Agenda

1. SVM Basics

- Visual introduction
- Example in Python

2. Additional Complexities

- Higher dimensions
- Multiple classes
- C parameter
- Kernel trick

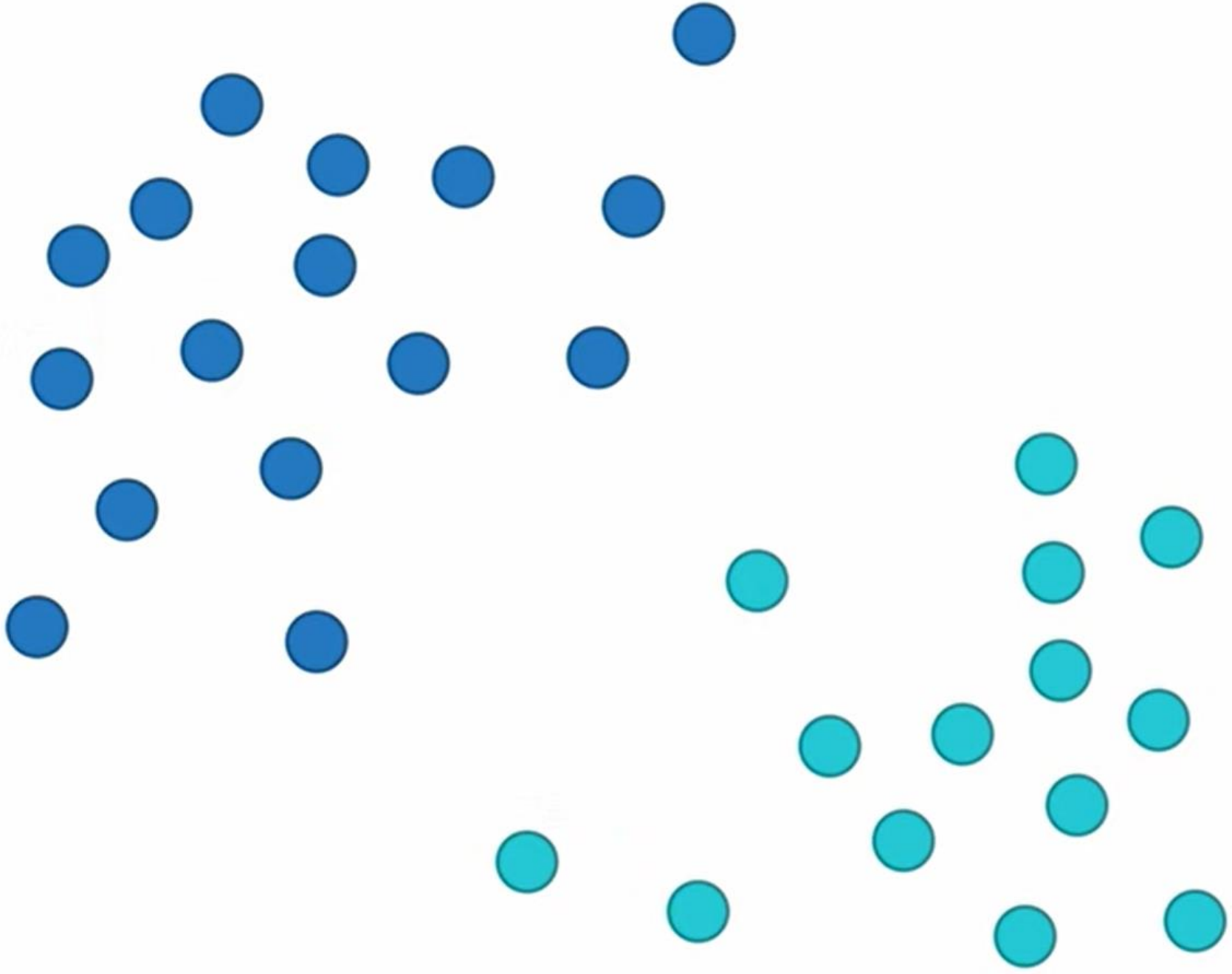
3. Closing Remarks

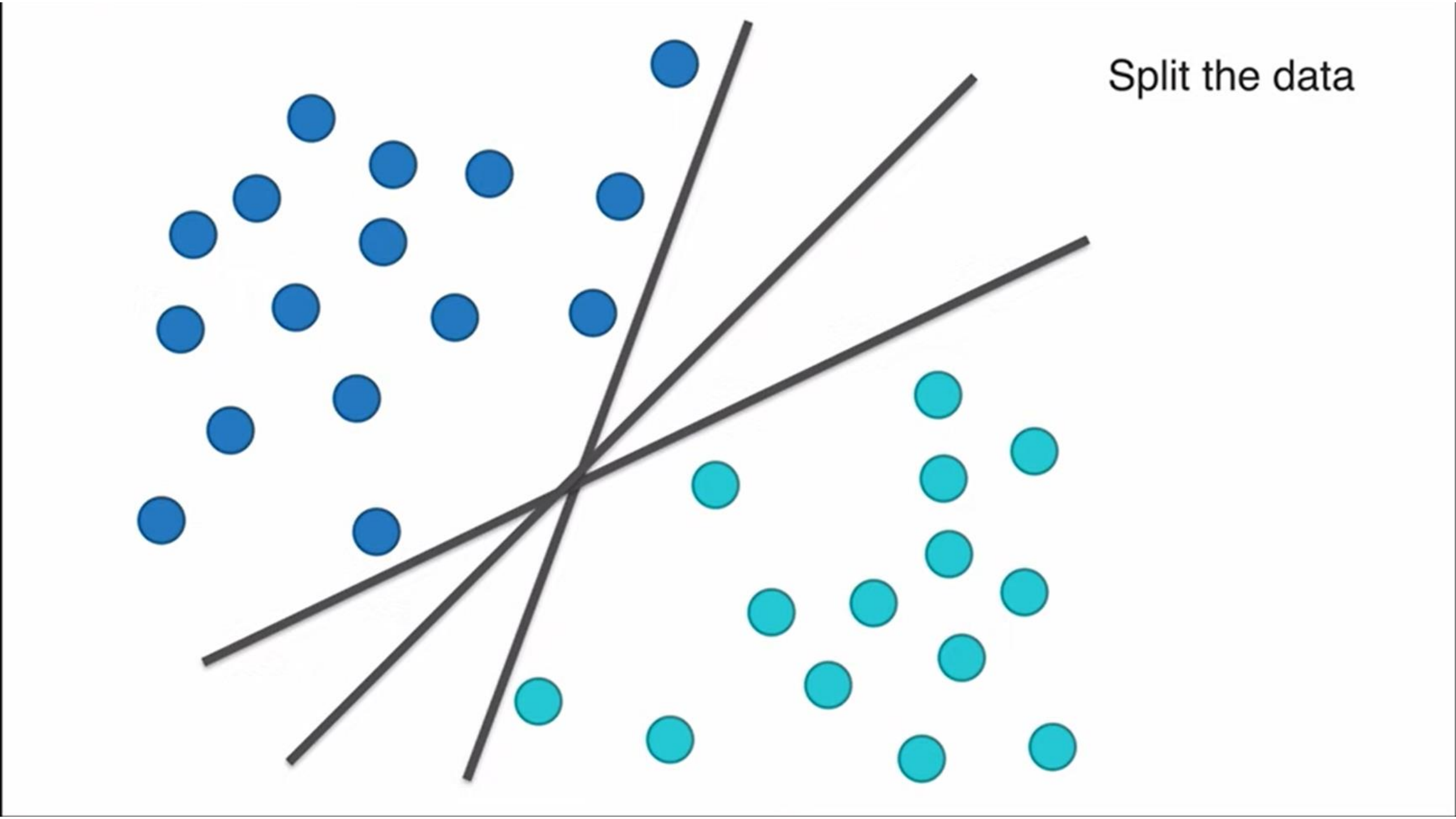
