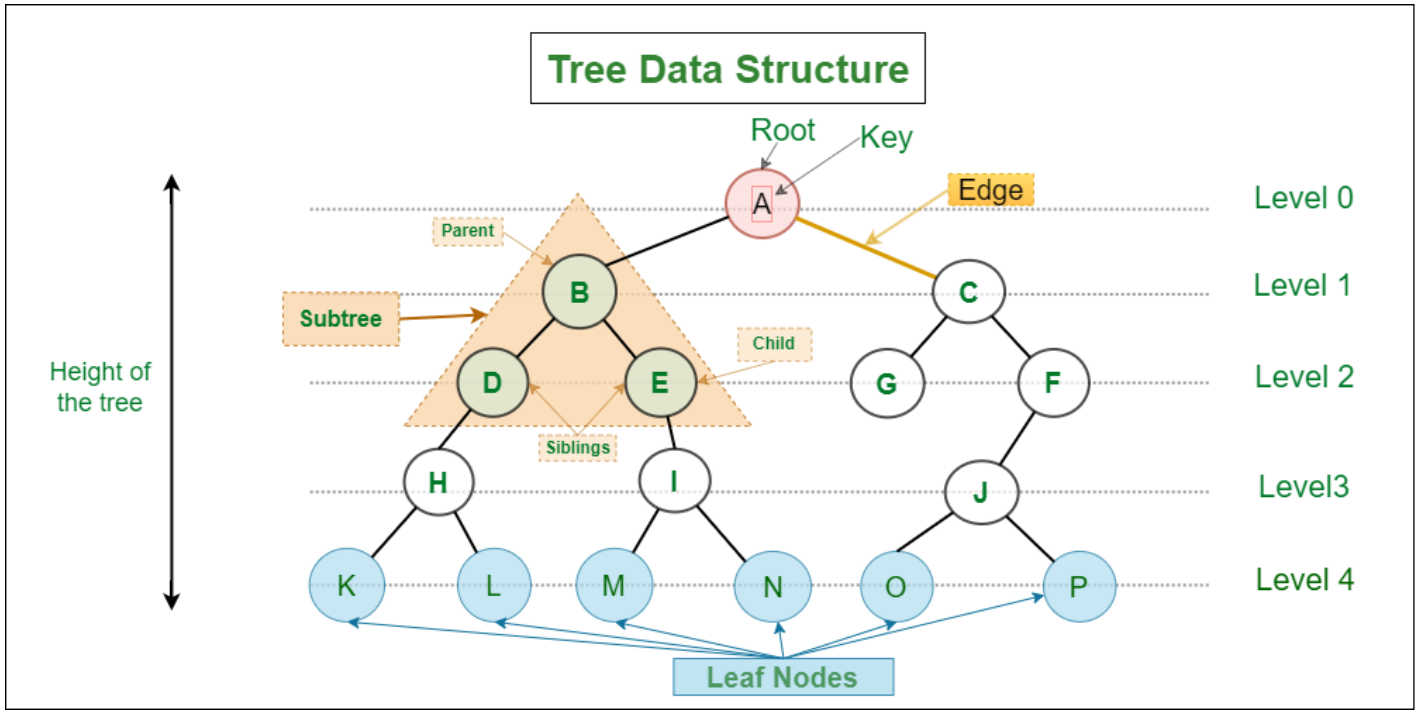
Tree Review

A non-linear data structure where nodes are organized in a hierarchy



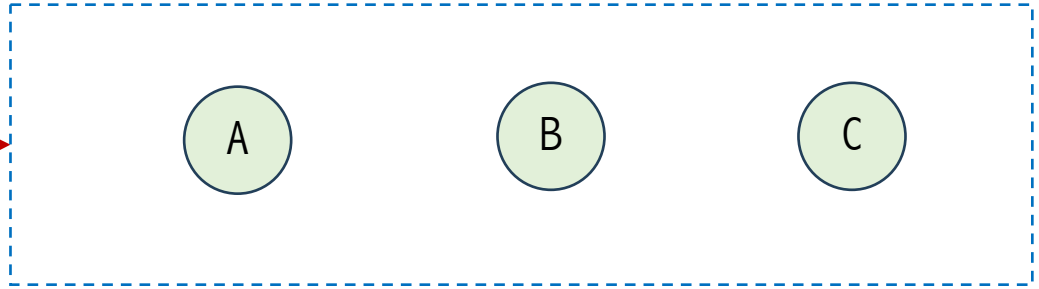
In the above figure, where do you think the root of the tree is?

Tree Review

```
class TreeNode:
    def __init__(self, data):
        self.data = data
        self.children = []
        self.parent = None
```

Node of a Tree

```
a_node = Node("A")
b_node = Node("B")
c_node = Node("C")
```



Create nodes, A, B, and C

Tree Review

```python
class TreeNode:
    def __init__(self, data):
        self.data = data
        self.children = []
        self.parent = None

    def add_child(self, child):
        child.parent = self
        self.children.append(child)

    def get_level(self): #to get level of each node
        level =0
        p = self.parent
        while p:
            level += 1
            p = p.parent

        return level
    def print_tree(self):
        space = ' ' * self.get_level() * 3
        prefix = space + '|__' if self.parent else ''
        print(prefix + self.data)#add prefix
        if self.children:
            for child in self.children:
                child.print_tree()
```

```python
def create_tree():
  a_node = TreeNode("A")
  b_node = TreeNode("B")
  c_node = TreeNode("C")
  d_node = TreeNode("D")
  e_node = TreeNode("E")
  f_node = TreeNode("F")
  g_node = TreeNode("G")

  a_node.add_child(b_node)
  a_node.add_child(c_node)

  b_node.add_child(d_node)
  b_node.add_child(e_node)

  c_node.add_child(f_node)
  c_node.add_child(g_node)
  return a_node
```

```python
tree = create_tree()
tree.print_tree()
```

```
A
    |__B
        |__D
        |__E
    |__C
        |__F
        |__G
```

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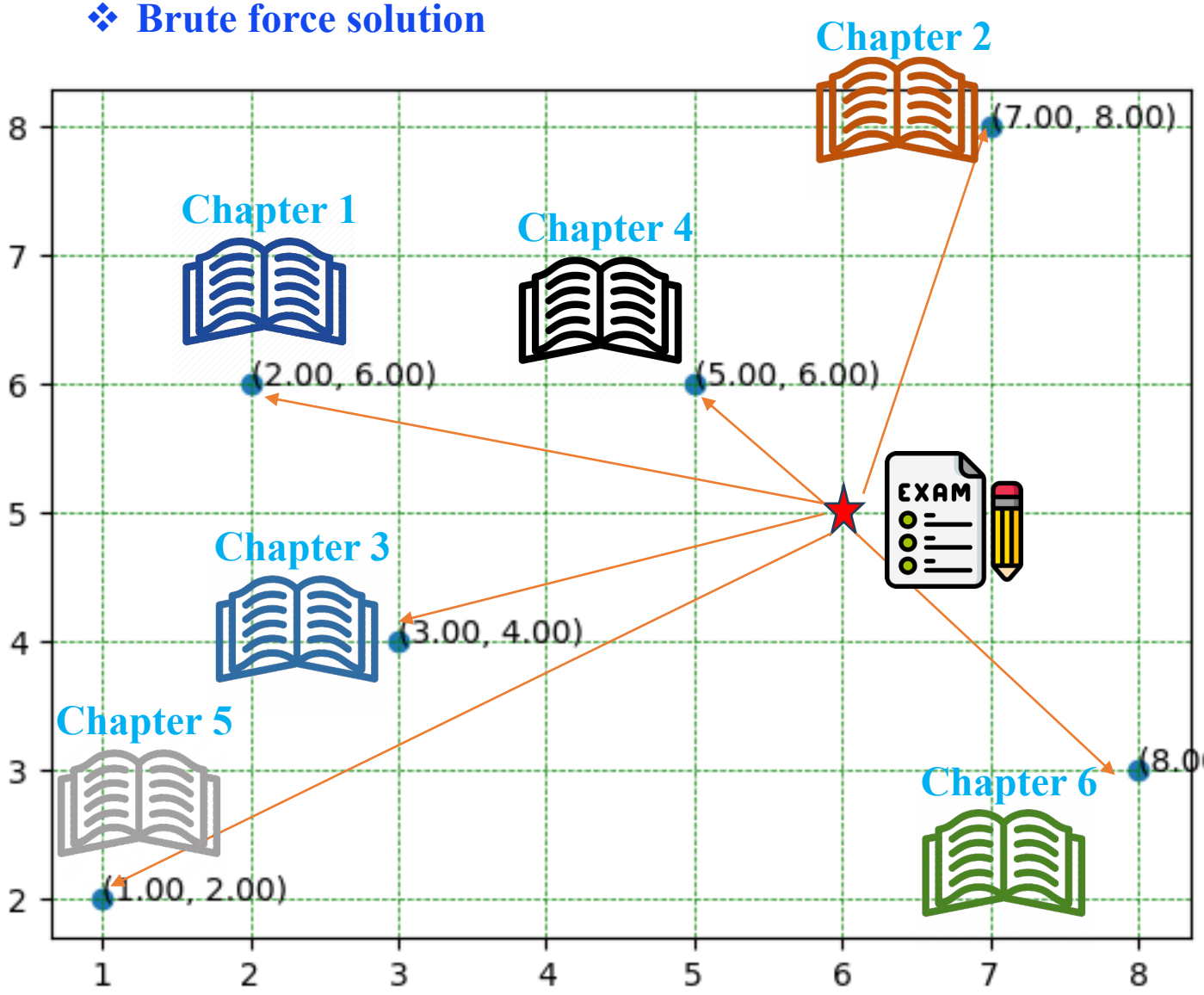
Classification Problem

