Introduction to KNN (Tuesday)

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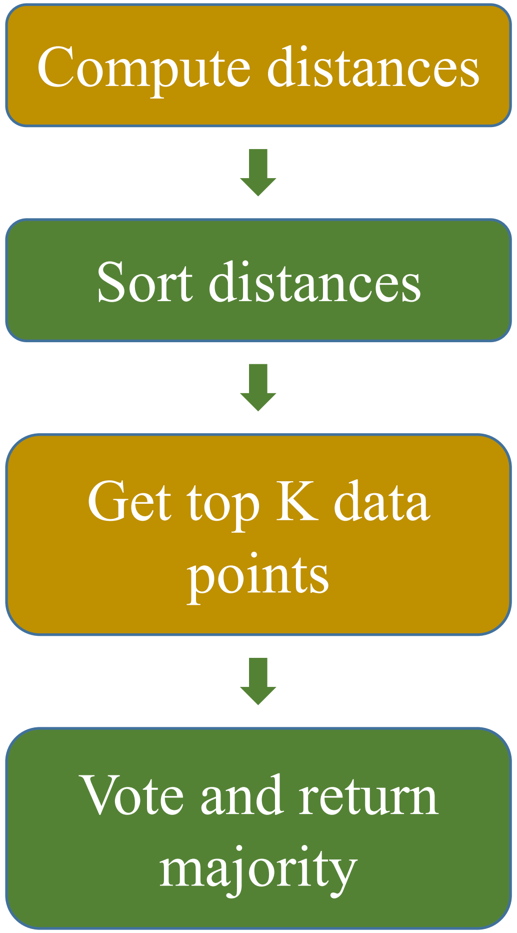
Ph.D. in Computer Science

Objectives

Basic KNN



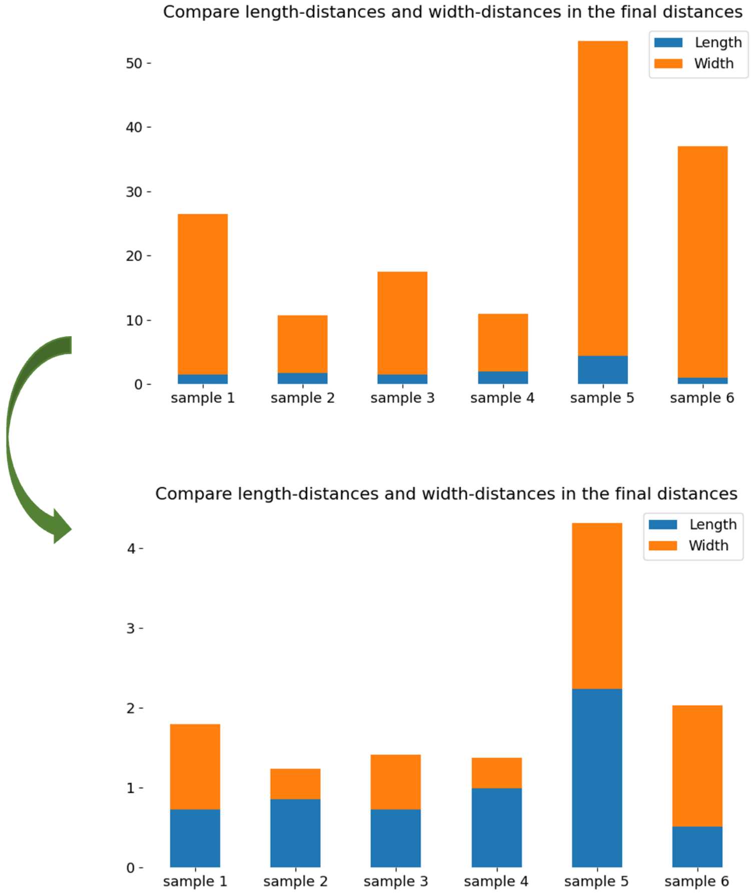
Compute distances

Sort distances

Get top K data points

Vote and return majority

Scaling

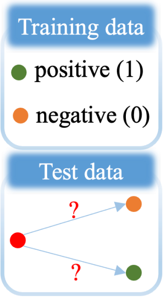


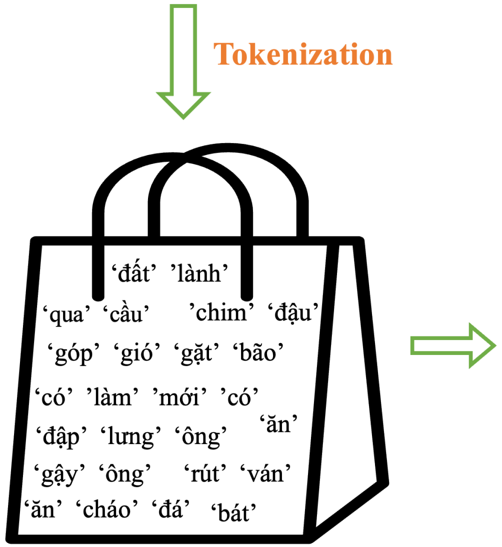
Compare length-distances and width-distances in the final distances

Compare length-distances and width-distances in the final distances

Text Classification

Doc	Label
góp gió gặt bão	1
có làm mới có ăn	1
đất lành chim đậu	1
ăn cháo đá bát	0
gậy ông đập lưng ông	0
qua cầu rút ván	0





Outline

SECTION 1

Basic KNN

SECTION 2

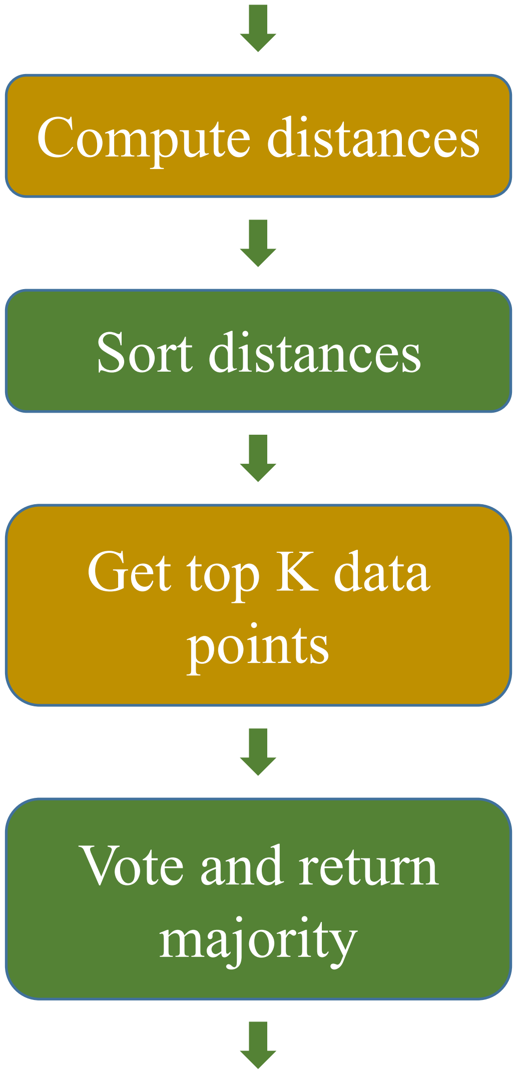
Scaling

SECTION 3

Text Classification

SECTION 4

KNN Regression



Compute distances

Sort distances

Get top K data points

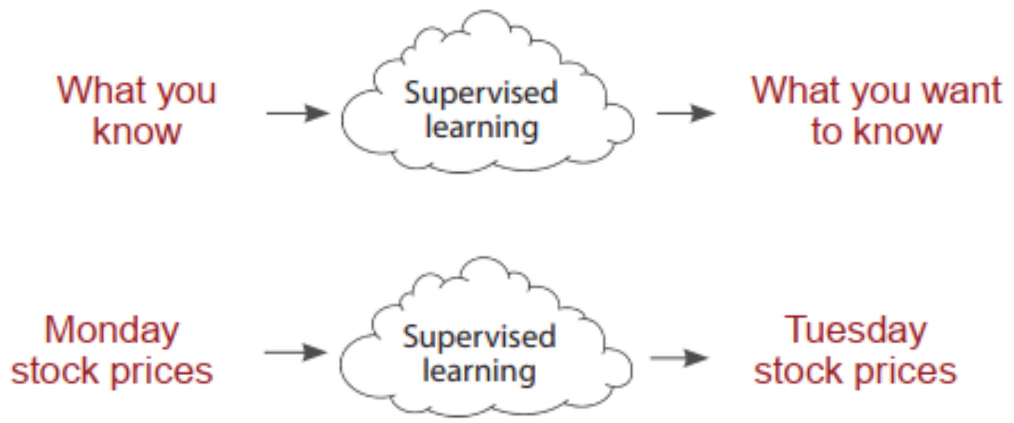
Vote and return majority

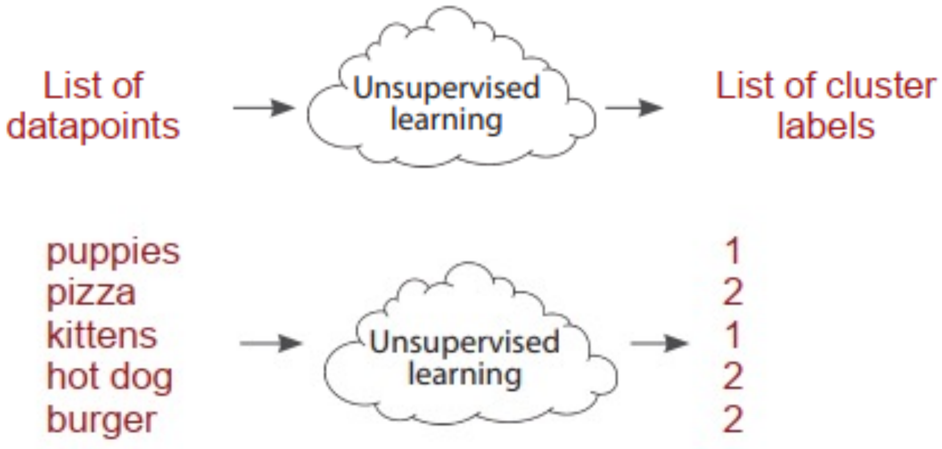
Machine Learning

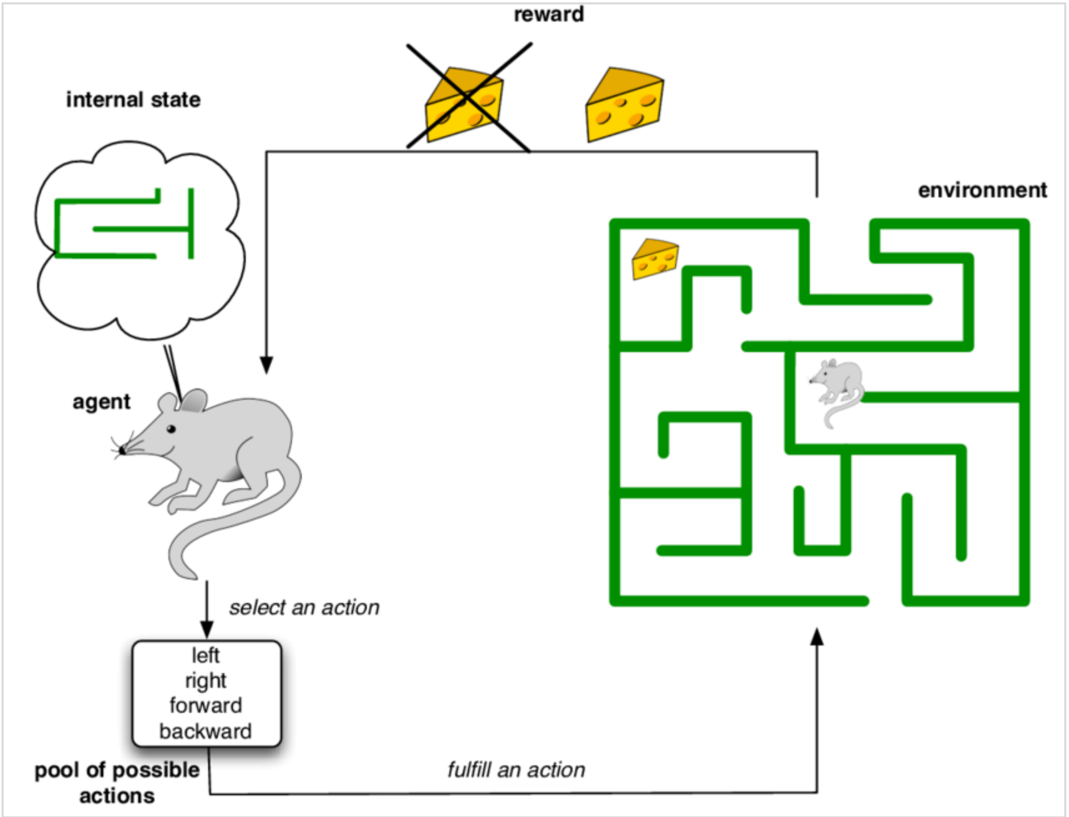
❖ Definition

What is machine learning?