- Pros and cons
- Other techniques

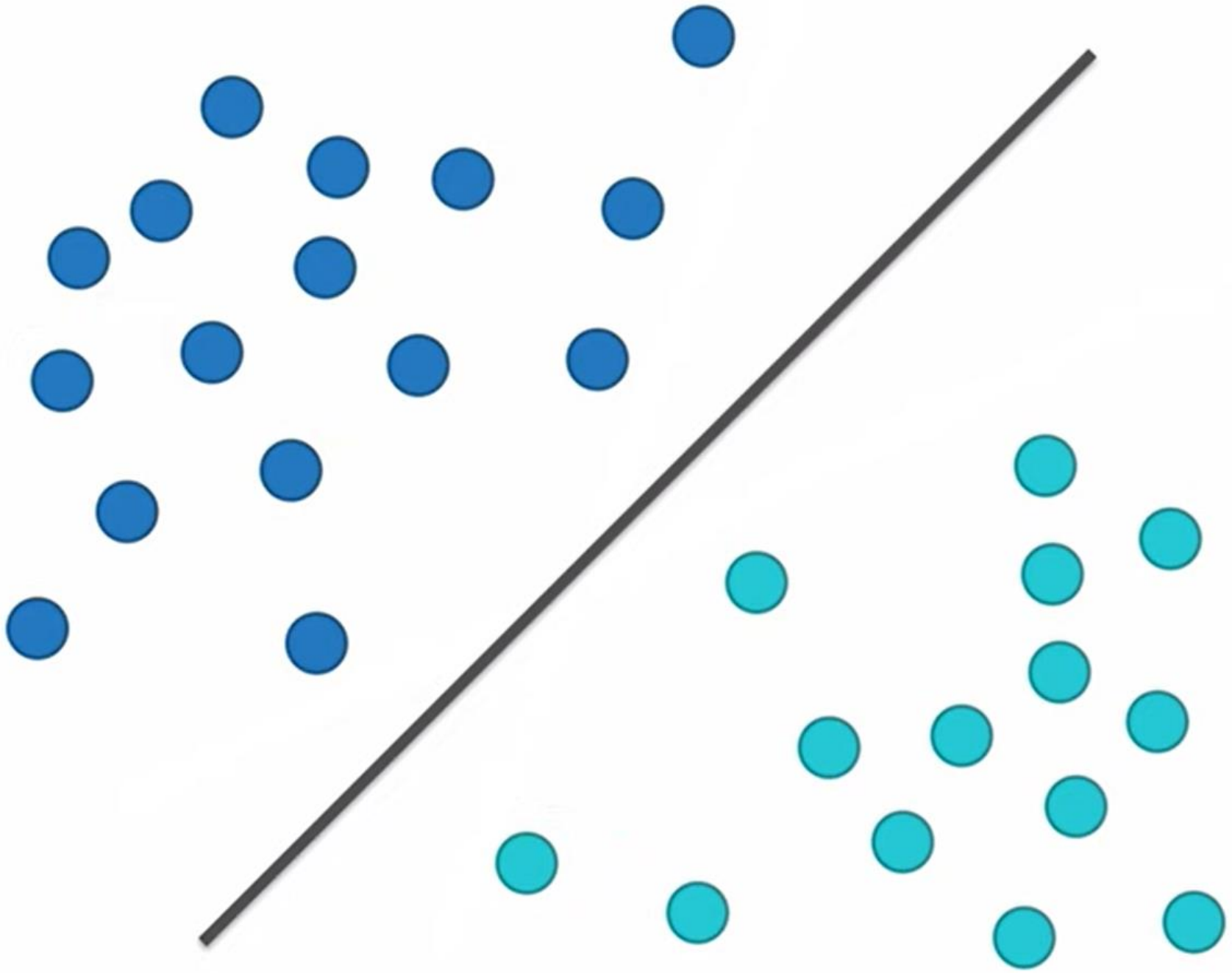
What is SVM?

It’s a classification technique.