❖ **Brute force solution**




```
import matplotlib.pyplot as plt

x = [1, 2, 3, 5, 7, 8]
y = [2, 6, 4, 6, 8, 3]

for xy in zip(x, y):
    plt.annotate('(%.2f, %.2f)' % xy, xy=xy)

plt.scatter(x, y)
plt.grid(color = 'green', linestyle = '--', linewidth = 0.5)

plt.show()
```

★ **New datapoint**

1. Find distance of each point in the dataset
2. The point with lowest distance would be nears

K-D Tree Implementation Solution

Algorithm 1: K-D Tree Construction

Function *kdtree(pointList, depth)*:

Input: a list of points, *pointList*, and an integer, *depth* ;

Output: a k-d tree rooted at the median point of *pointList* ;

```
/* Select axis based on depth so that axis cycles
   through all valid values                          */
```

let $axis := depth \mod k$;

```
/* Sort point list and choose median as pivot element
   */
```

select median by *axis* from *pointList*;

```
/* Create node and construct subtree                 */
```

let *node.location* := *median*;

let *node.leftChild* := kdtree(points in *pointList* before *median*, $depth + 1$);

let *node.rightChild* := kdtree(points in *pointList* after *median*, $depth + 1$);

return *node*;

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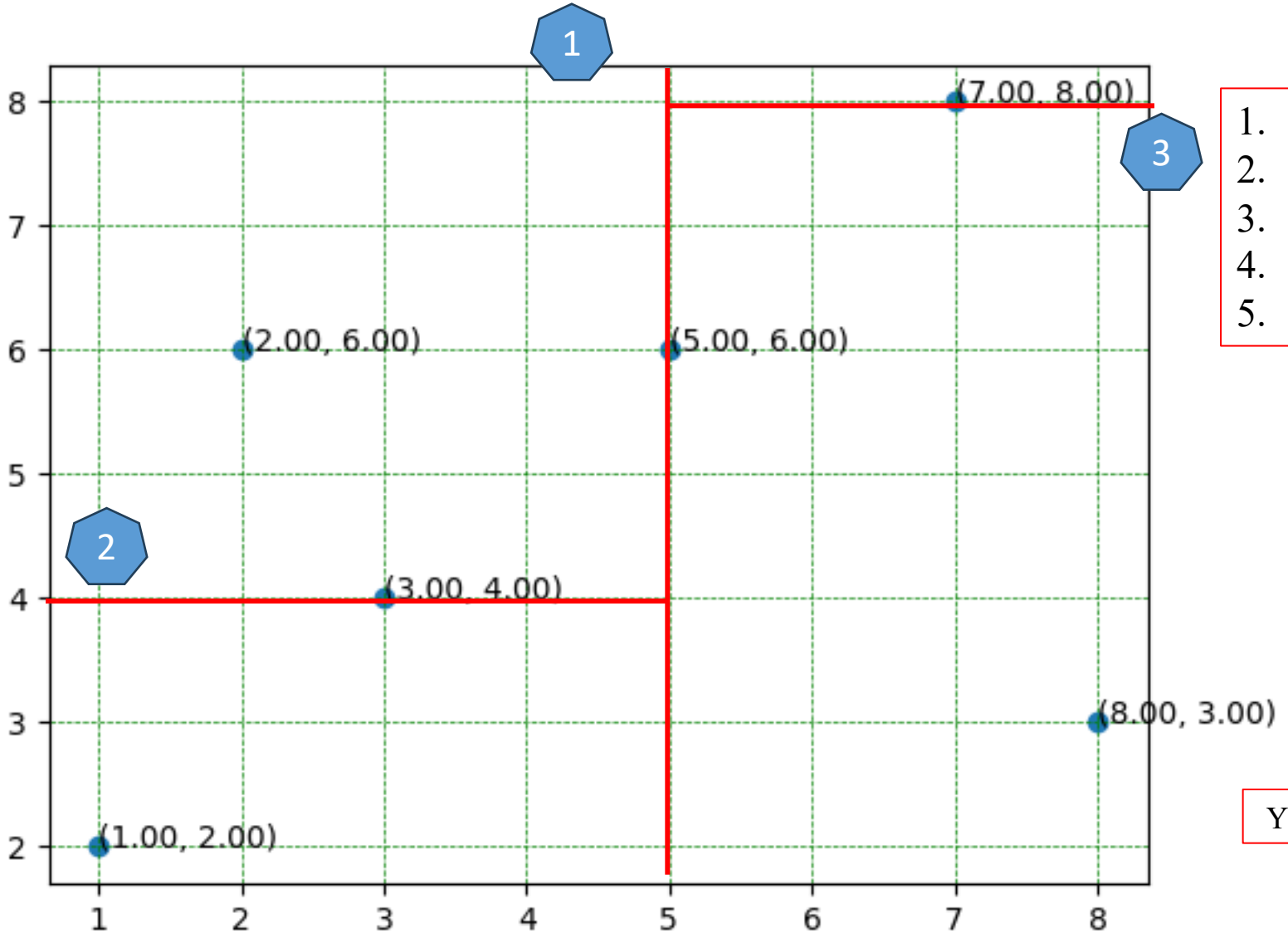
K-D Tree Implementation Solution



1. Pick any one feature at random
2. Find median
3. Split dataset in approximate equal halves
4. Pick next feature and repeat step #2,3
5. Continue until all data points are partitioned