> A field of study that gives computers the ability to learn without being explicitly programmed.
>
> —Attributed to Arthur Samuel







Machine Learning

❖ Supervised learning

❖ Data

Input and output data are provided

🟩 Training data

🟥 Cats

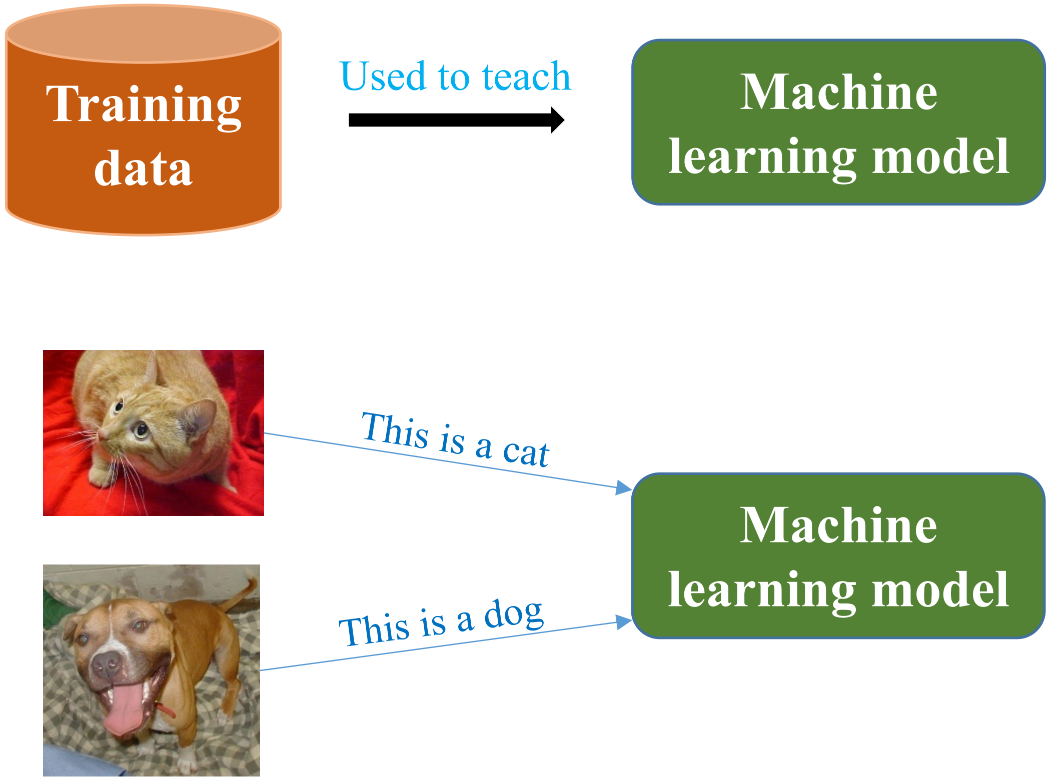
🟪 Dogs

From Cat-Dog dataset

Machine Learning

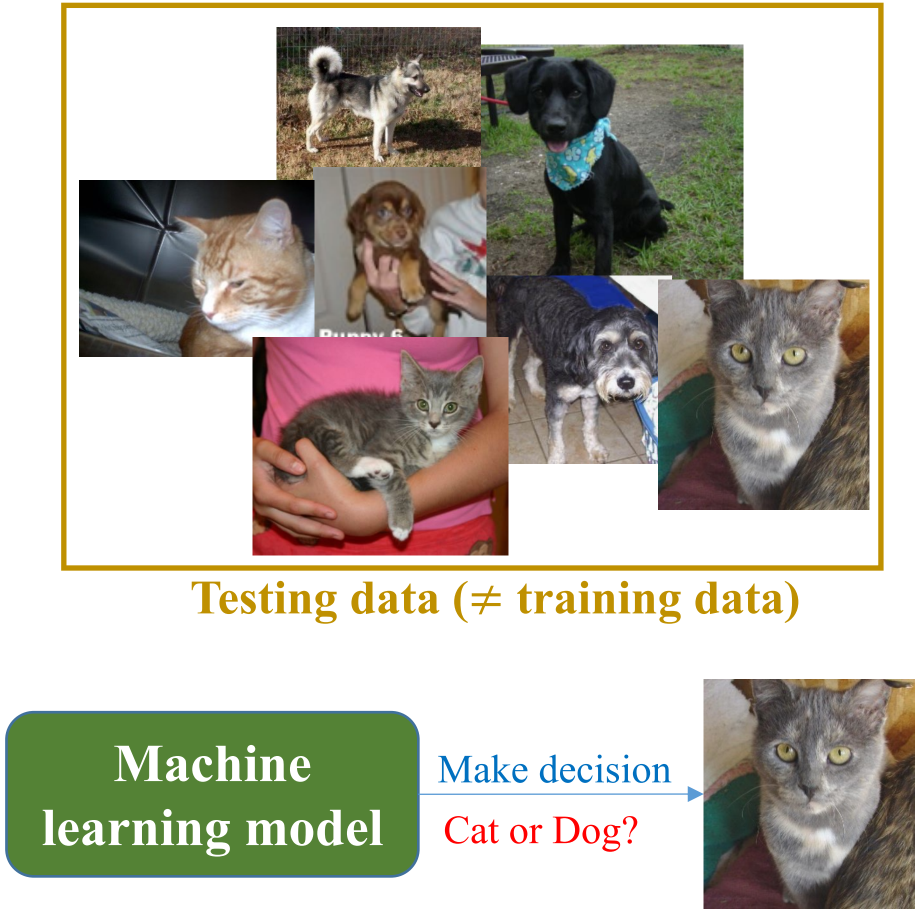
❖ Supervised learning

❖ Data



Training phase

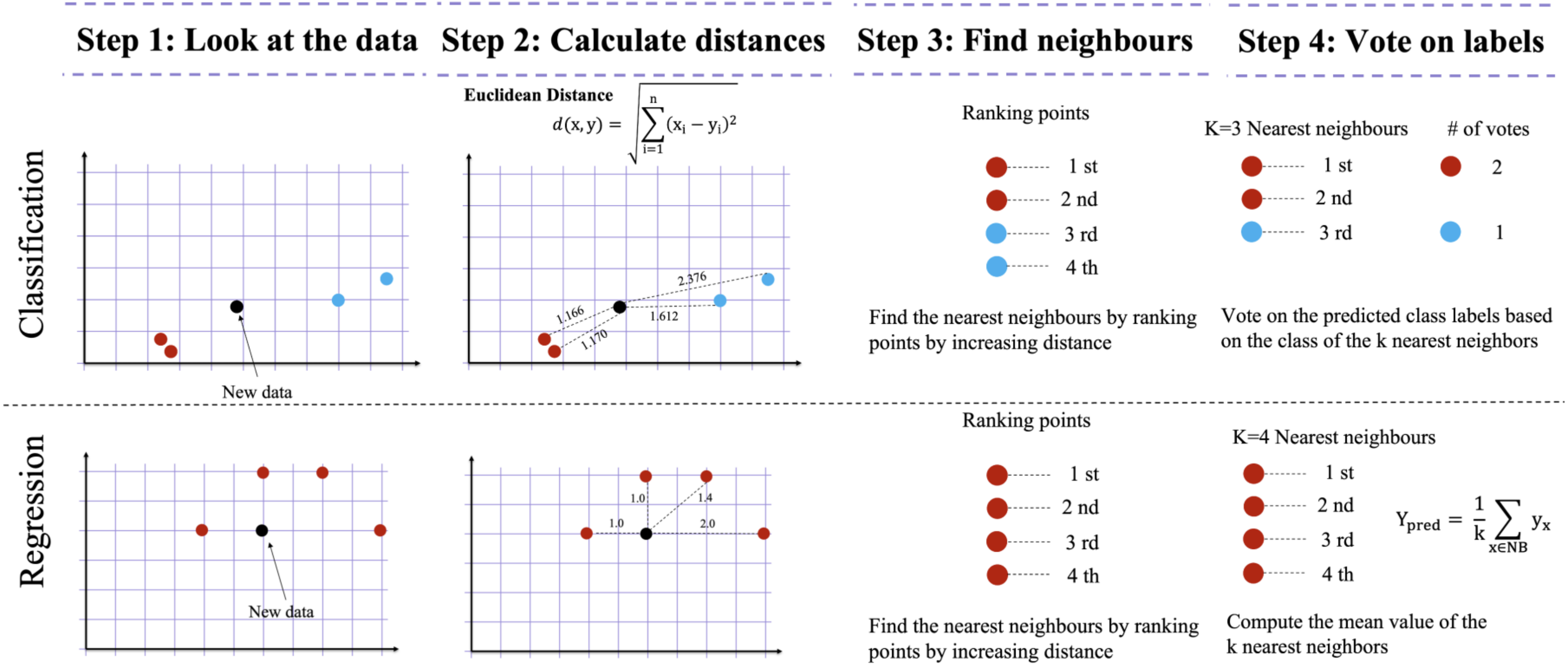
From Cat-Dog dataset



Testing phase

K-Nearest Neighbors

❖ Overview



Step 1: Look at the data

Step 2: Calculate distances

Step 3: Find neighbours

Step 4: Vote on labels

Classification

Euclidean Distance

$$d(x,y) = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$

Ranking points

🔴 ------- 1 st
🔴 ------- 2 nd
🔵 ------- 3 rd
🔵 ------- 4 th

Find the nearest neighbours by ranking points by increasing distance

K=3 Nearest neighbours

🔴 ------- 1 st
🔴 ------- 2 nd
🔵 ------- 3 rd

	# of votes
🔴	2
🔵	1

Vote on the predicted class labels based on the class of the k nearest neighbors

Regression

Ranking points

🔴 ------- 1 st
🔴 ------- 2 nd
🔴 ------- 3 rd
🔴 ------- 4 th

Find the nearest neighbours by ranking points by increasing distance

K=4 Nearest neighbours

🔴 ------- 1 st
🔴 ------- 2 nd
🔴 ------- 3 rd
🔴 ------- 4 th

$$Y_{pred} = \frac{1}{k}\sum_{x \in NB} y_x$$

Compute the mean value of the k nearest neighbors

K-Nearest Neighbors

❖ Procedure

1. Initialize the value of k

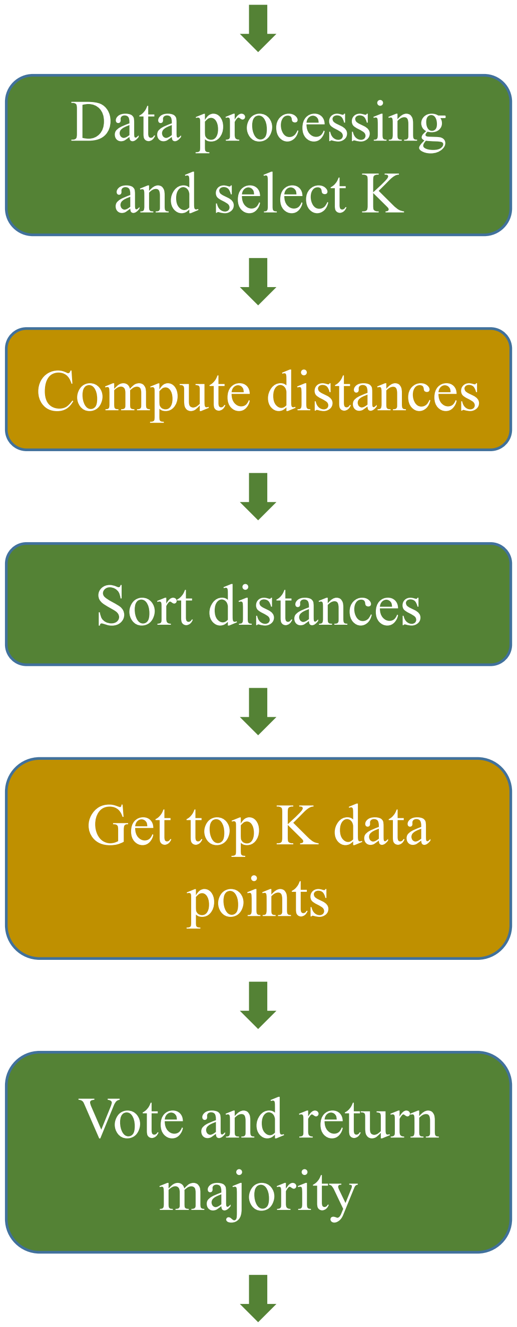
2. Calculate the distance between test data and each row of training dataset.