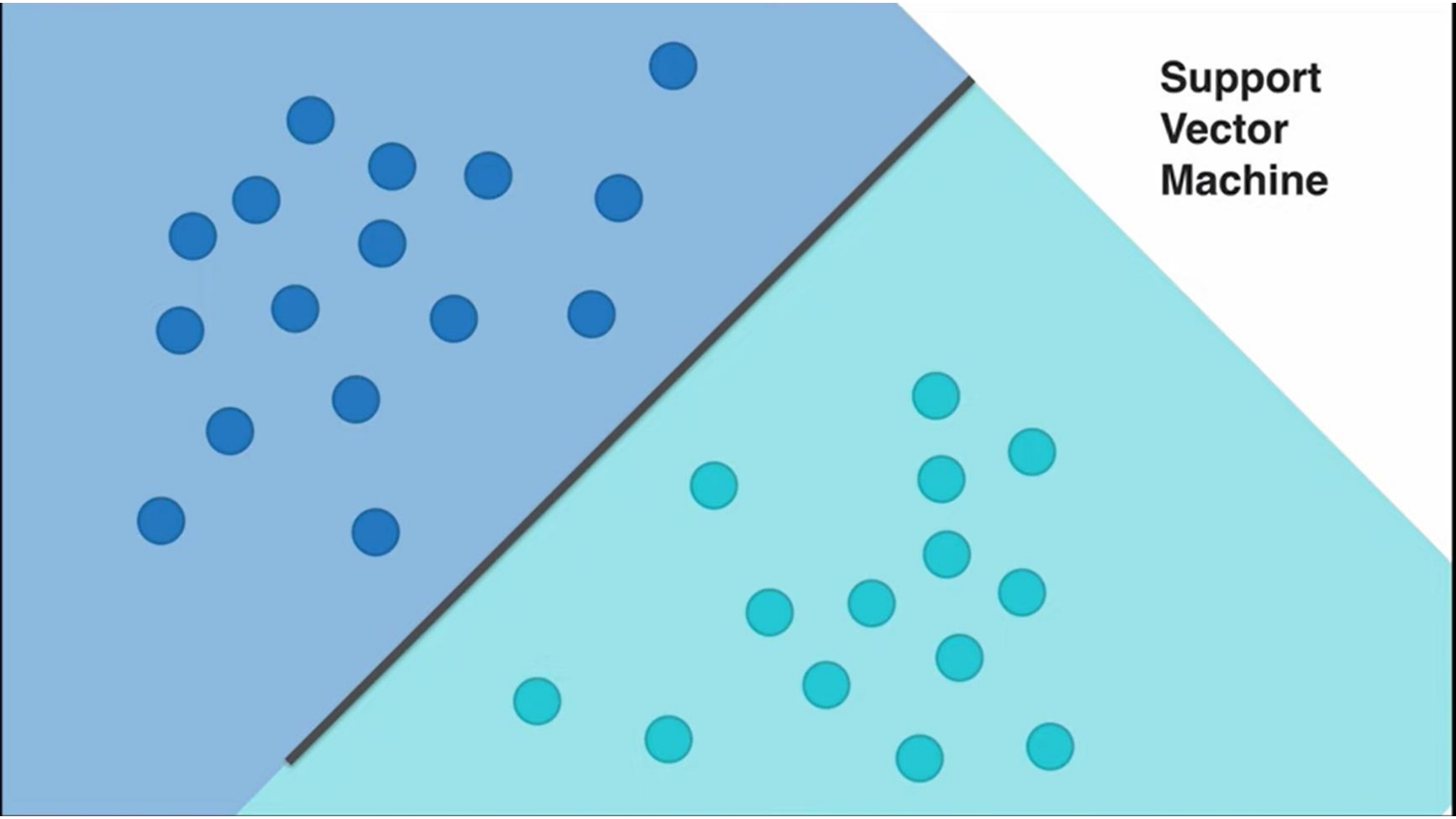
Split the data

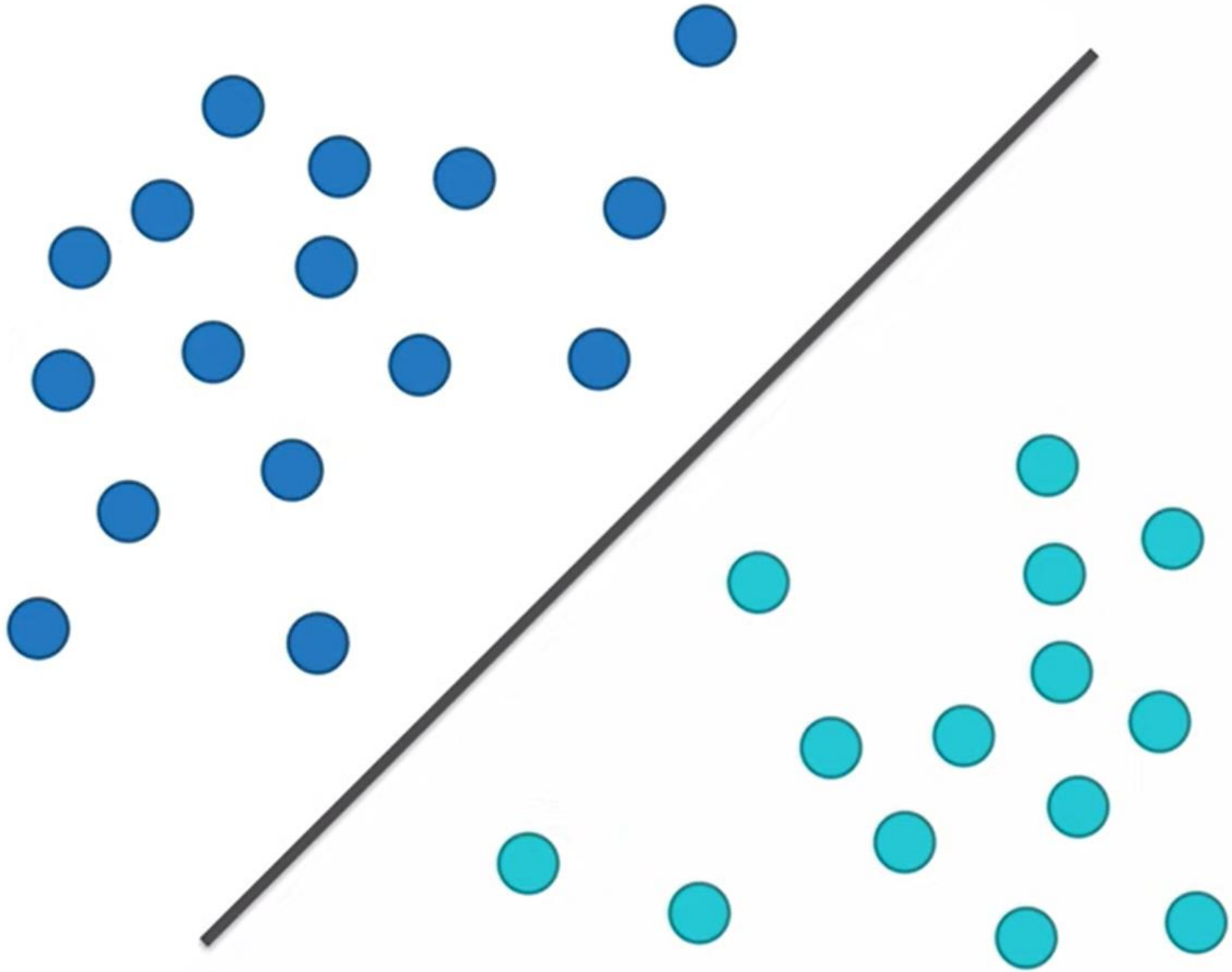