X = 1, 2, 3, 5, 7, 8; median = 5

1

Left

Right

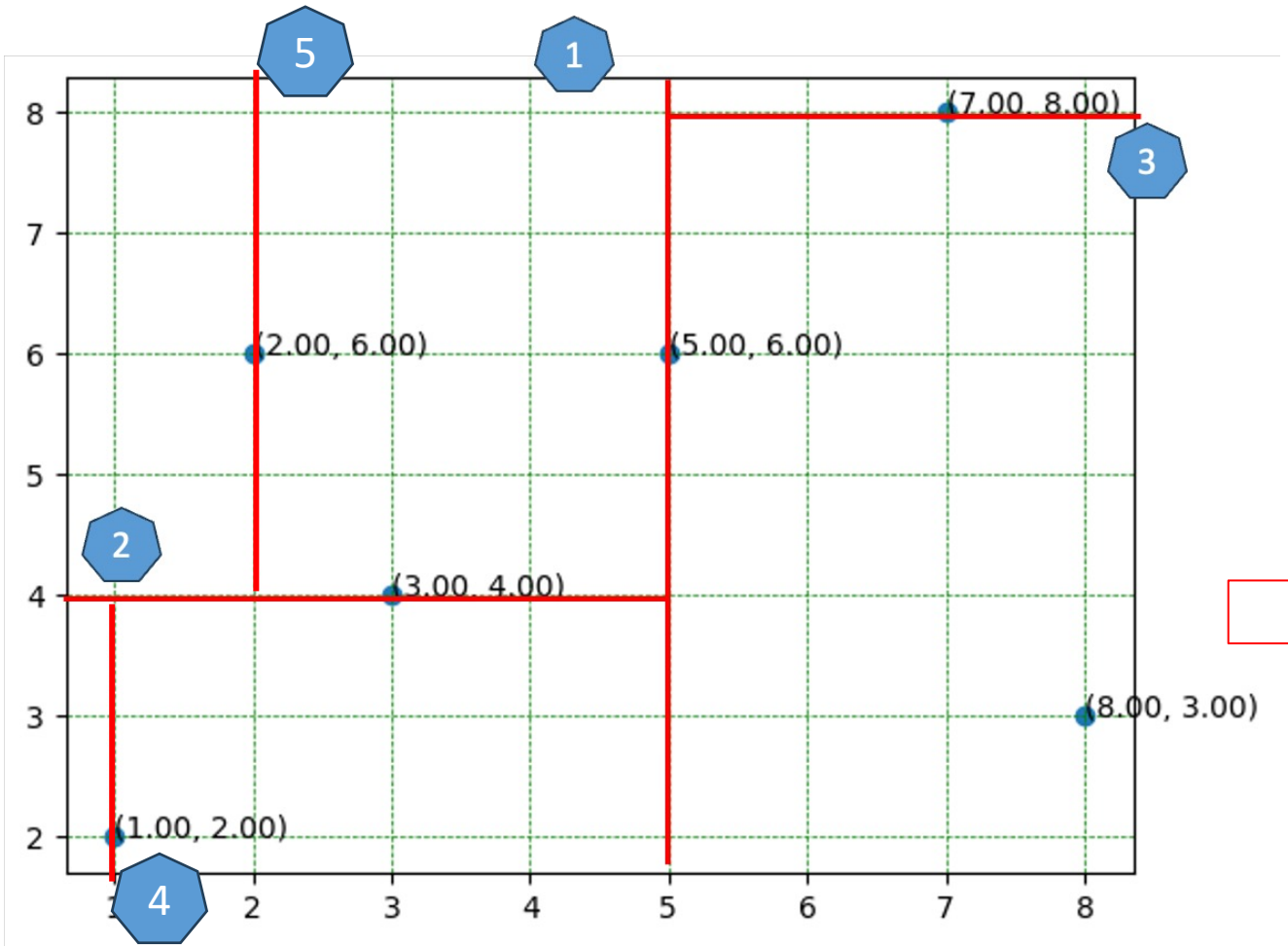
Y = 2, 4, 6; median = 4

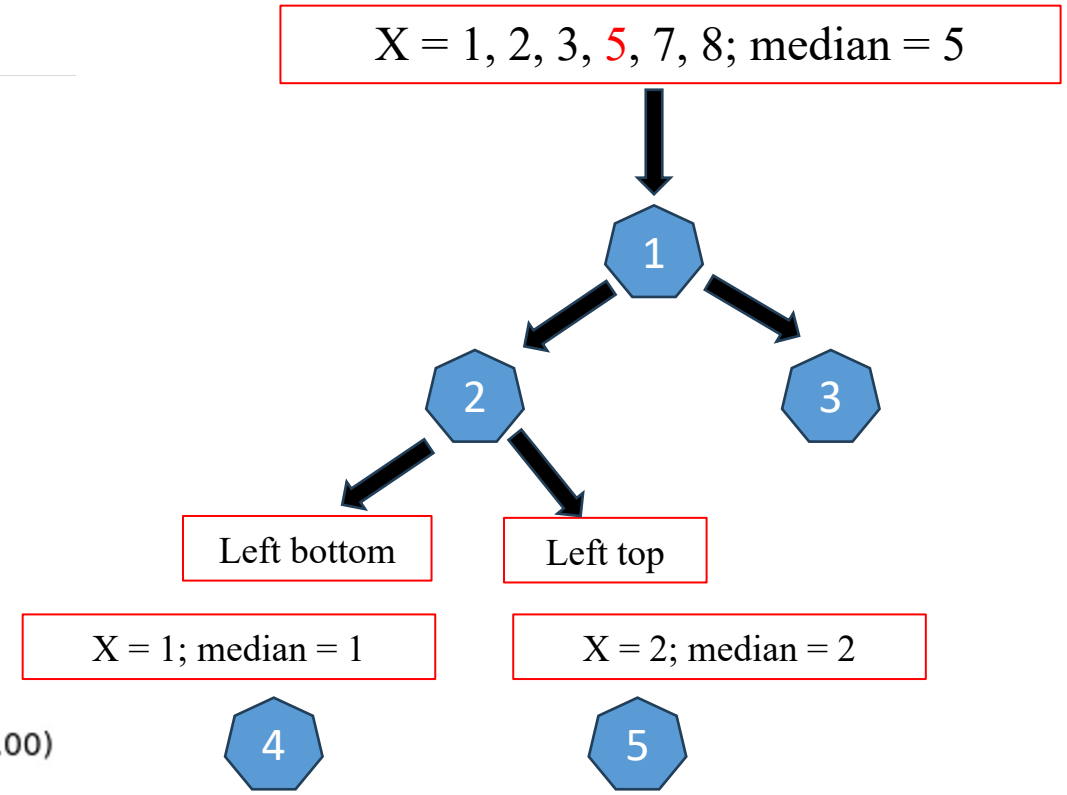
Y = 3, 8; median = 8

2

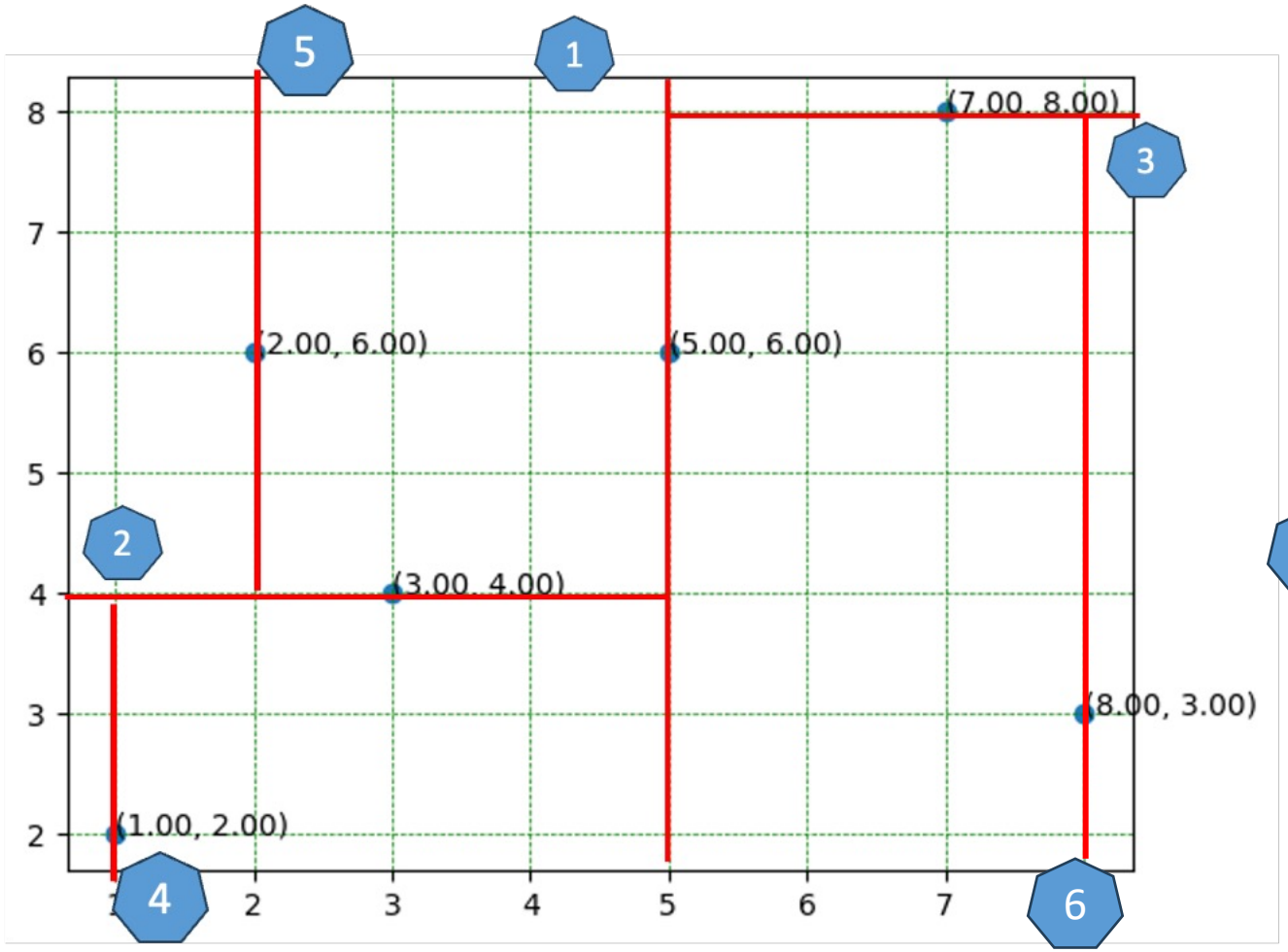