3. Sort the calculated distances in ascending order based on distance values

4. Get top k rows from the sorted array

5. Get the most frequent class of these rows

6. Return the predicted class



Data processing and select K

Compute distances

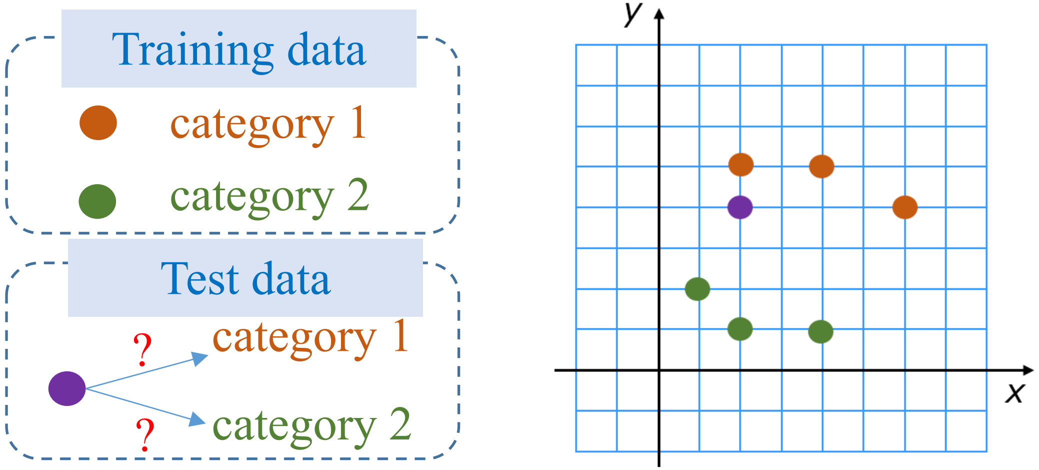
Sort distances

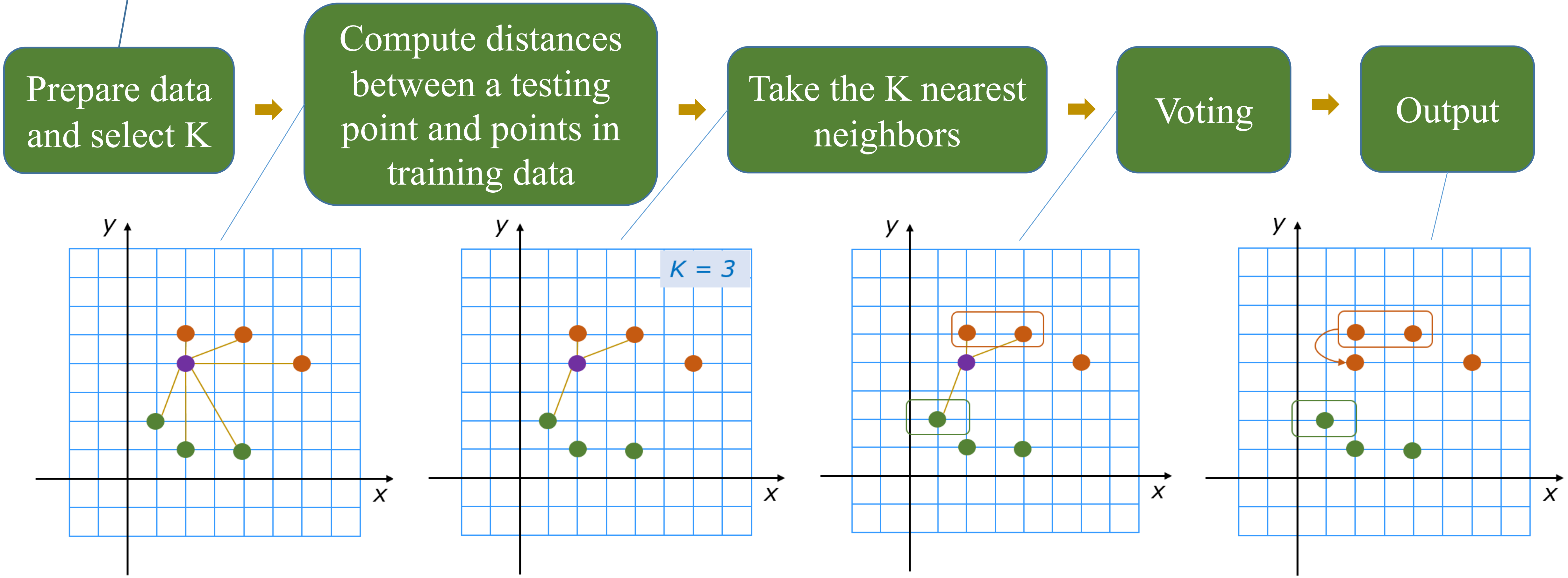
Get top K data points

Vote and return majority

KNN Algorithm

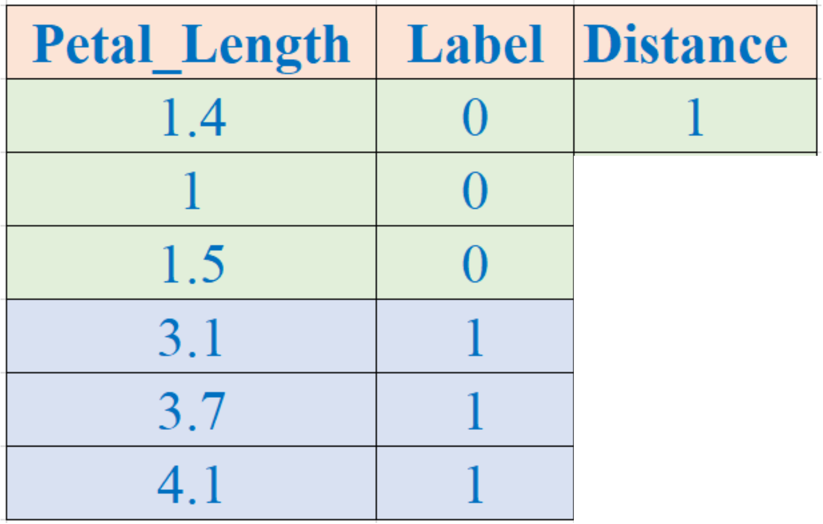
Petal_Length (cm)	Petal_Width (cm)	Label
1.4	0.2	0
1.3	0.4	0
1.4	0.3	0
4	1	1
4.7	1.4	1
3.6	1.3	1




Prepare data and select K ➡ Compute distances between a testing point and points in training data ➡ Take the K nearest neighbors ➡ Voting ➡ Output

KNN

❖ Example



Petal_Length	Label	Distance
1.4	0	1
1	0	
1.5	0	
3.1	1	
3.7	1	
4.1	1	

New input data
x_test = 2.4

KNN

❖ Example

Petal_Length	Label	Distance
1.4	0	1
1	0	1.4
1.5	0	0.9
3.1	1	0.7
3.7	1	1.3
4.1	1	1.7

New input data
x_test = 2.4

Petal_Length	Label	Distance
1.4	0	1
1	0	1.4
1.5	0	0.9
3.1	1	0.7
3.7	1	1.3
4.1	1	1.7

k=1
→ y_test = 1

k=3
→ y_test = ?

KNN

❖ Example

Petal_Length	Petal_Width	Label	Distance
1.4	0.2	0	1.166
1.3	0.4	0	
1.4	0.3	0	
4	1	1	
4.7	1.4	1	
3.6	1.3	1	

New input data
x_test = (2.4, 0.8)

KNN

❖ Example

Petal_Length	Petal_Width	Label	Distance
1.4	0.2	0	1.166
1.3	0.4	0	1.17
1.4	0.3	0	1.118
4	1	1	1.612
4.7	1.4	1	2.376
3.6	1.3	1	1.3

New input data
x_test = (2.4, 0.8)

K = 1

K = 3

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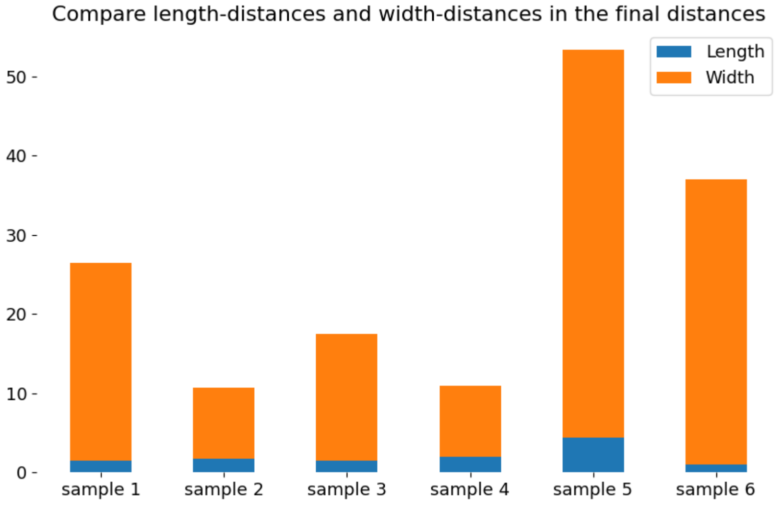
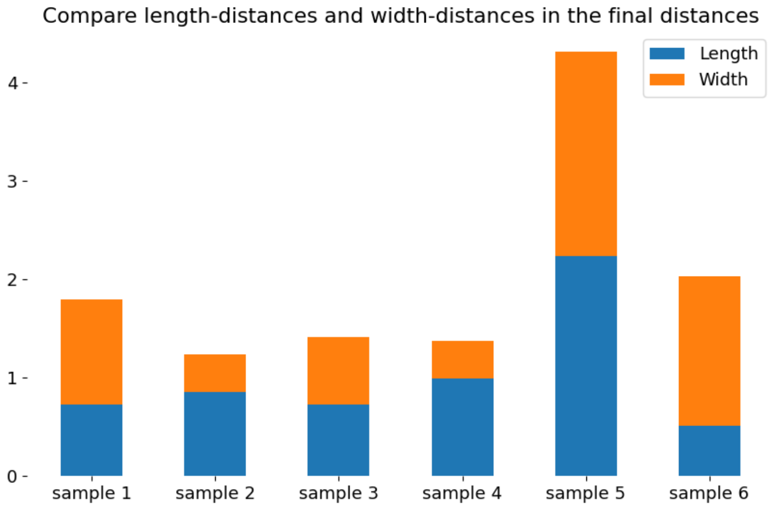
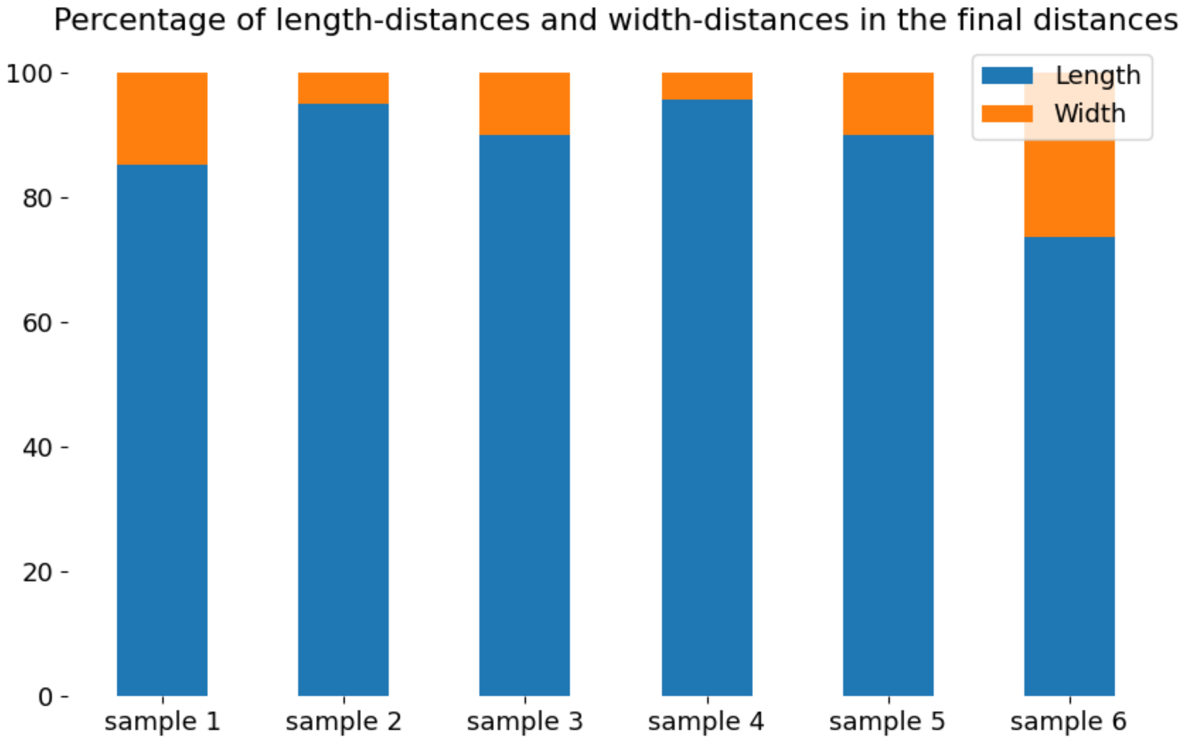