Split the data

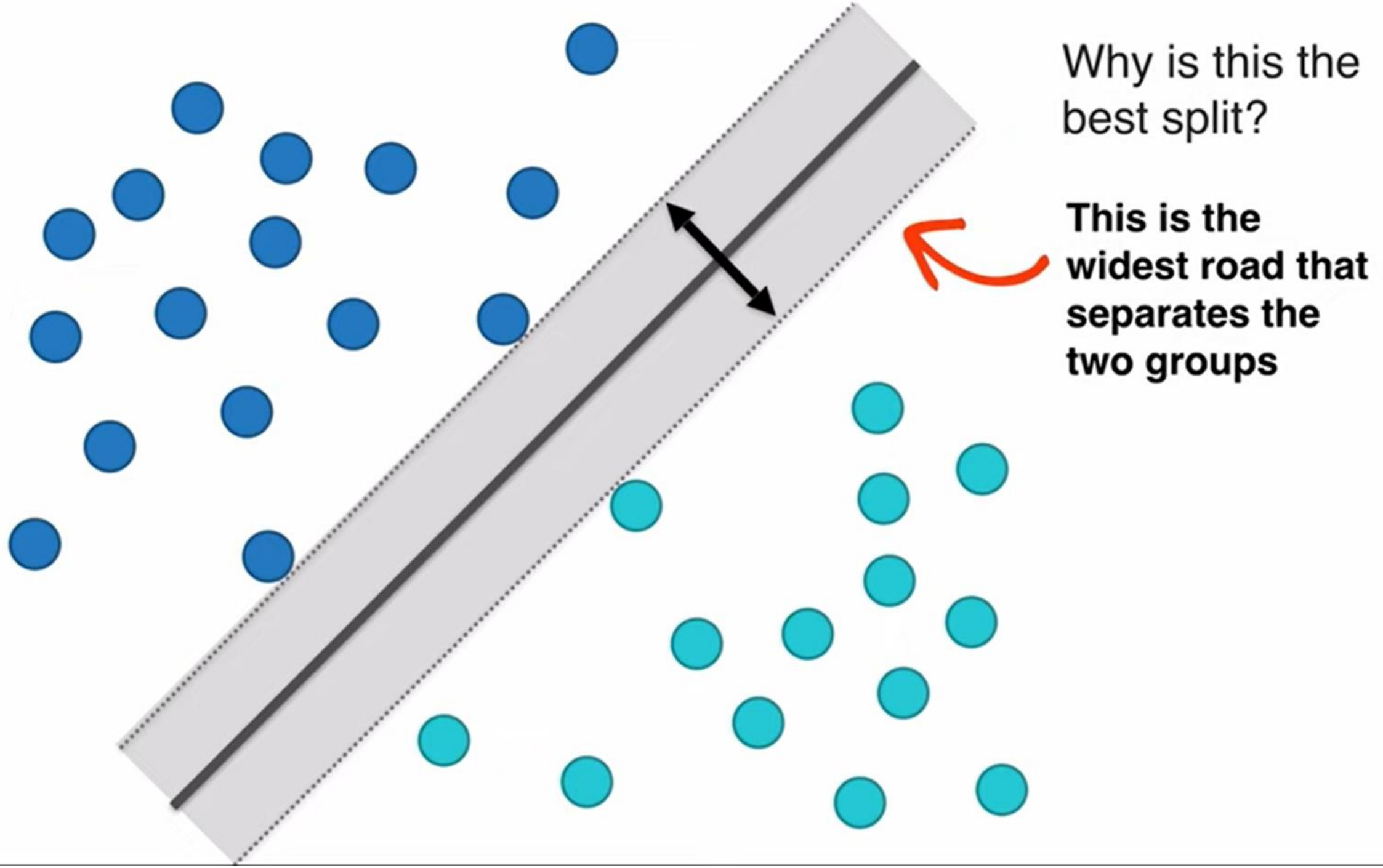