3

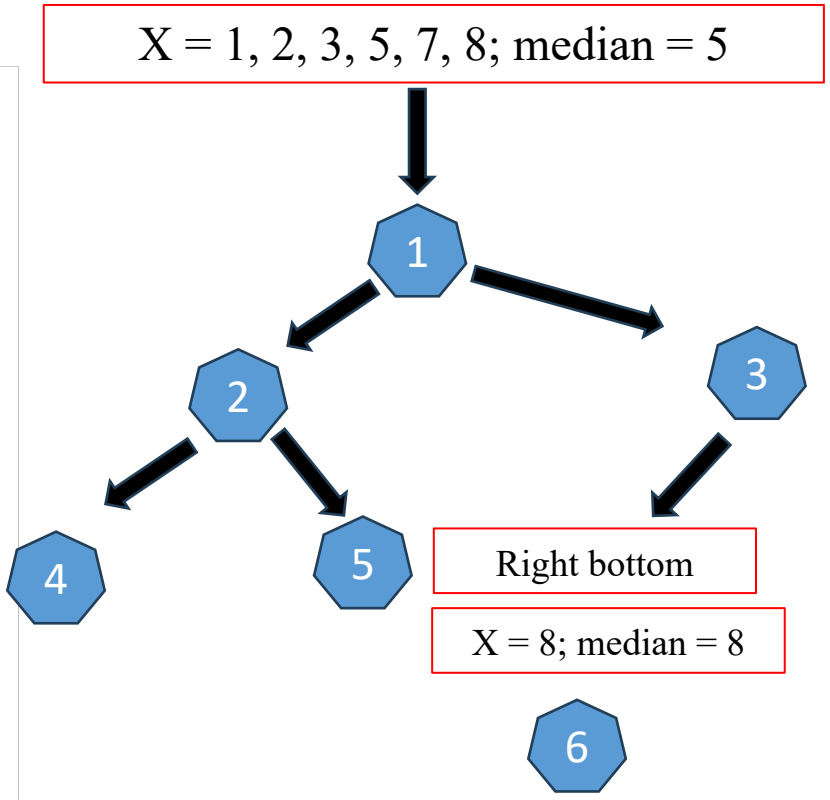
K-D Tree Implementation Solution



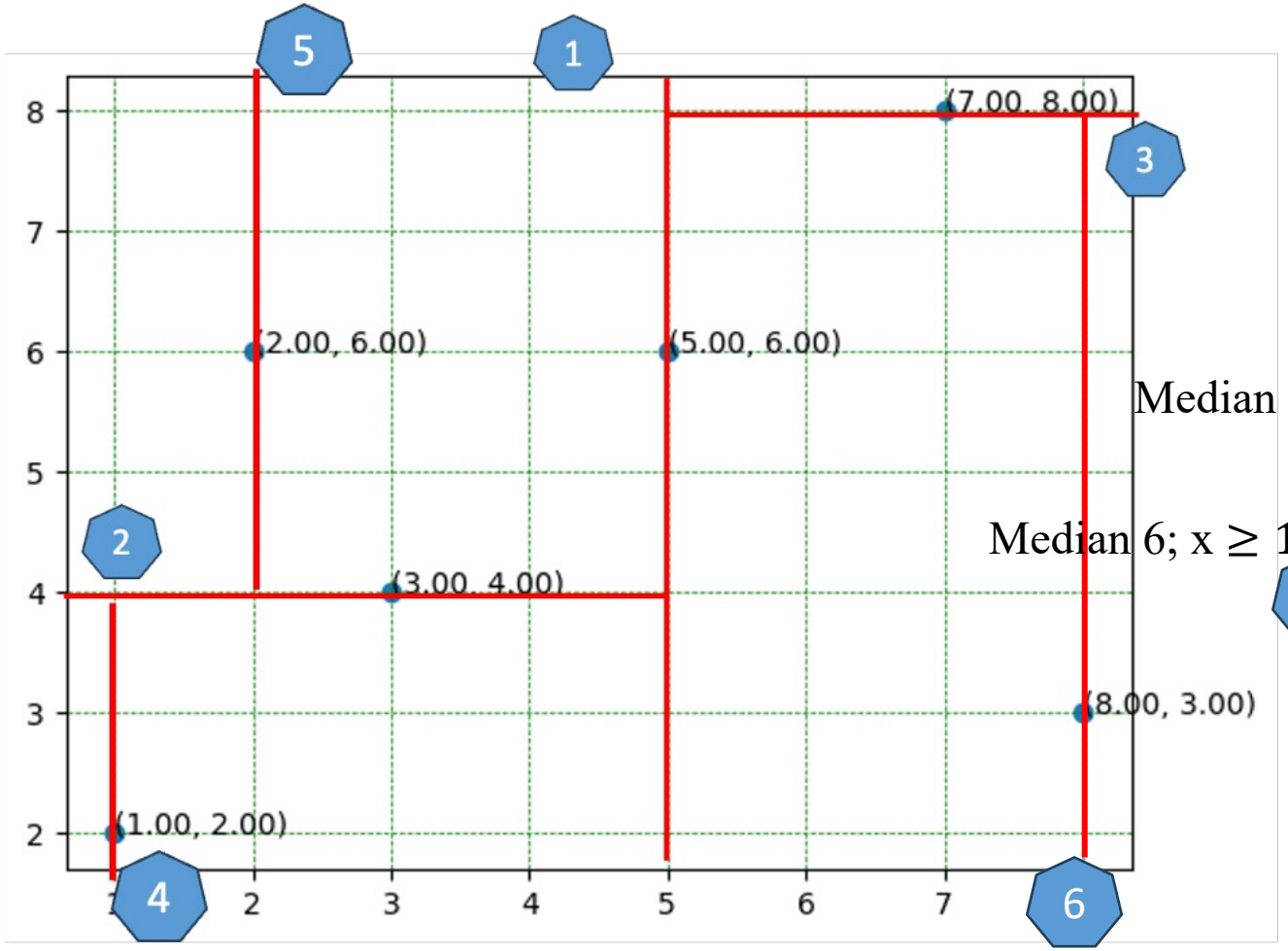


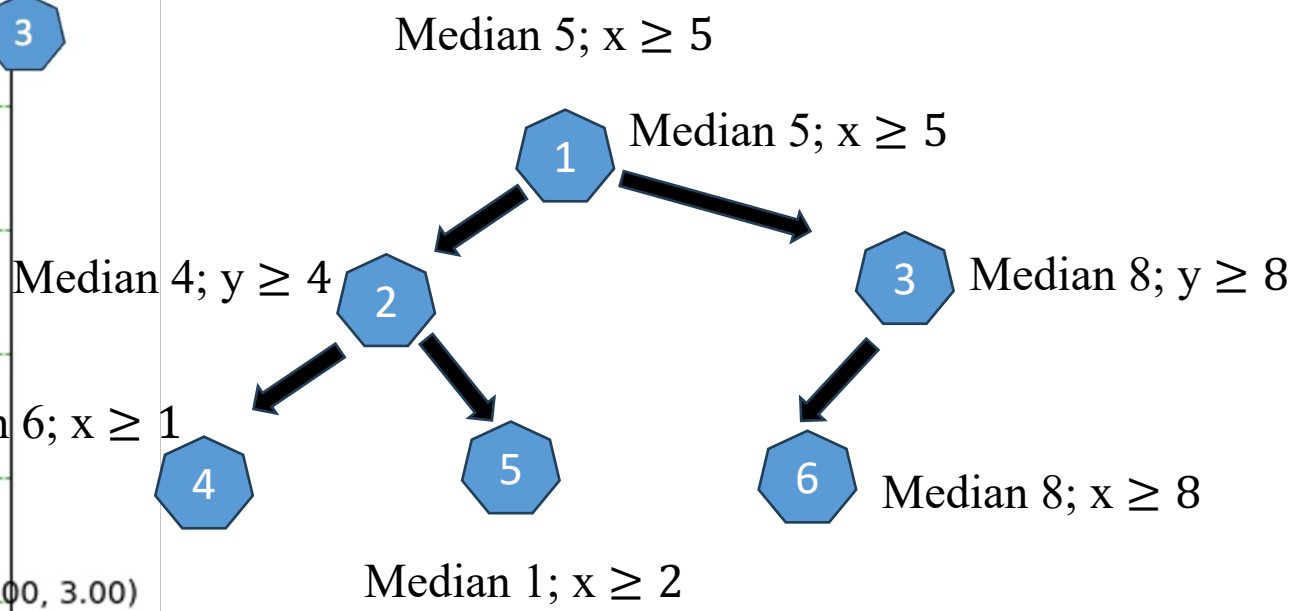
K-D Tree Implementation Solution