Compare length-distances and width-distances in the final distances

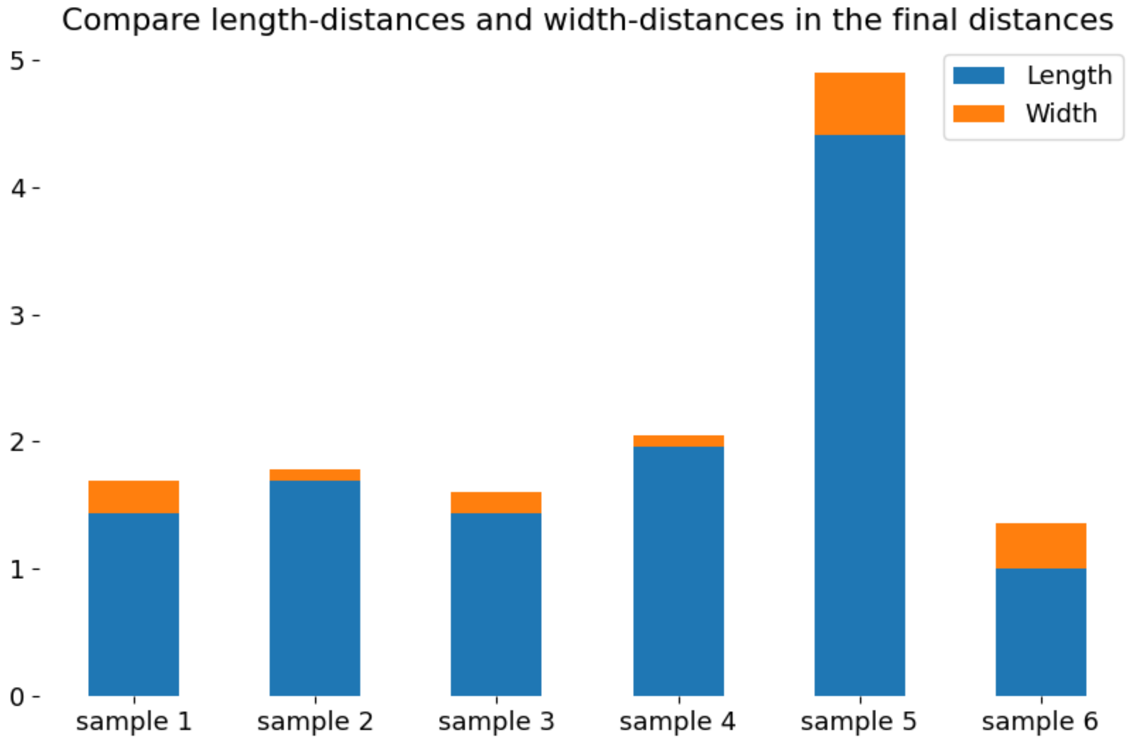

Compare length-distances and width-distances in the final distances

Example (1)

Unnormalized 2D data

Petal_Length (cm)	Petal_Width (cm)	Label	Length_distance	Width_distance	Distance
1.4	0.2	0	1.44	0.25	1.3
1.3	0.4	0	1.69	0.09	1.33
1.4	0.3	0	1.44	0.16	1.26
4	1	1	1.96	0.09	1.43
4.7	1.4	1	4.41	0.49	2.21
3.6	1.3	1	1	0.36	1.16

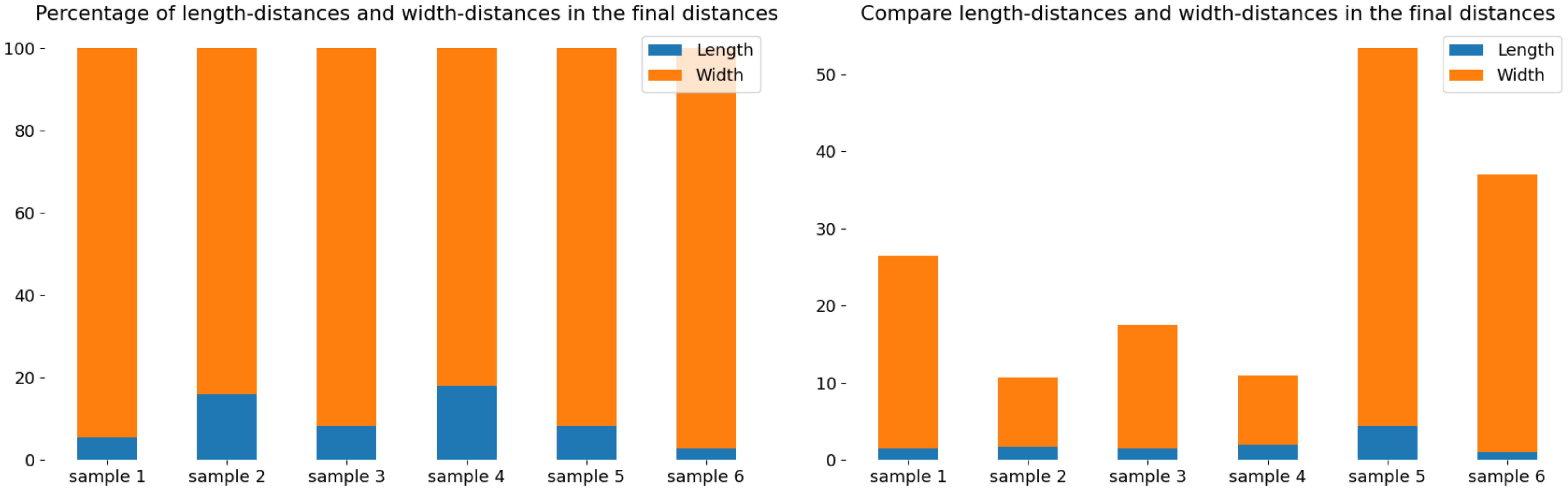

Percentage of length-distances and width-distances in the final distances


Compare length-distances and width-distances in the final distances

Example (2)

Unnormalized 2D data

Petal_Length (cm)	Petal_Width (mm)	Label	Length_distance	Width_distance	Distance
1.4	2	0	1.44	25	5.14
1.3	4	0	1.69	9	3.26
1.4	3	0	1.44	16	4.17
4	10	1	1.96	9	3.31
4.7	14	1	4.41	49	7.31
3.6	13	1	1	36	6.08


Percentage of length-distances and width-distances in the final distances

Compare length-distances and width-distances in the final distances

Data normalization

$$d = \sqrt{\left(x_1^{test} - x_1^{train}\right)^2 + \left(x_2^{test} - x_2^{train}\right)}$$

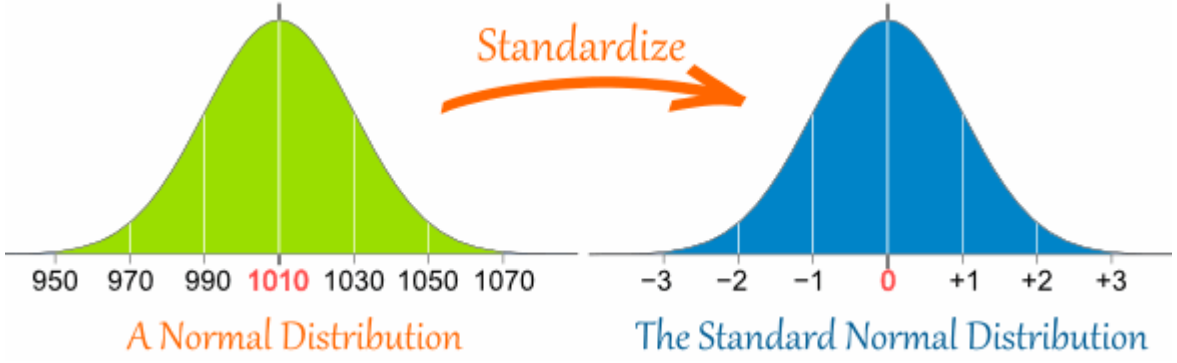
x_1	x_2		d
Petal_Length (cm)	**Petal_Width (mm)**	**Label**	**Distance**
1.4	2	0	5.14
1.3	4	0	3.26
1.4	3	0	4.17
4	10	1	3.31
4.7	14	1	7.31
3.6	13	1	6.08

Training Data 1

x_1	x_2		d
Petal_Length (cm)	**Petal_Width (cm)**	**Label**	**Distance**
1.4	0.2	0	1.3
1.3	0.4	0	1.33
1.4	0.3	0	1.26
4	1	1	1.43
4.7	1.4	1	2.21
3.6	1.3	1	1.16