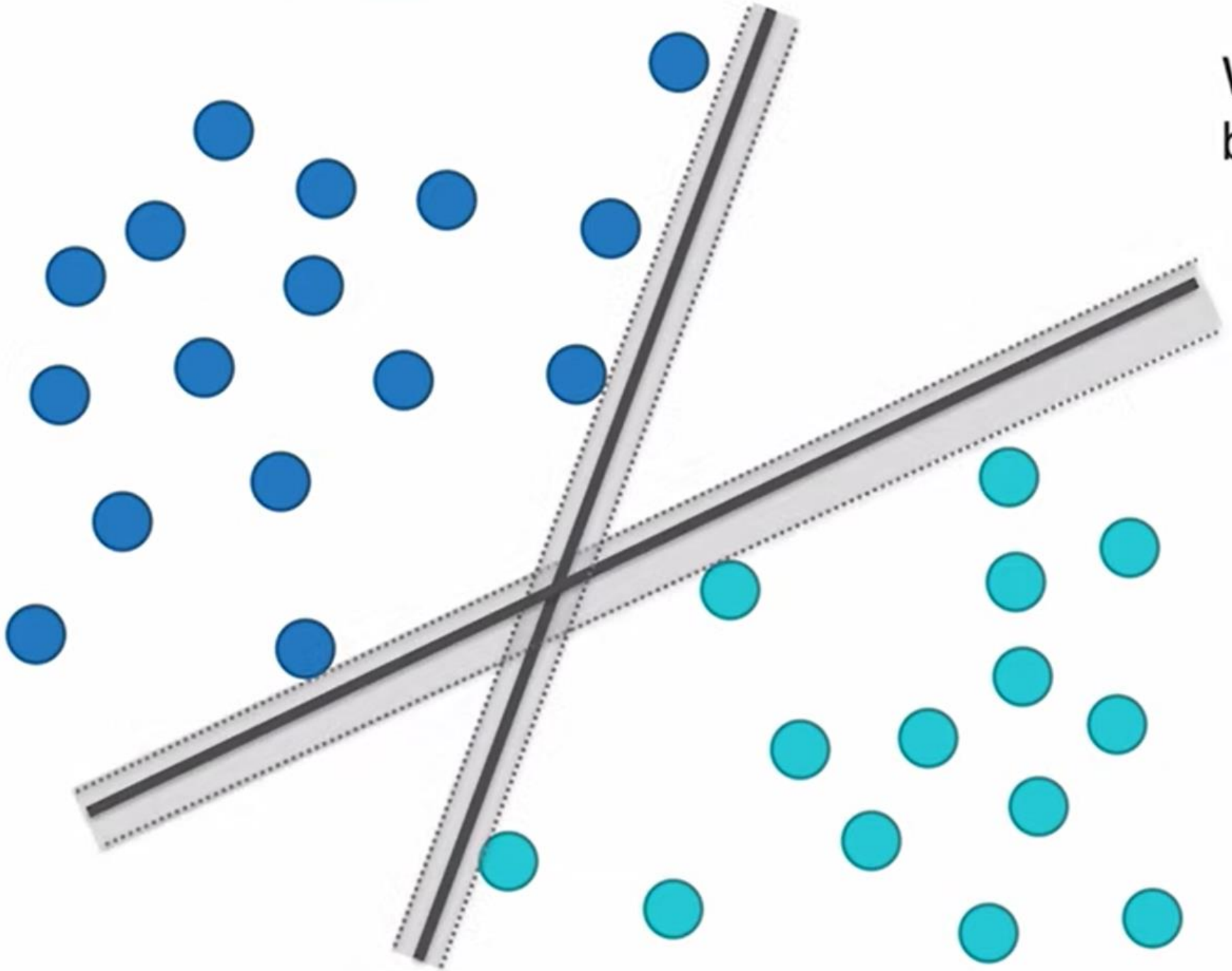
Split the data
in the best possible way


Support
Vector