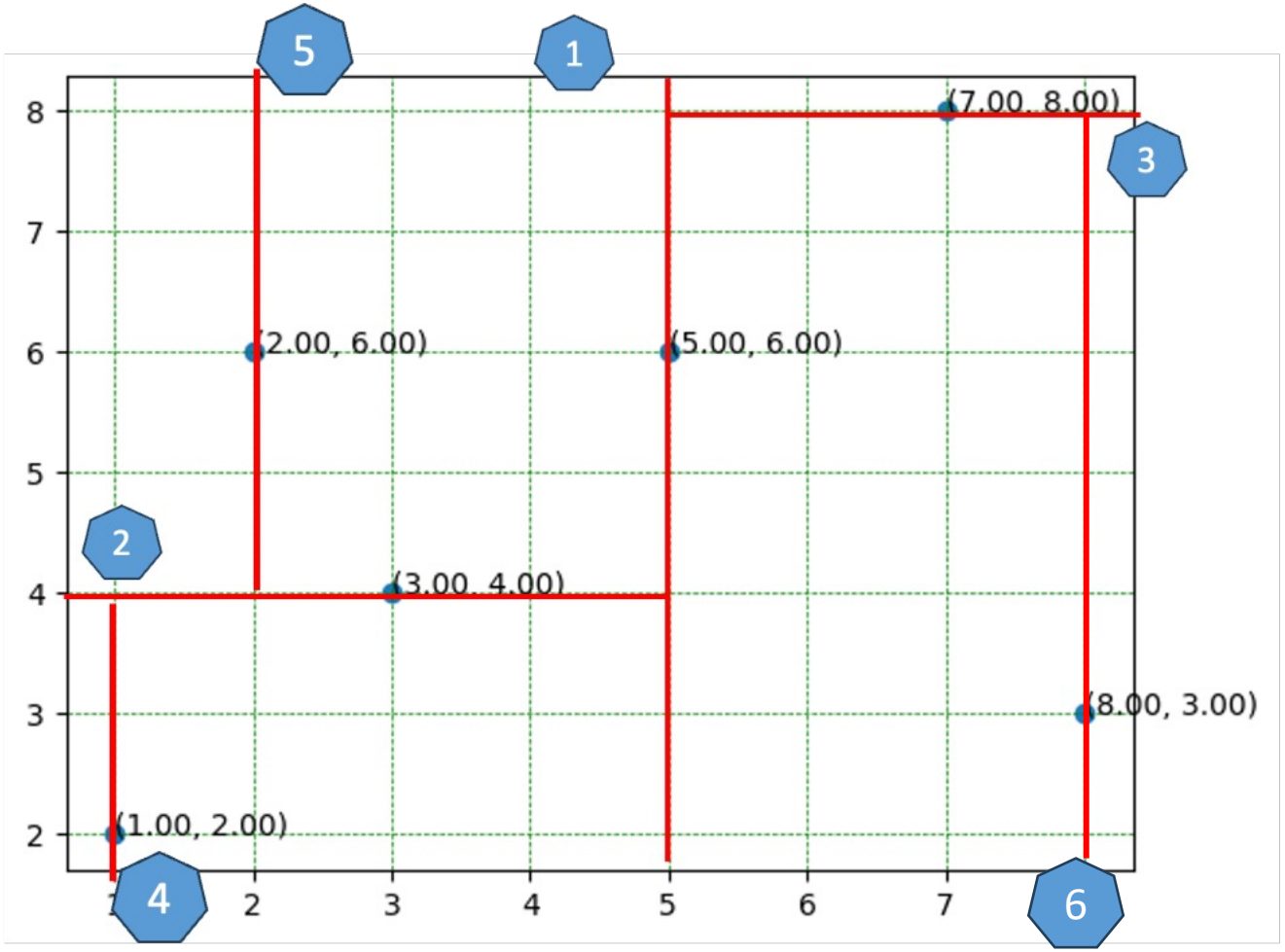
K-D Tree Implementation Solution

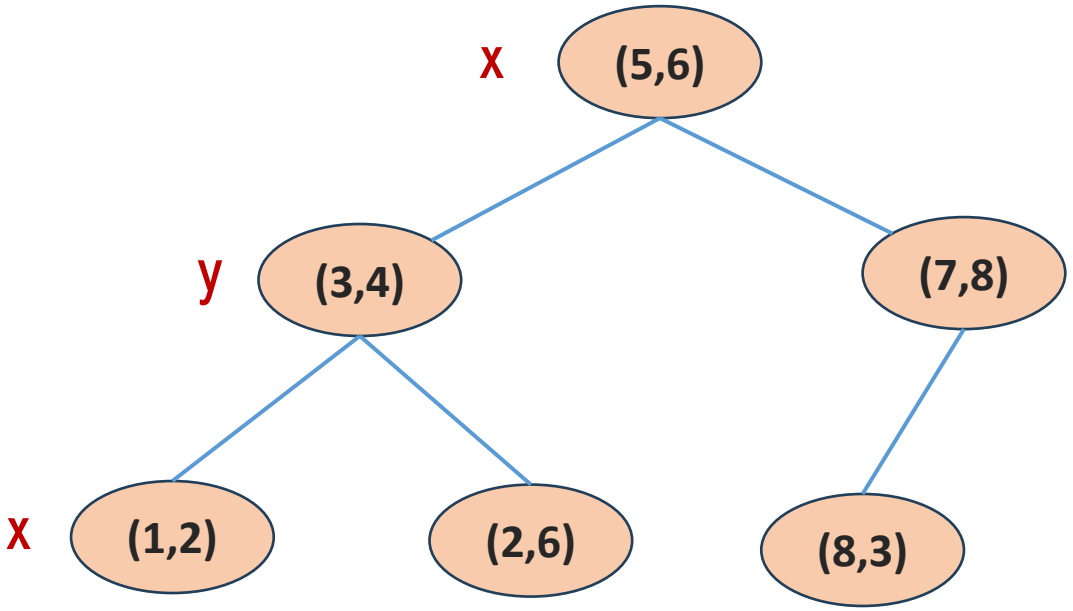




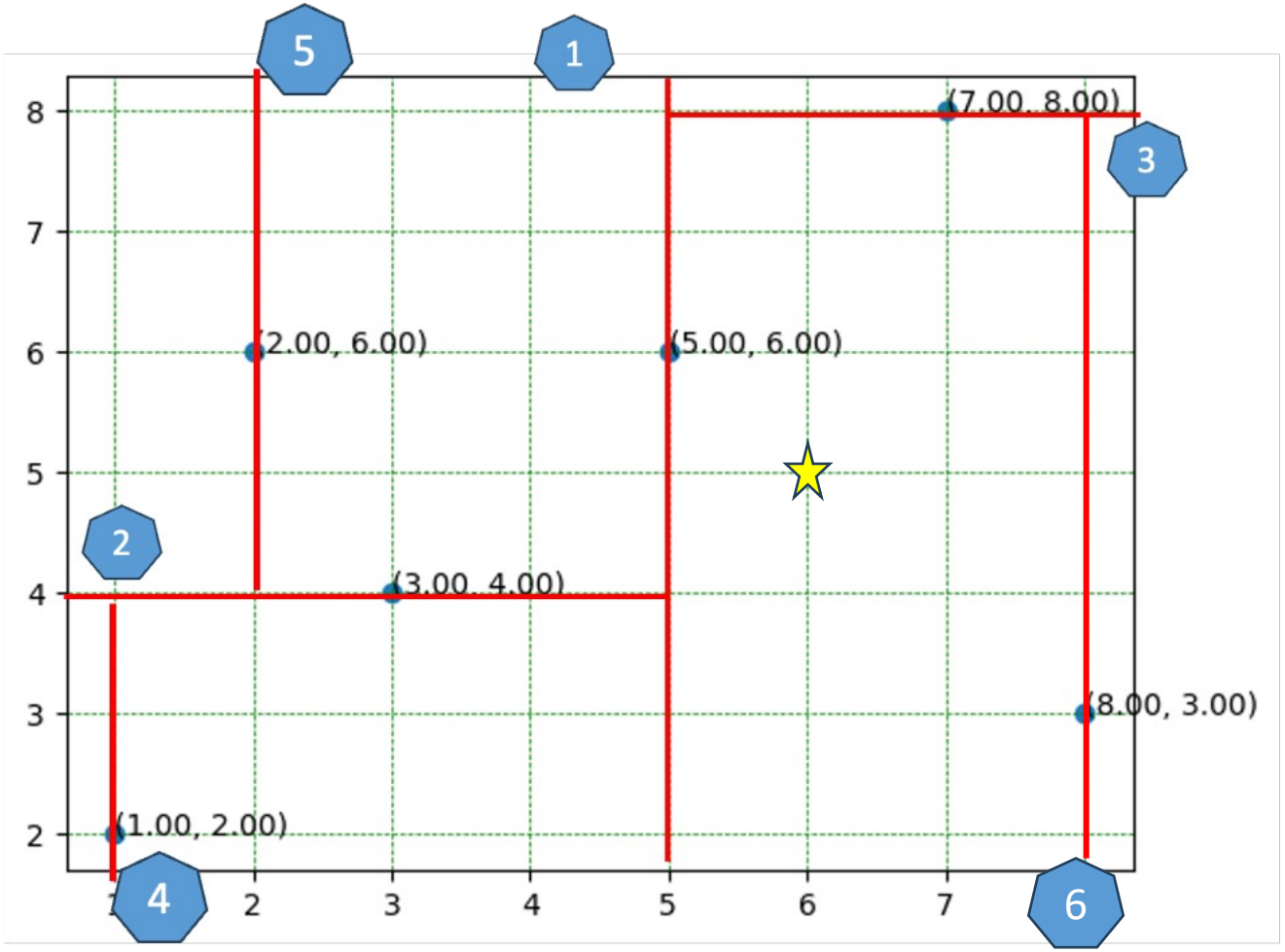
★ **New datapoint**

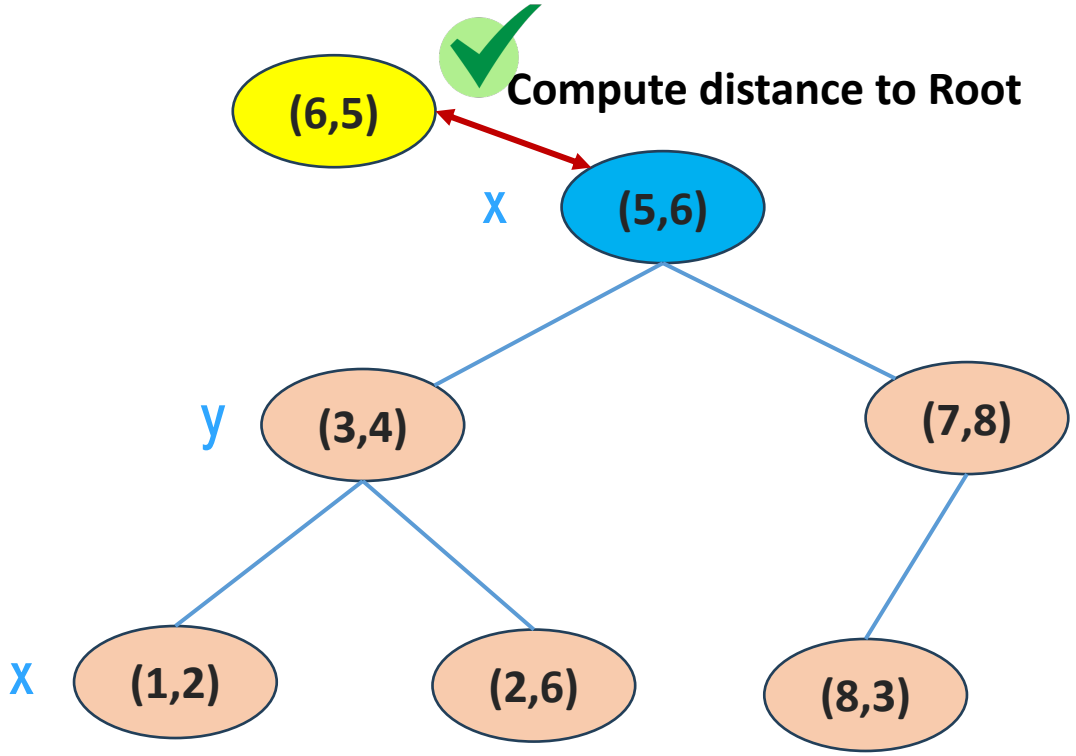