Training Data 2

$$x = \frac{x - \bar{x}}{\sigma}$$

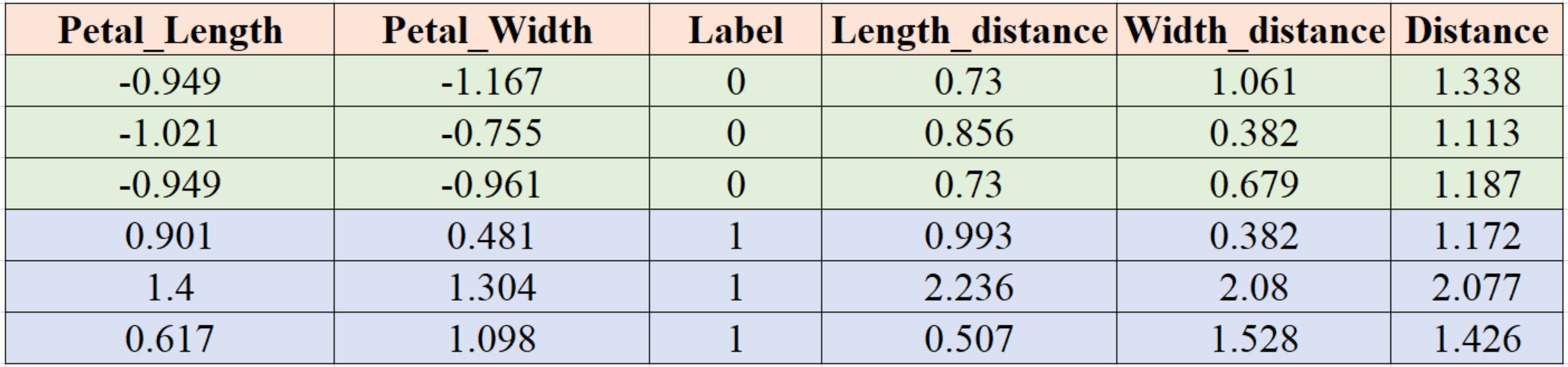


https://www.quora.com/Why-is-the-mean-of-normal-distribution-equal-to-zero

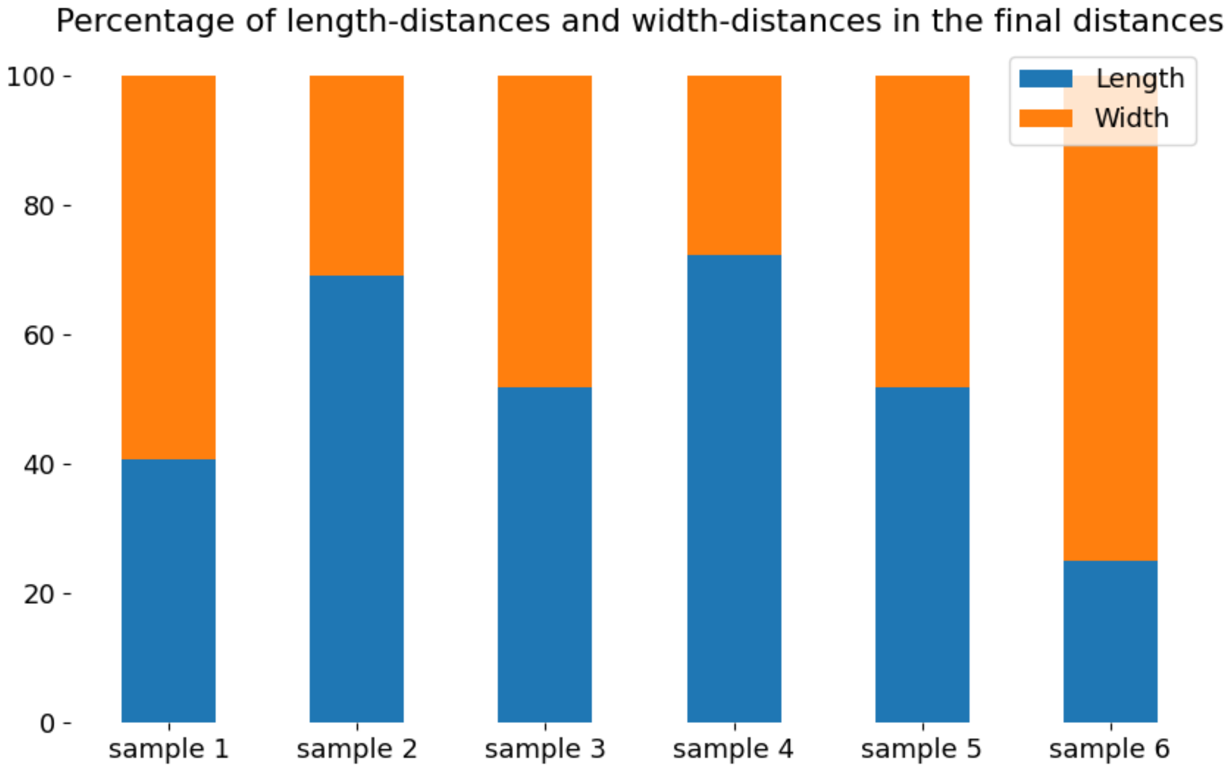
Petal_Length	**Petal_Width**	**Label**	**Distance**
-0.949	-1.167	0	1.338
-1.021	-0.755	0	1.113
-0.949	-0.961	0	1.187
0.901	0.481	1	1.172
1.4	1.304	1	2.077
0.617	1.098	1	1.426

Example (3)

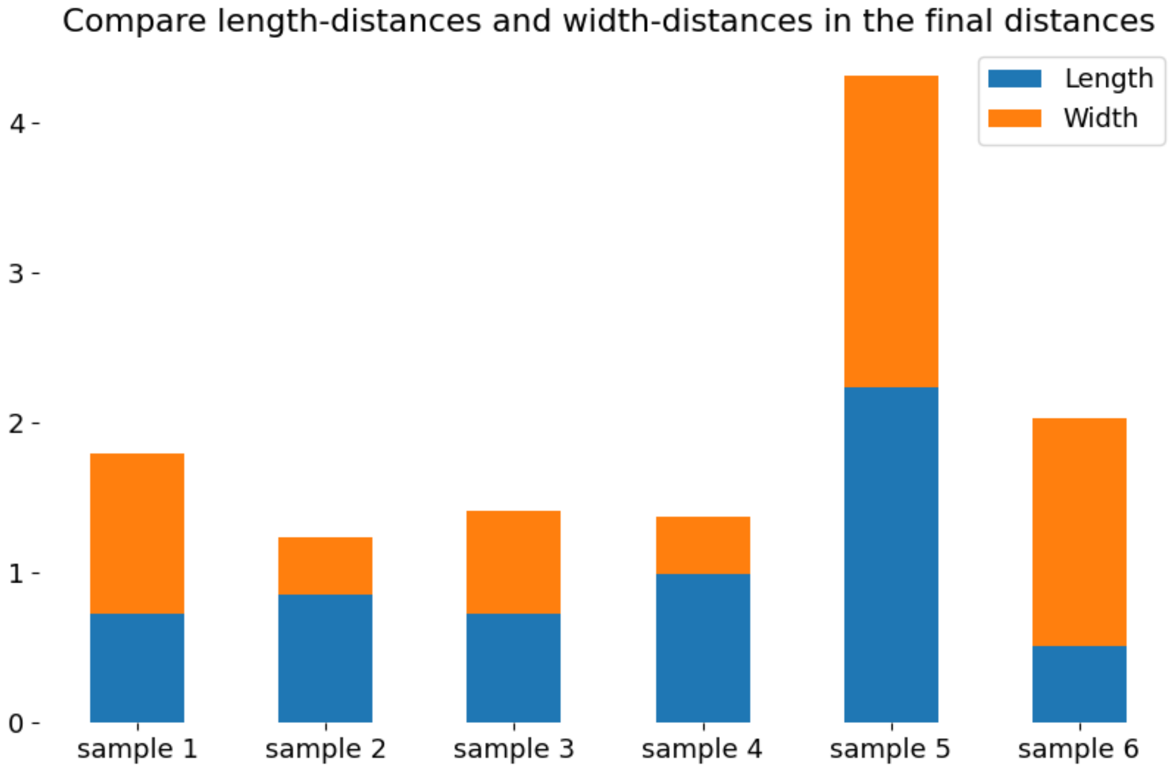
normalized 2D data



Petal_Length	Petal_Width	Label	Length_distance	Width_distance	Distance
-0.949	-1.167	0	0.73	1.061	1.338
-1.021	-0.755	0	0.856	0.382	1.113
-0.949	-0.961	0	0.73	0.679	1.187
0.901	0.481	1	0.993	0.382	1.172
1.4	1.304	1	2.236	2.08	2.077
0.617	1.098	1	0.507	1.528	1.426



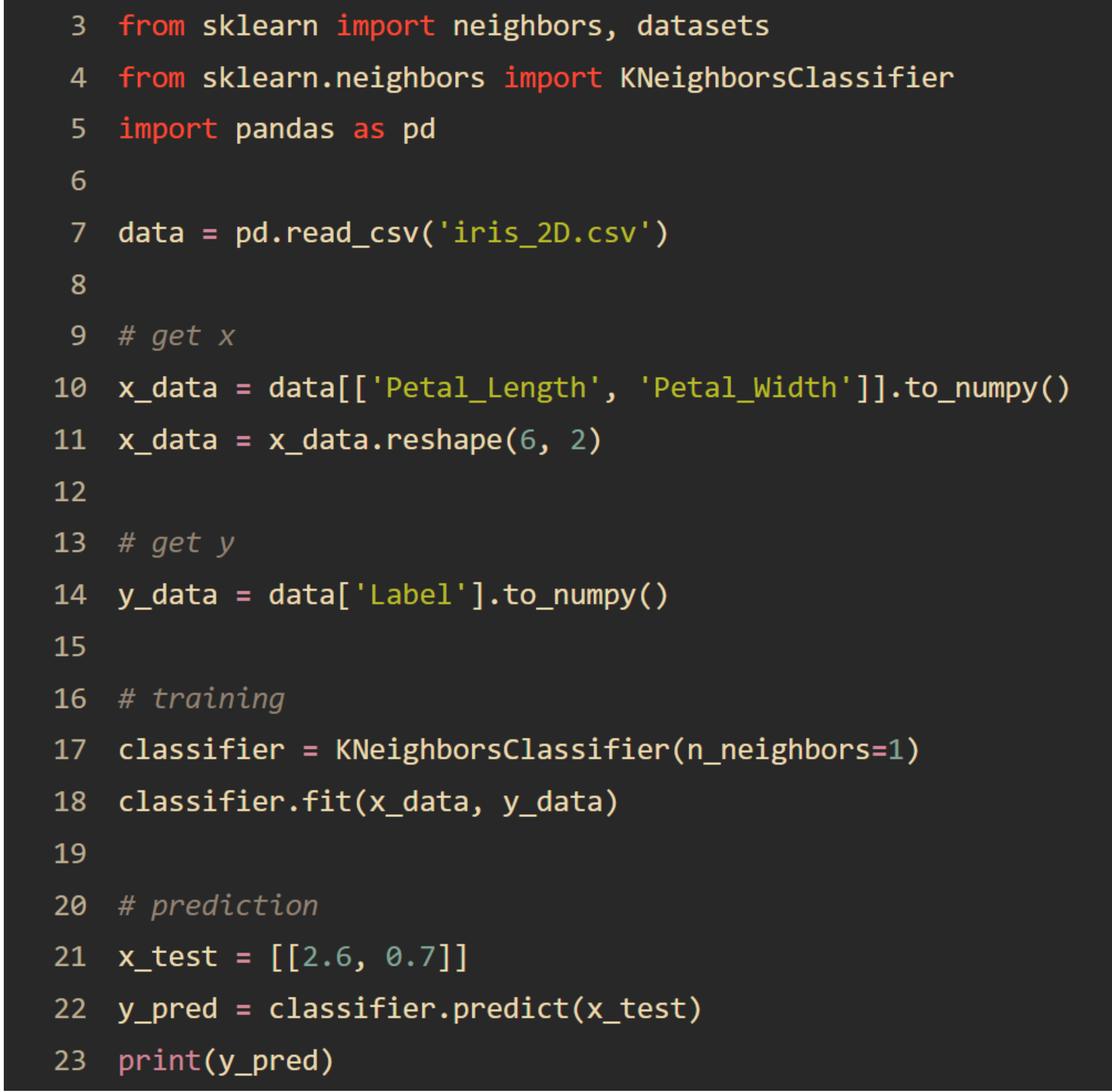
Percentage of length-distances and width-distances in the final distances



Compare length-distances and width-distances in the final distances

KNN

❖ Implementation



```python
from sklearn import neighbors, datasets
from sklearn.neighbors import KNeighborsClassifier
import pandas as pd

data = pd.read_csv('iris_2D.csv')

# get x
x_data = data[['Petal_Length', 'Petal_Width']].to_numpy()
x_data = x_data.reshape(6, 2)

# get y
y_data = data['Label'].to_numpy()

# training
classifier = KNeighborsClassifier(n_neighbors=1)
classifier.fit(x_data, y_data)

# prediction
x_test = [[2.6, 0.7]]
y_pred = classifier.predict(x_test)
print(y_pred)
```

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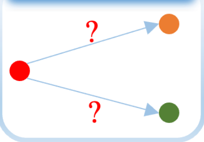
Doc	Label
góp gió gặt bão	1
có làm mới có ăn	1
đất lành chim đậu	1
ăn cháo đá bát	0
gậy ông đập lưng ông	0
qua cầu rút ván	0

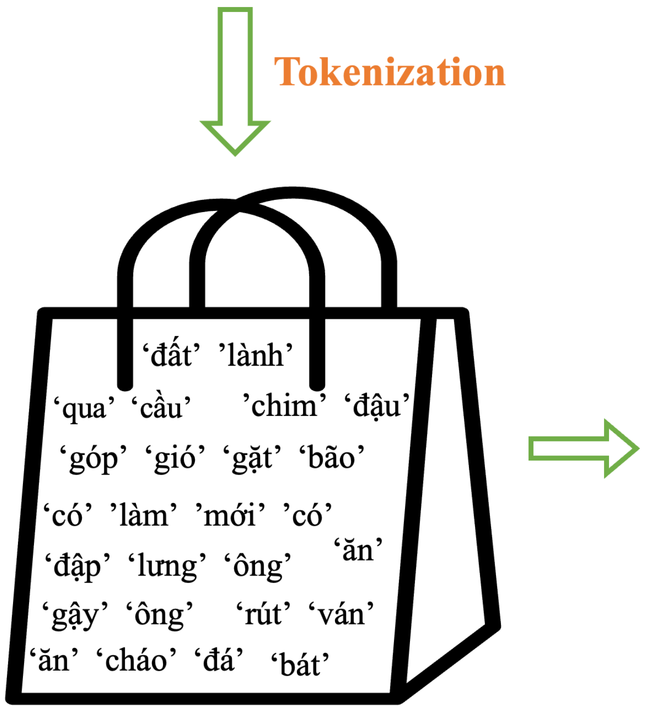
Training data

● positive (1)