Machine

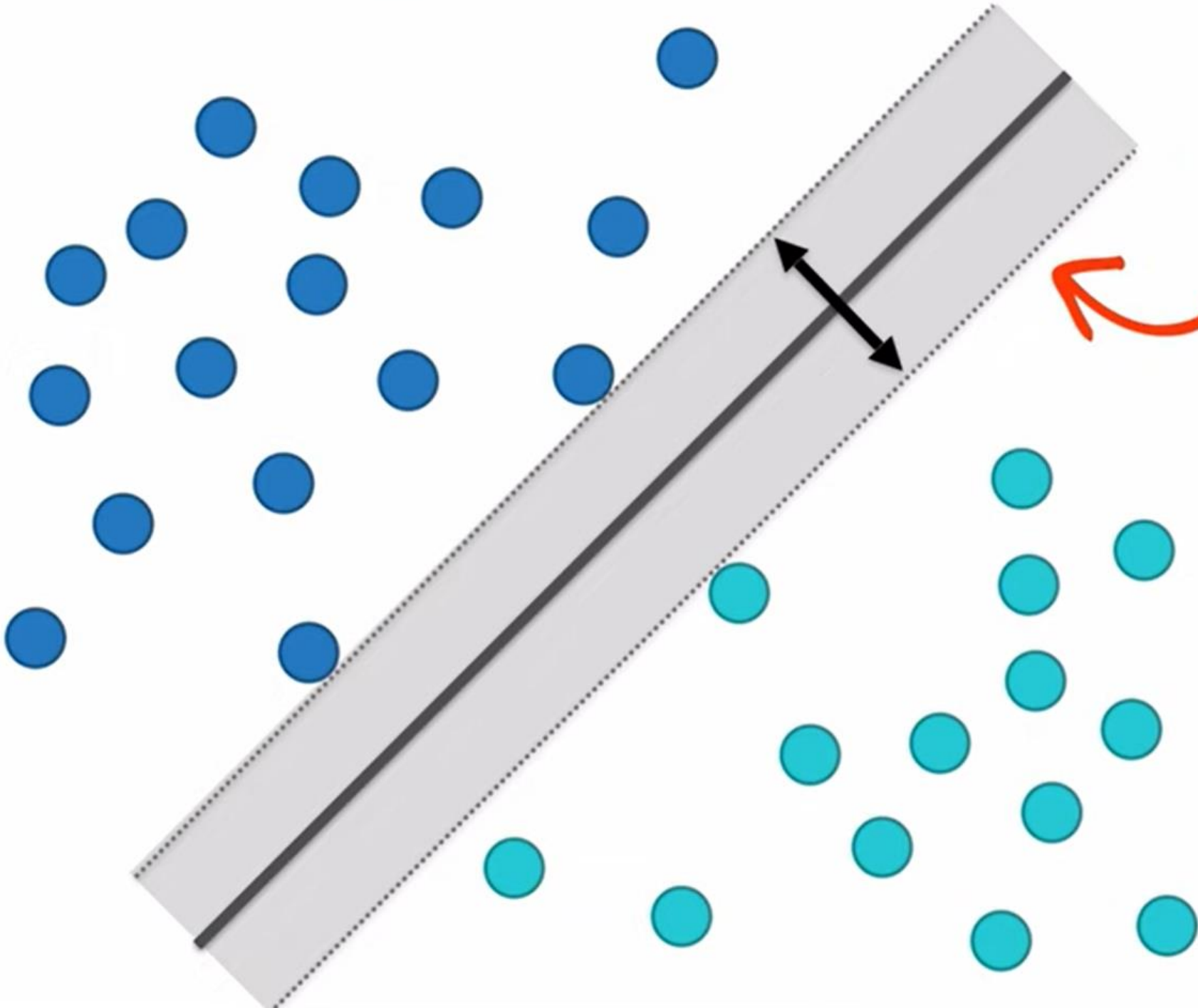


Why is this the best split?