K-D Tree Implementation Solution





K-D Tree Implementation Solution

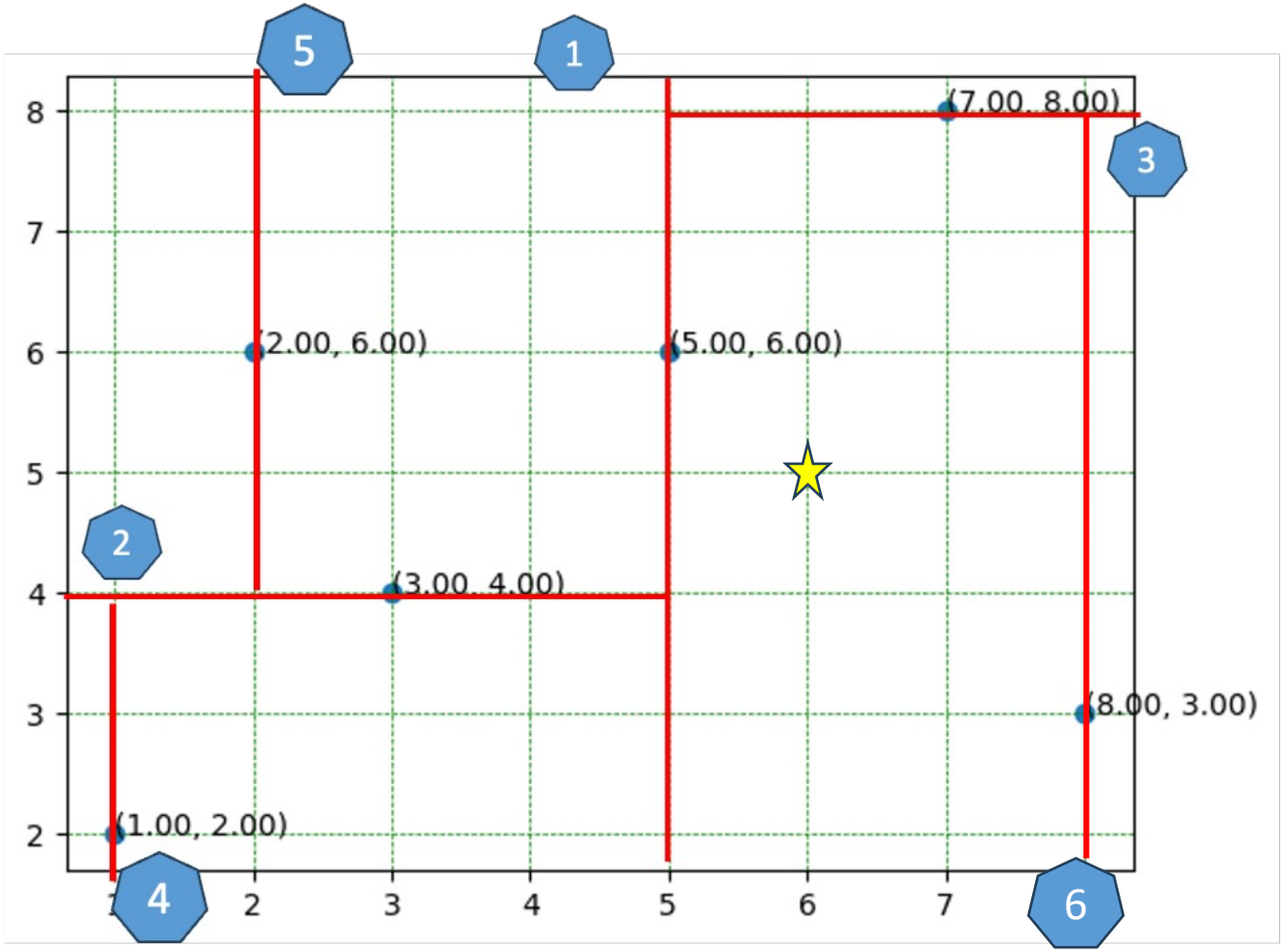


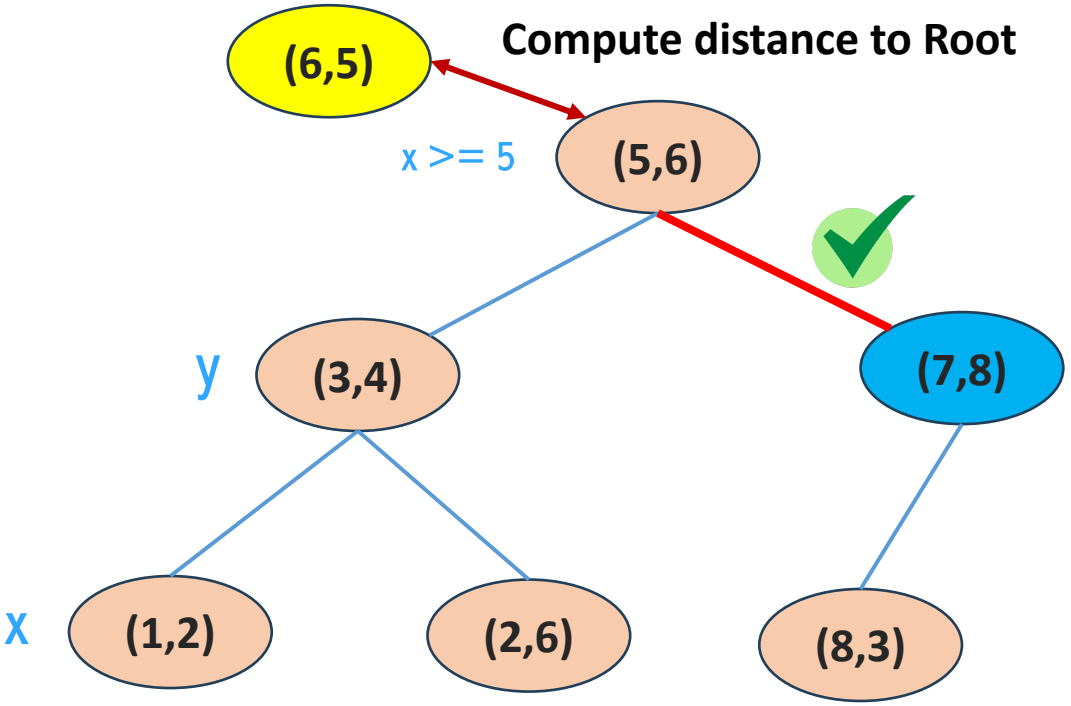


Best distance = 1.41
Best label = (5,6)