● negative (0)

Test data





Text classification with KNN

Vectorization with Bag of Words

Text Representation

❖ Bag of words

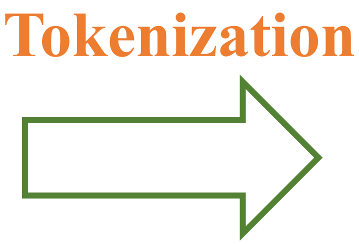
Corpus

doc1 = “deep learning book”

doc2 = “machine learning algorithm”

doc3 = “learning ai from scratch”

doc4 = “ai vietnam”



[‘deep’, ‘learning’, ‘book’]

[‘machine’, ‘learning’, ‘algorithm’]

[‘learning’, ‘ai’, ‘from’, ‘scratch’]

[‘ai’, ‘vietnam’]

Vocabulary =

deep	**learning**	**book**	**machine**	**algorithm**	**ai**	**from**	**scratch**	**vietnam**

👉 **Given a string =** “vietnam machine learning deep learning book”

	deep	**learning**	**book**	**machine**	**algorithm**	**ai**	**from**	**scratch**	**vietnam**
BoW	1	2	1	1	0	0	0	0	1
Binary BoW	1	1	1	1	0	0	0	0	1

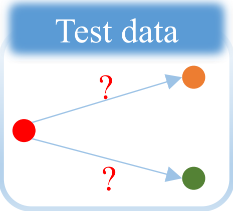
Doc	Label
góp gió gặt bão	1
có làm mới có ăn	1
đất lành chim đậu	1
ăn cháo đá bát	0
gậy ông đập lưng ông	0
qua cầu rút ván	0

Training data

● positive (1)

● negative (0)

Test data



Tokenization

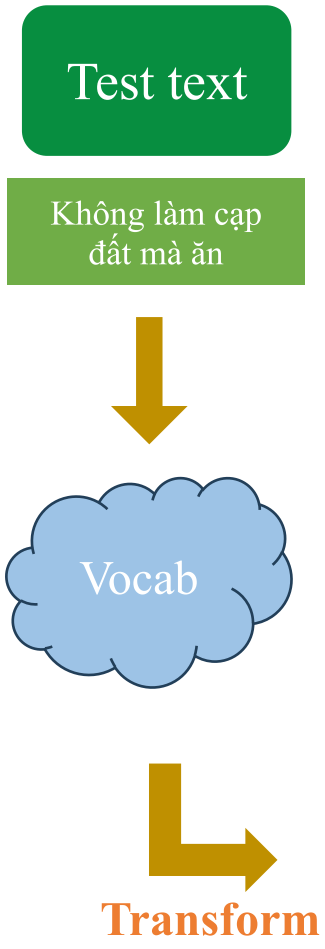
'đất' 'lành'
'qua' 'cầu' 'chim' 'đậu'
'góp' 'gió' 'gặt' 'bão'
'có' 'làm' 'mới' 'có'
'đập' 'lưng' 'ông' 'ăn'
'gậy' 'ông' 'rút' 'ván'
'ăn' 'cháo' 'đá' 'bát'

Vocabulary
bát
bão
chim
cháo
có
cầu
gió
góp
gậy
gặt
làm
lành
lưng
mới
qua
rút
ván
ông
ăn
đá
đất
đập
đậu

gậy ông đập lưng ông

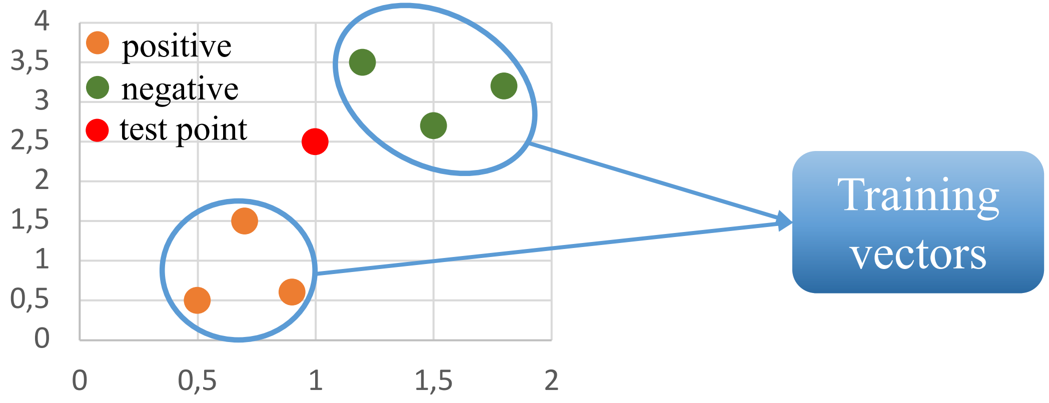
	doc_0	doc_1	doc_2	doc_3	doc_4	doc_5
bát	0	0	0	1	0	0
bão	1	0	0	0	0	0
chim	0	0	1	0	0	0
cháo	0	0	0	1	0	0
có	0	2	0	0	0	0
cầu	0	0	0	0	0	1
gió	1	0	0	0	0	0
góp	1	0	0	0	0	0
gậy	0	0	0	0	1	0
gặt	1	0	0	0	0	0
làm	0	1	0	0	0	0
lành	0	0	1	0	0	0
lưng	0	0	0	0	1	0
mới	0	1	0	0	0	0
qua	0	0	0	0	0	1
rút	0	0	0	0	0	1
ván	0	0	0	0	0	1
ông	0	0	0	0	2	0
ăn	0	1	0	1	0	0
đá	0	0	0	1	0	0
đất	0	0	1	0	0	0
đập	0	0	0	0	1	0
đậu	0	0	1	0	0	0

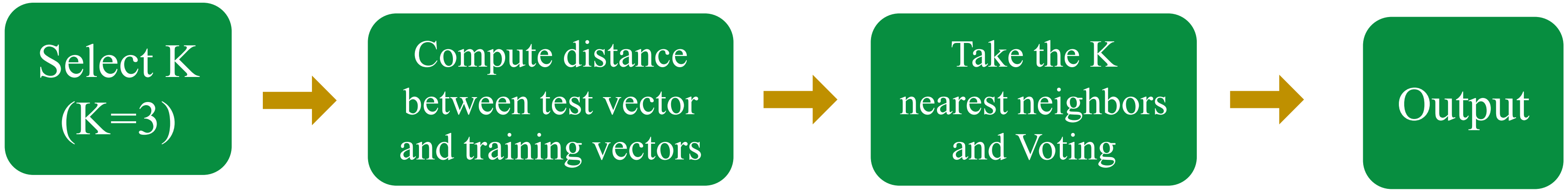
BoW vectors

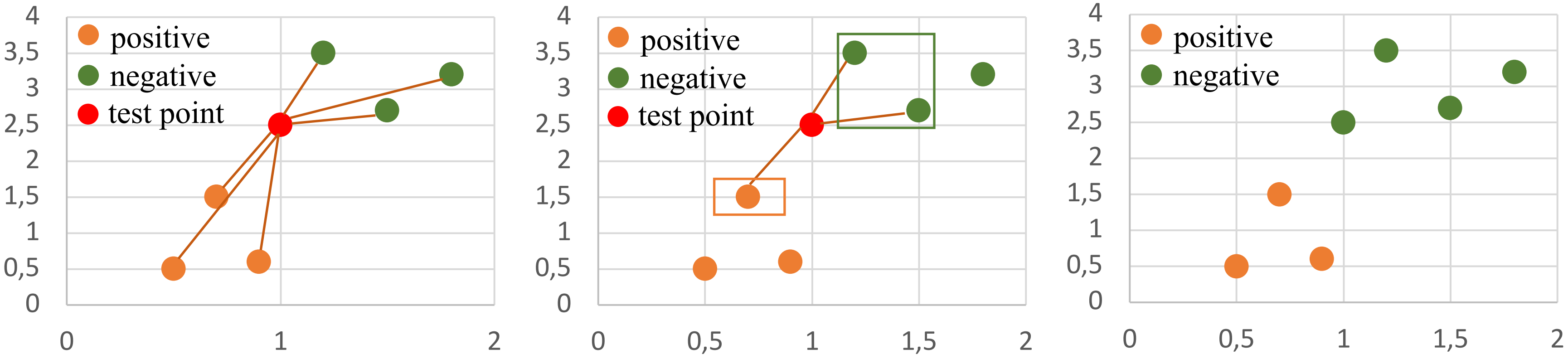


0
0
0
0
0
0
0
0
0
0
1
0
0
0
0
0
0
0
1
0
1
0
0

Doc	Label	Distance
góp gió gặt bão	1	2.645
có làm mới có ăn	1	2.449
đất lành chim đậu	1	2.236
ăn cháo đá bát	0	2.236
gậy ông đập lưng ông	0	3.162
qua cầu rút ván	0	2.645




Select K (K=3)
Compute distance between test vector and training vectors
Take the K nearest neighbors and Voting
Output



Text classification with KNN

TF-IDF vectorizer (extension)

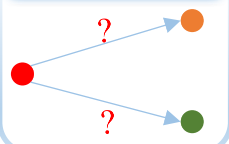
Doc	Label
góp gió gặt bão	0
có làm mới có ăn	0
đất lành chim đậu	0
ăn cháo đá bát	1
gậy ông đập lưng ông	1
qua cầu rút ván	1

Training data

● positive (1)

● negative (0)

Test data



Clean data

Build Doc-Term matrix

Compute IDF vector

	doc_0	doc_1	doc_2	doc_3	doc_4	doc_5
bát	0	0	0	1	0	0
bão	1	0	0	0	0	0
chim	0	0	1	0	0	0
cháo	0	0	0	1	0	0
có	0	2	0	0	0	0
cầu	0	0	0	0	0	1
gió	1	0	0	0	0	0
góp	1	0	0	0	0	0
gậy	0	0	0	0	1	0
gặt	1	0	0	0	0	0
làm	0	1	0	0	0	0
lành	0	0	1	0	0	0
lưng	0	0	0	0	1	0
mới	0	1	0	0	0	0
qua	0	0	0	0	0	1
rút	0	0	0	0	0	1
ván	0	0	0	0	0	1
ông	0	0	0	0	2	0
ăn	0	1	0	1	0	0
đá	0	0	0	1	0	0
đất	0	0	1	0	0	0
đập	0	0	0	0	1	0
đậu	0	0	1	0	0	0

Doc-term matrix

$$log\left(\frac{6+1}{1+1}\right)+1$$

$$IDF_t = log\left(\frac{N+1}{DF_t+1}\right)+1$$

Smothing

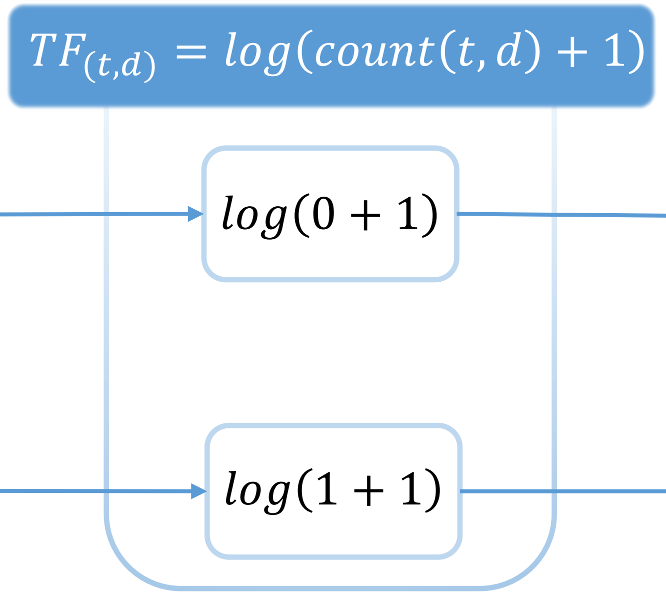
$$log\left(\frac{6+1}{2+1}\right)+1$$

N = number of documents

IDF vector
2.25
2.25
2.25
2.25
1.84
2.25
2.25
2.25
2.25
2.25
2.25
2.25
2.25
2.25
2.25
2.25
2.25
1.84
1.84
2.25
2.25
2.25
2.25

	doc_0	doc_1	doc_2	doc_3	doc_4	doc_5
bát	0	0	0	1	0	0
bão	1	0	0	0	0	0
chim	0	0	1	0	0	0
cháo	0	0	0	1	0	0
có	0	2	0	0	0	0
cầu	0	0	0	0	0	1
gió	1	0	0	0	0	0
góp	1	0	0	0	0	0
gậy	0	0	0	0	1	0
gặt	1	0	0	0	0	0
làm	0	1	0	0	0	0
lành	0	0	1	0	0	0
lưng	0	0	0	0	1	0
mới	0	1	0	0	0	0
qua	0	0	0	0	0	1
rút	0	0	0	0	0	1
ván	0	0	0	0	0	1
ông	0	0	0	0	2	0
ăn	0	1	0	1	0	0
đá	0	0	0	1	0	0
đất	0	0	1	0	0	0
đập	0	0	0	0	1	0
đậu	0	0	1	0	0	0