New datapoint

K-D Tree Implementation Solution





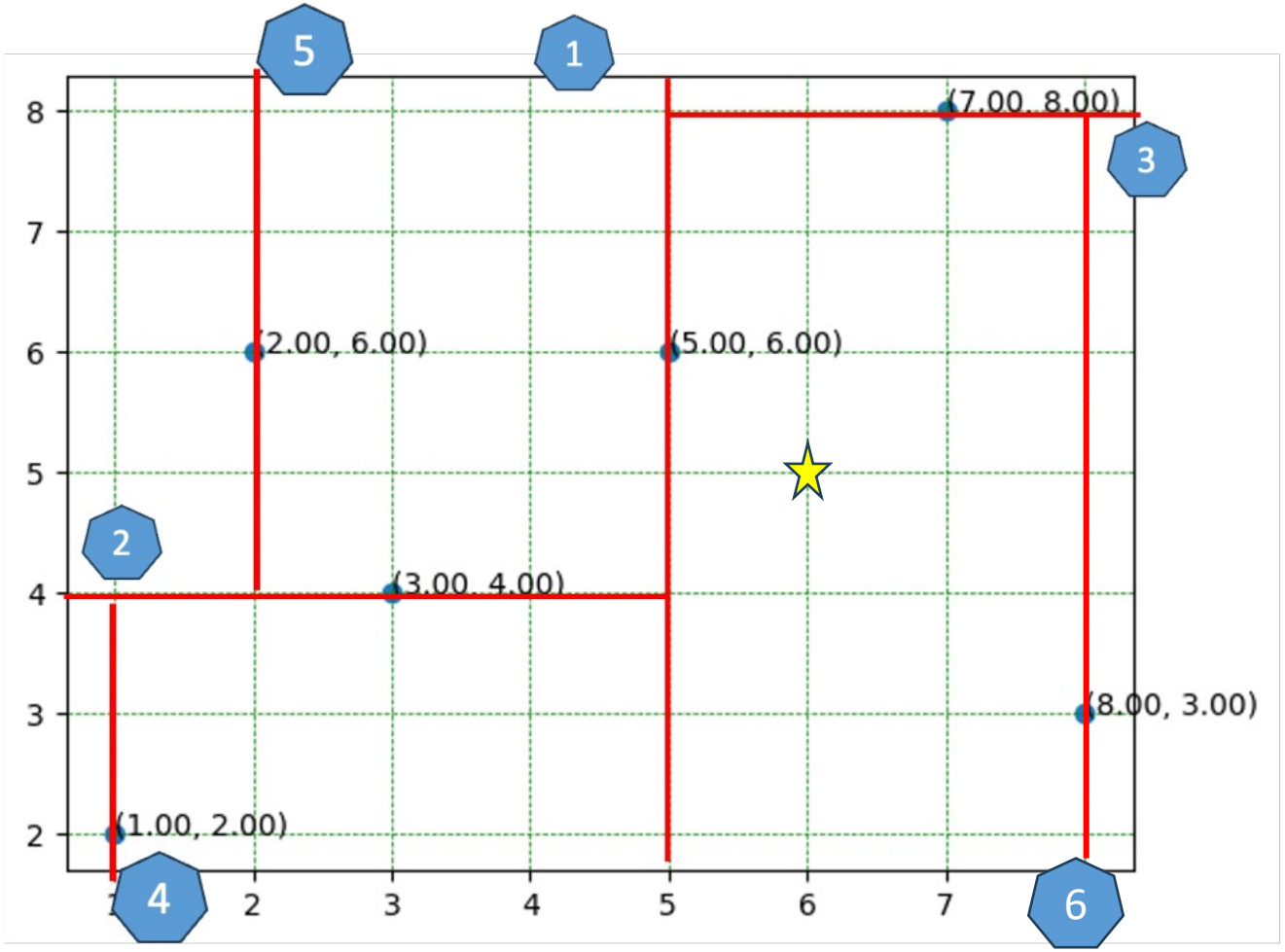
☆ **New datapoint**

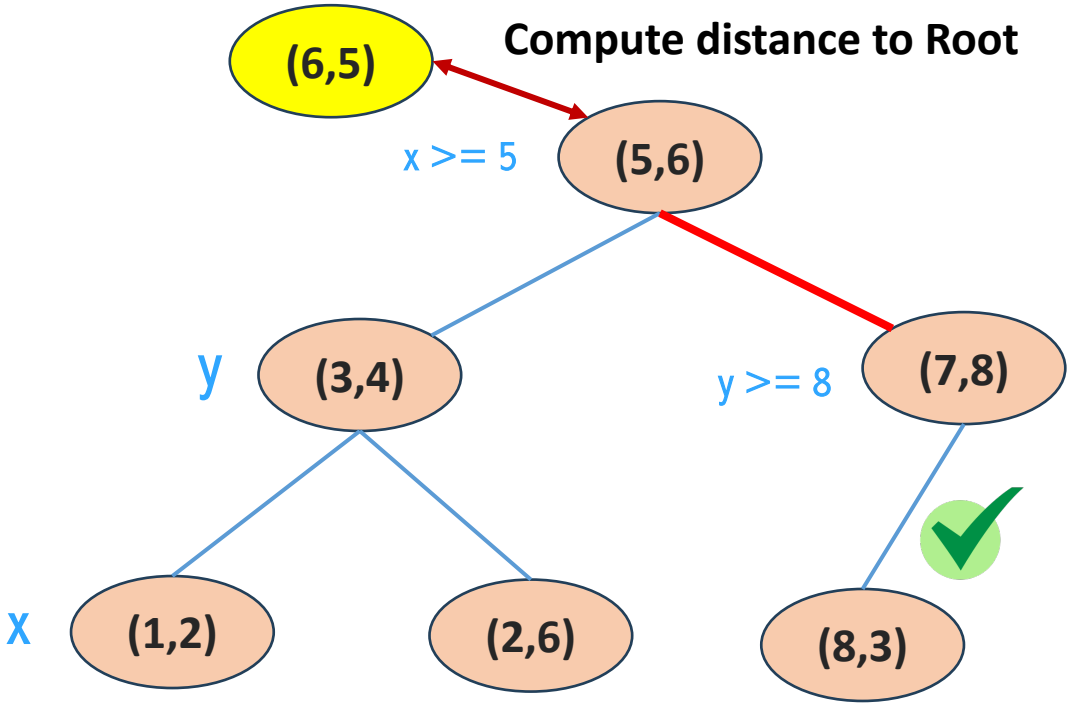
Best distance = 1.41
Best label = (5,6)

Curent distance = 3.16
Curent label = (5,6)

Not update the best distance

K-D Tree Implementation Solution





(6,5)

The closest points is (5,6)

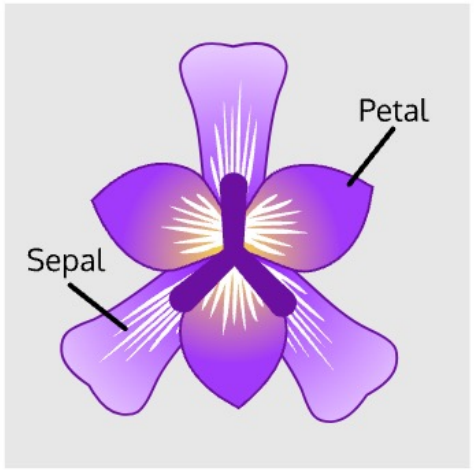
Best distance = 1.41
Best label = (5,6)

Curent distance = 2.82
Curent label = (8,3)

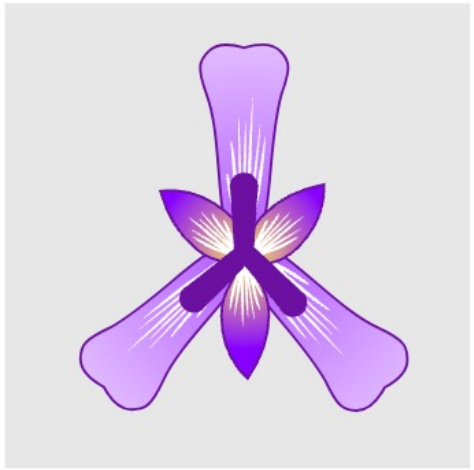
Not update the best distance

K-D Tree Implementation

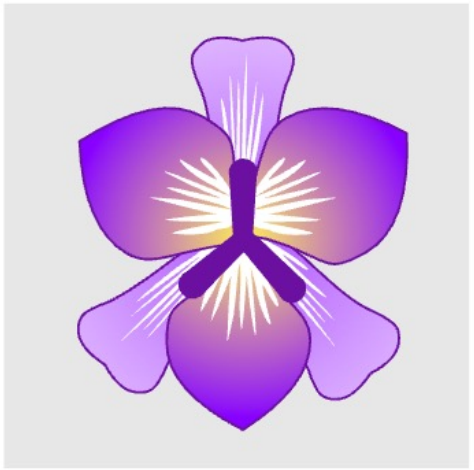
Iris Dataset Classification: Self-study



Iris Versicolor



Iris Setosa

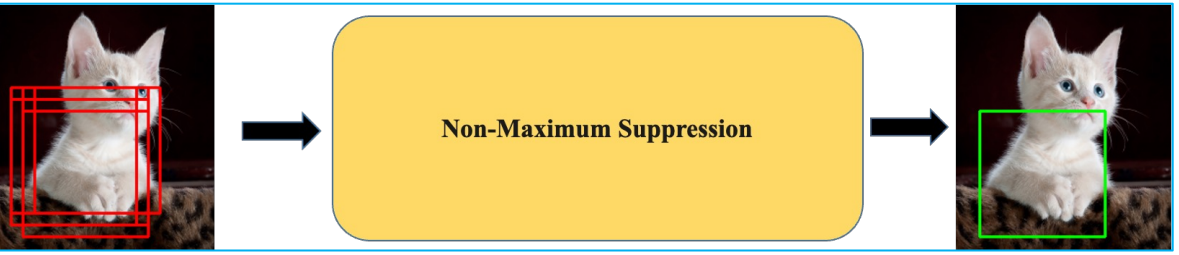


Iris Virginica

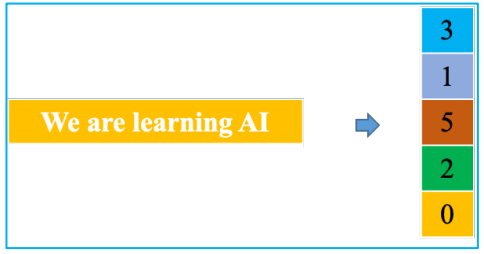
	sepal_length	sepal_width	petal_length	petal_width	species
0	5.1	3.5	1.4	0.2	Iris-setosa
1	4.9	3.0	1.4	0.2	Iris-setosa
2	4.7	3.2	1.3	0.2	Iris-setosa
3	4.6	3.1	1.5	0.2	Iris-setosa
4	5.0	3.6	1.4	0.2	Iris-setosa