Doc-term matrix



$$TF_{(t,d)} = log(count(t,d) + 1)$$

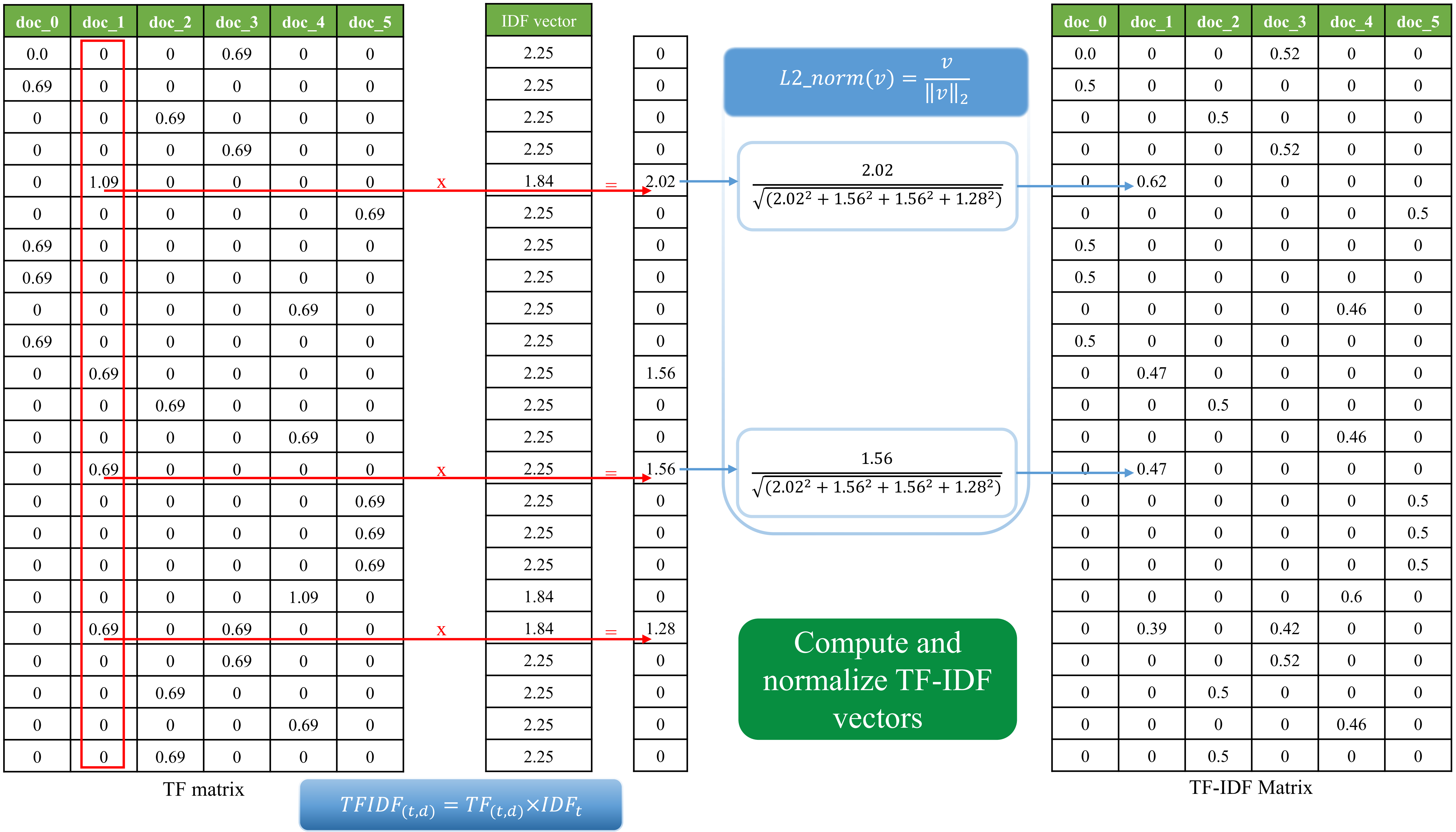
$$log(0 + 1)$$

$$log(1 + 1)$$

Compute TF matrix

doc_0	doc_1	doc_2	doc_3	doc_4	doc_5
0.0	0	0	0.69	0	0
0.69	0	0	0	0	0
0	0	0.69	0	0	0
0	0	0	0.69	0	0
0	1.09	0	0	0	0
0	0	0	0	0	0.69
0.69	0	0	0	0	0
0.69	0	0	0	0	0
0	0	0	0	0.69	0
0.69	0	0	0	0	0
0	0.69	0	0	0	0
0	0	0.69	0	0	0
0	0	0	0	0.69	0
0	0.69	0	0	0	0
0	0	0	0	0	0.69
0	0	0	0	0	0.69
0	0	0	0	0	0.69
0	0	0	0	1.09	0
0	0.69	0	0.69	0	0
0	0	0	0.69	0	0
0	0	0.69	0	0	0
0	0	0	0	0.69	0
0	0	0.69	0	0	0

TF matrix



doc_0	doc_1	doc_2	doc_3	doc_4	doc_5
0.0	0	0	0.69	0	0
0.69	0	0	0	0	0
0	0	0.69	0	0	0
0	0	0	0.69	0	0
0	1.09	0	0	0	0
0	0	0	0	0	0.69
0.69	0	0	0	0	0
0.69	0	0	0	0	0
0	0	0	0	0.69	0
0.69	0	0	0	0	0
0	0.69	0	0	0	0
0	0	0.69	0	0	0
0	0	0	0	0.69	0
0	0.69	0	0	0	0
0	0	0	0	0	0.69
0	0	0	0	0	0.69
0	0	0	0	0	0.69
0	0	0	0	1.09	0
0	0.69	0	0.69	0	0
0	0	0	0.69	0	0
0	0	0.69	0	0	0
0	0	0	0	0.69	0
0	0	0.69	0	0	0

TF matrix

IDF vector
2.25
2.25
2.25
2.25
1.84
2.25
2.25
2.25
2.25
2.25
2.25
2.25
2.25
2.25
2.25
2.25
2.25
1.84
1.84
2.25
2.25
2.25
2.25

0
0
0
0
2.02
0
0
0
0
0
1.56
0
0
1.56
0
0
0
0
1.28
0
0
0
0

$$TFIDF_{(t,d)} = TF_{(t,d)} \times IDF_t$$

$$L2\_norm(v) = \frac{v}{\|v\|_2}$$

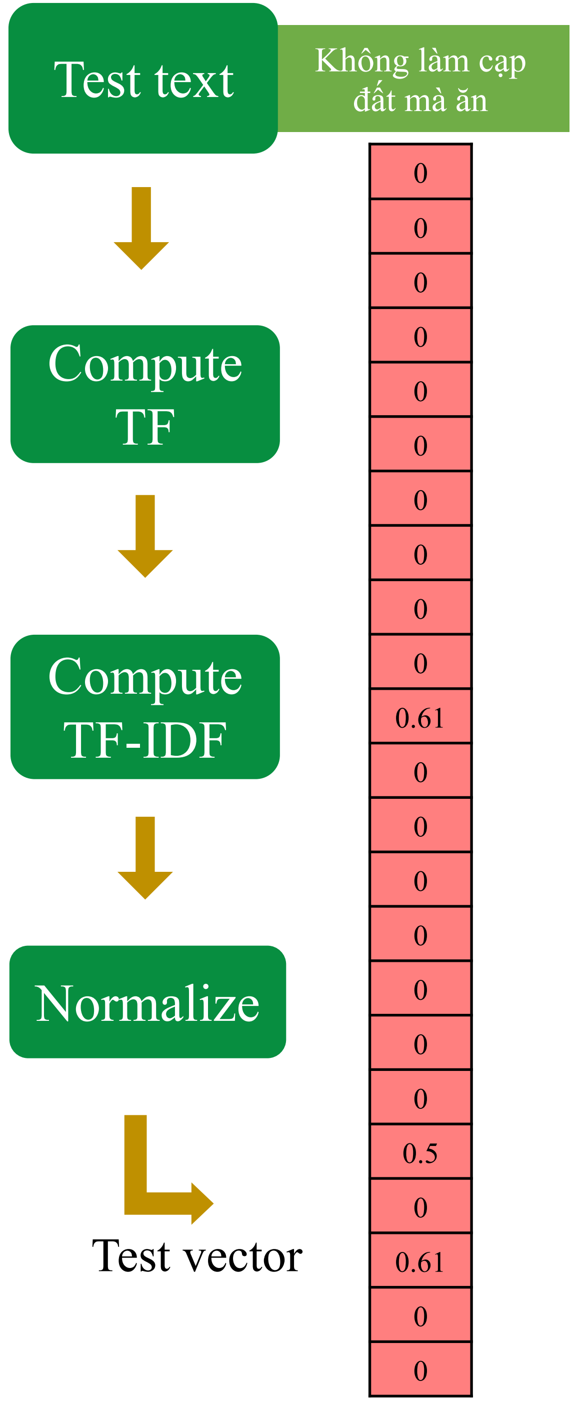
$$\frac{2.02}{\sqrt{(2.02^2 + 1.56^2 + 1.56^2 + 1.28^2)}}$$

$$\frac{1.56}{\sqrt{(2.02^2 + 1.56^2 + 1.56^2 + 1.28^2)}}$$

Compute and normalize TF-IDF vectors

doc_0	doc_1	doc_2	doc_3	doc_4	doc_5
0.0	0	0	0.52	0	0
0.5	0	0	0	0	0
0	0	0.5	0	0	0
0	0	0	0.52	0	0
0	0.62	0	0	0	0
0	0	0	0	0	0.5
0.5	0	0	0	0	0
0.5	0	0	0	0	0
0	0	0	0	0.46	0
0.5	0	0	0	0	0
0	0.47	0	0	0	0
0	0	0.5	0	0	0
0	0	0	0	0.46	0
0	0.47	0	0	0	0
0	0	0	0	0	0.5
0	0	0	0	0	0.5
0	0	0	0	0	0.5
0	0	0	0	0.6	0
0	0.39	0	0.42	0	0
0	0	0	0.52	0	0
0	0	0.5	0	0	0
0	0	0	0	0.46	0
0	0	0.5	0	0	0