Summary

Data Structure	Ordered	Mutable	Constructor	Example
List	Yes	Yes	[] or list()	[5. 7, ‘yes’, 5.7]
Tuple	Yes	No	() or tuple()	(5.7, ‘yes’, 5.7)
Set	No	Yes	{} or set()	{5.7, ‘yes’ }
Dictionary	No	Yes	{} or dict{}	{‘key’: value}



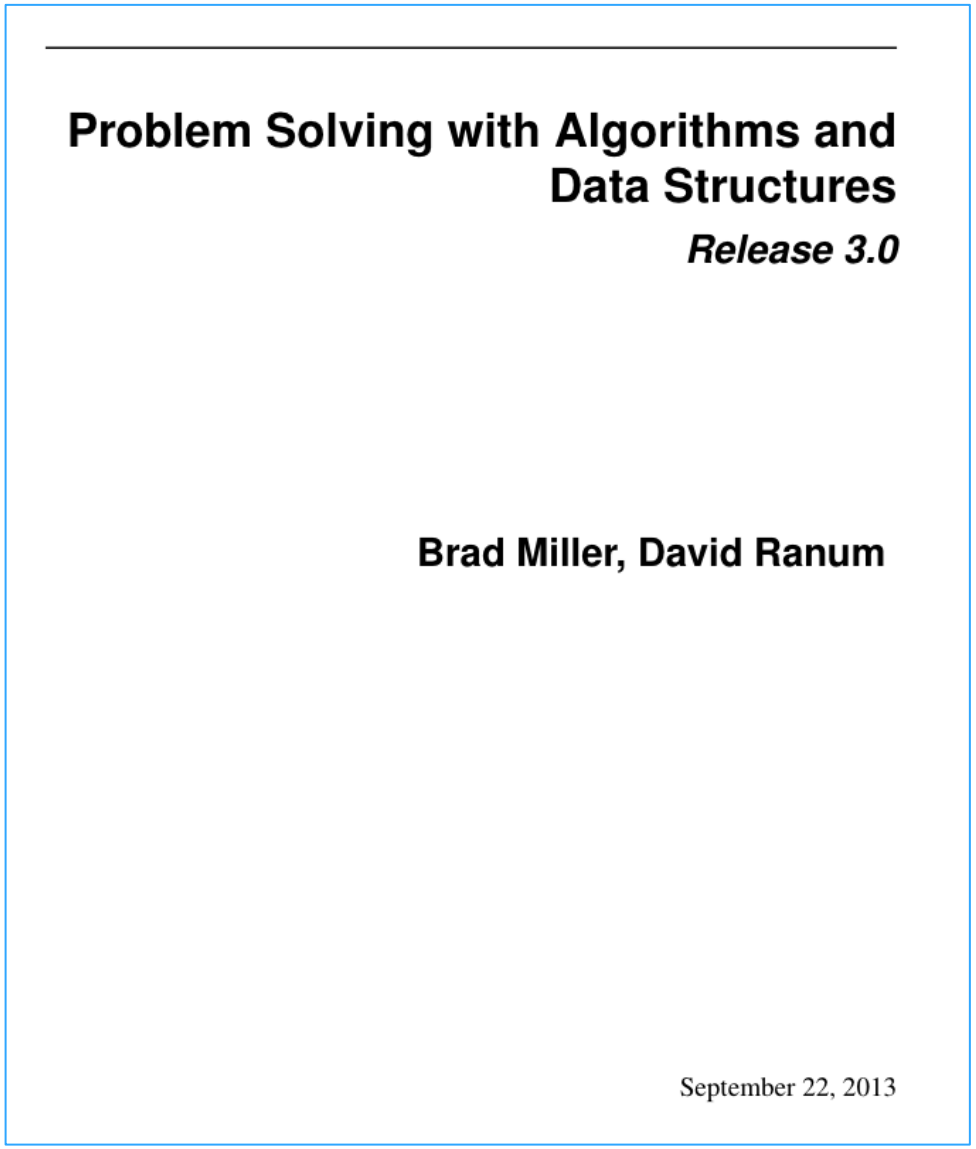
IOU, NMS using Tuple

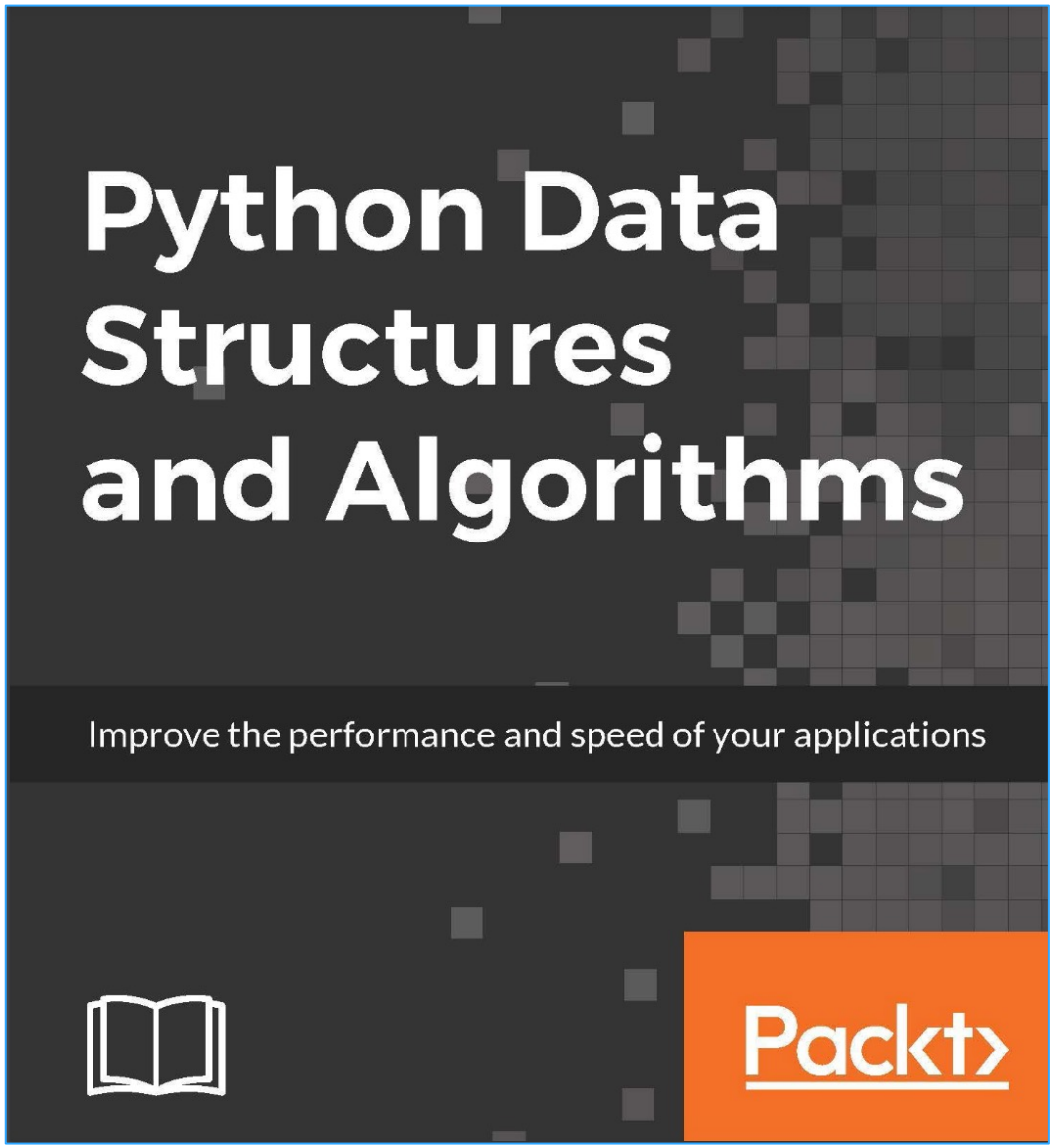


Text embedding using Set

Histogram using Dictionary

References


Problem Solving with Algorithms and Data Structures
Release 3.0
Brad Miller, David Ranum
September 22, 2013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