TF-IDF Matrix



Test text

Không làm cạp đất mà ăn

Compute TF

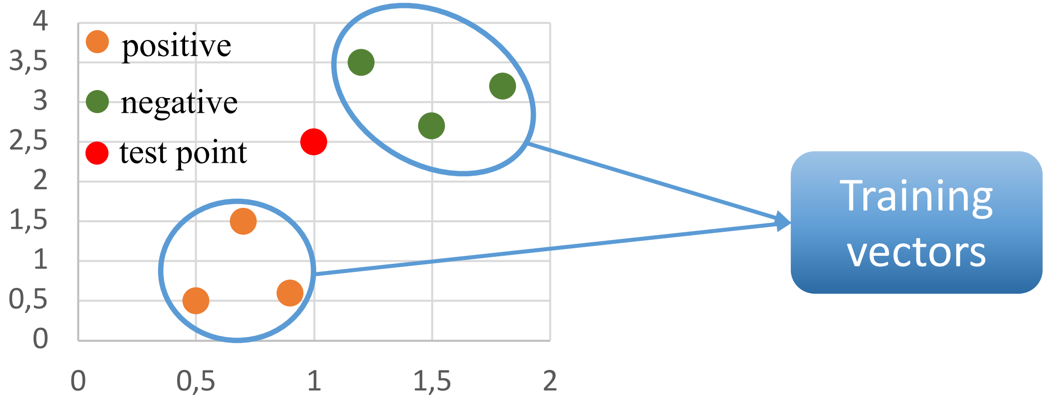
Compute TF-IDF

Normalize

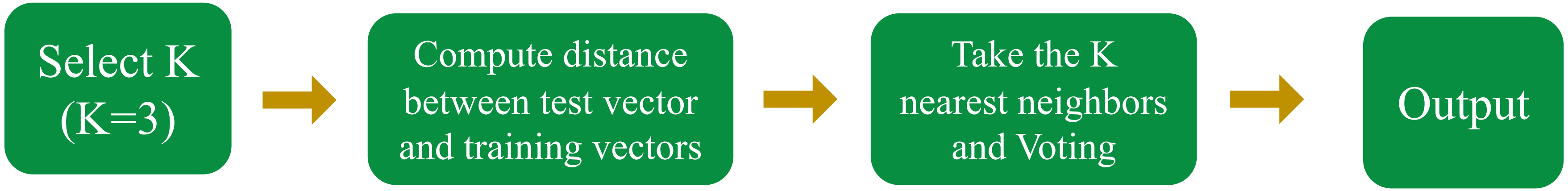
Test vector

0
0
0
0
0
0
0
0
0
0
0.61
0
0
0
0
0
0
0
0.5
0
0.61
0
0

Doc	Label	Distance
góp gió gặt bão	1	1.41
có làm mới có ăn	1	1.01
đất lành chim đậu	1	1.17
ăn cháo đá bát	0	1.25
gậy ông đập lưng ông	0	1.41
qua cầu rút ván	0	1.41



Training vectors

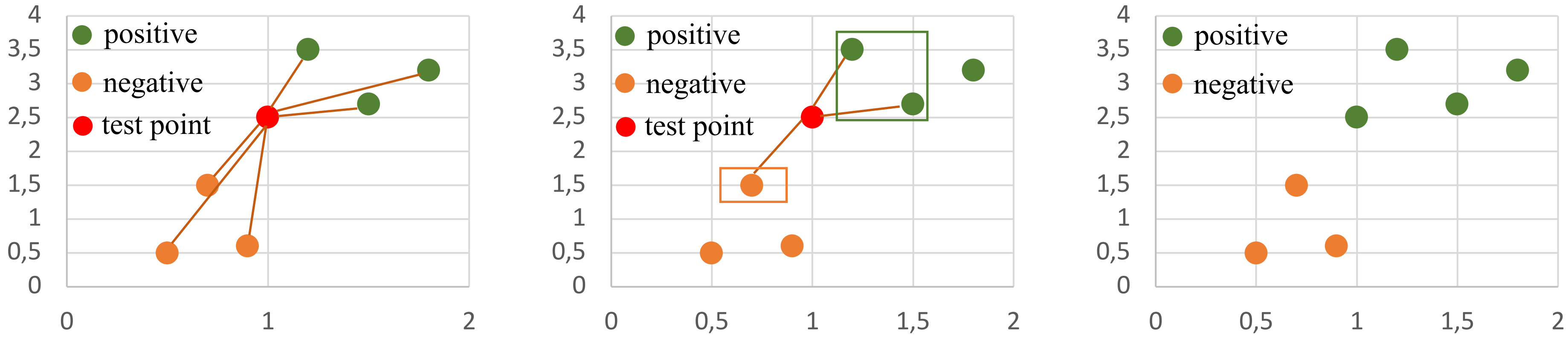


Select K (K=3)

Compute distance between test vector and training vectors

Take the K nearest neighbors and Voting

Output



Outline

SECTION 1

Basic KNN

SECTION 2

Scaling

SECTION 3

Text Classification

SECTION 4

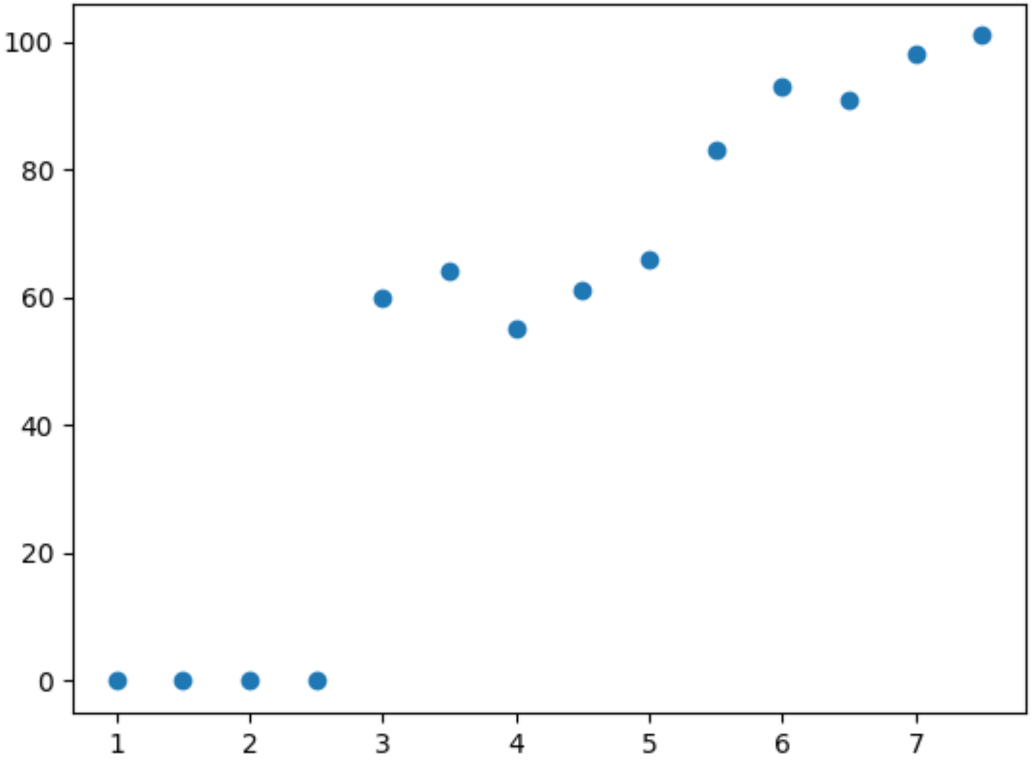
KNN Regression (Extension)

Experience	Salary
1	0
1.5	0
2	0
2.5	0
3	60
3.5	64
4	55
4.5	61
5	66
5.5	83
6	93
6.5	91
7	98
7.5	101

Regression

❖ Salary prediction

Experience	Salary
1	0
1.5	0
2	0
2.5	0
3	60
3.5	64
4	55
4.5	61
5	66
5.5	83
6	93
6.5	91
7	98
7.5	101



When Experience = 5.3,

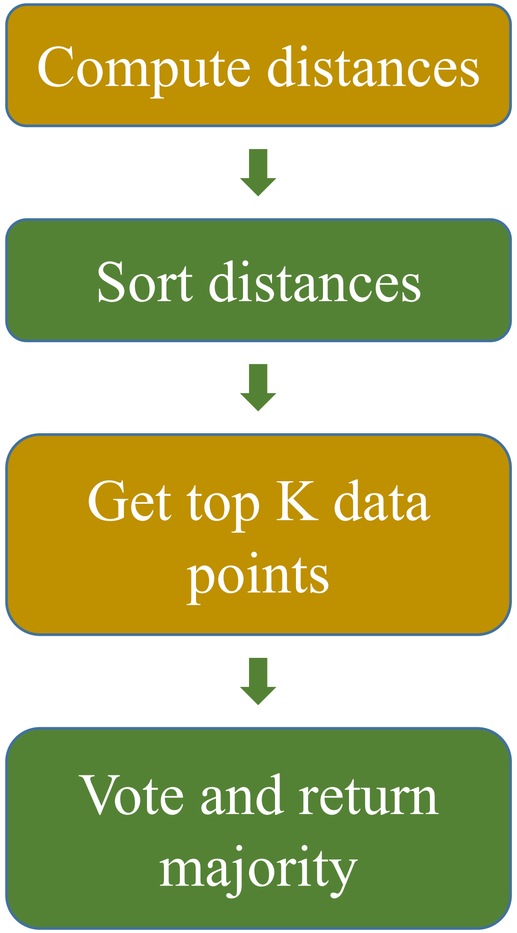
Salary = ?

Experience	Salary
1	0
1.5	0
2	0
2.5	0
3	60
3.5	64
4	55
4.5	61
5	66
5.5	83
6	93
6.5	91
7	98
7.5	101

When Experience = 5.3,
Salary = ?

Summary

Basic KNN



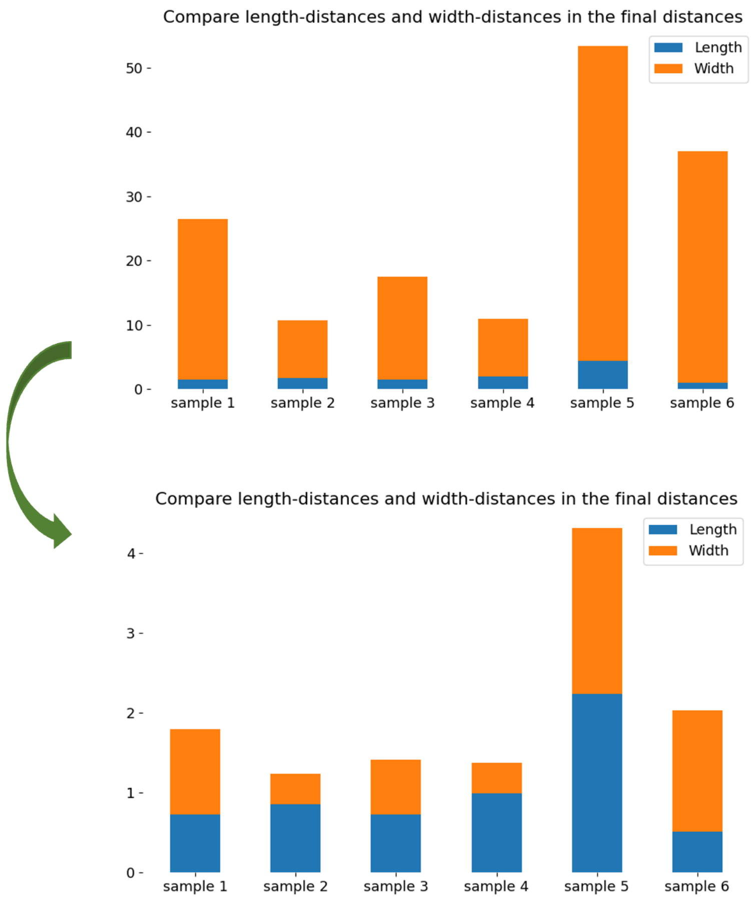
Compute distances

Sort distances

Get top K data points

Vote and return majority

Scaling



Compare length-distances and width-distances in the final distances

Compare length-distances and width-distances in the final distances

Text Classification

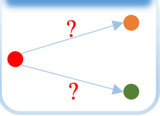
Doc	Label
góp gió gặt bão	1
có làm mới có ăn	1
đất lành chim đậu	1
ăn cháo đá bát	0
gậy ông đập lưng ông	0
qua cầu rút ván	0

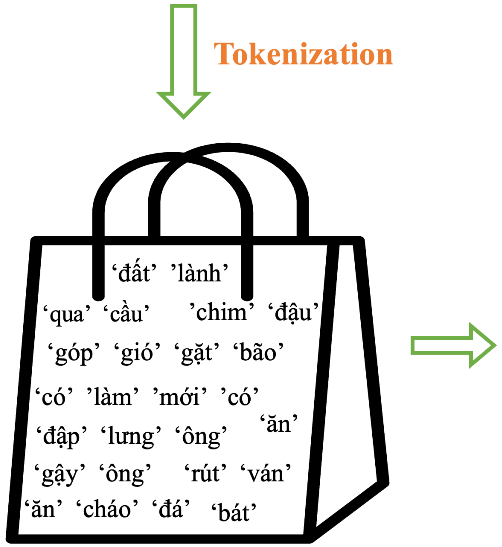
Training data

● positive (1)

● negative (0)

Test data





Tokenization