Why is this the best split?
This is the widest road that separates the two groups

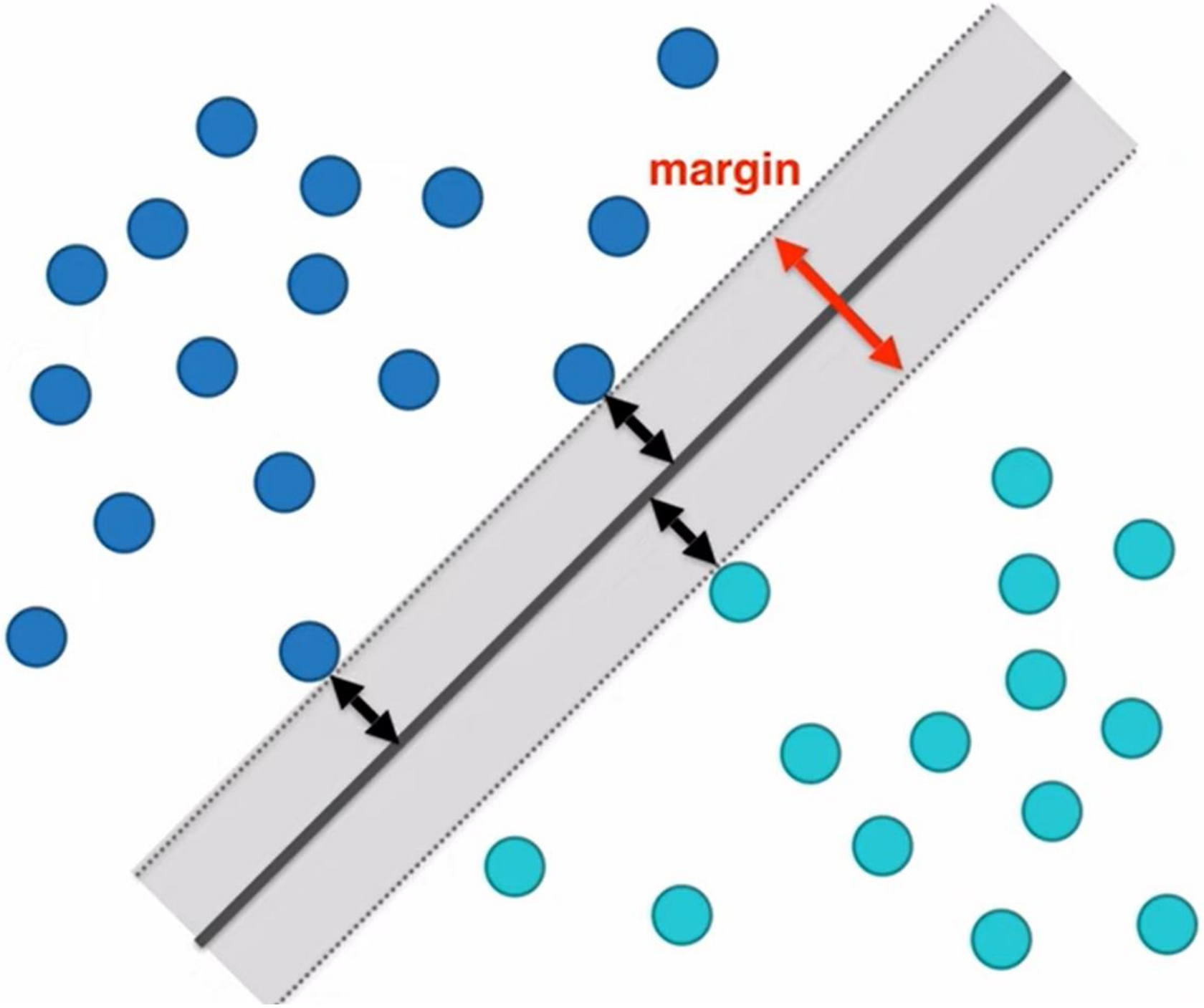


Why is this the best split?



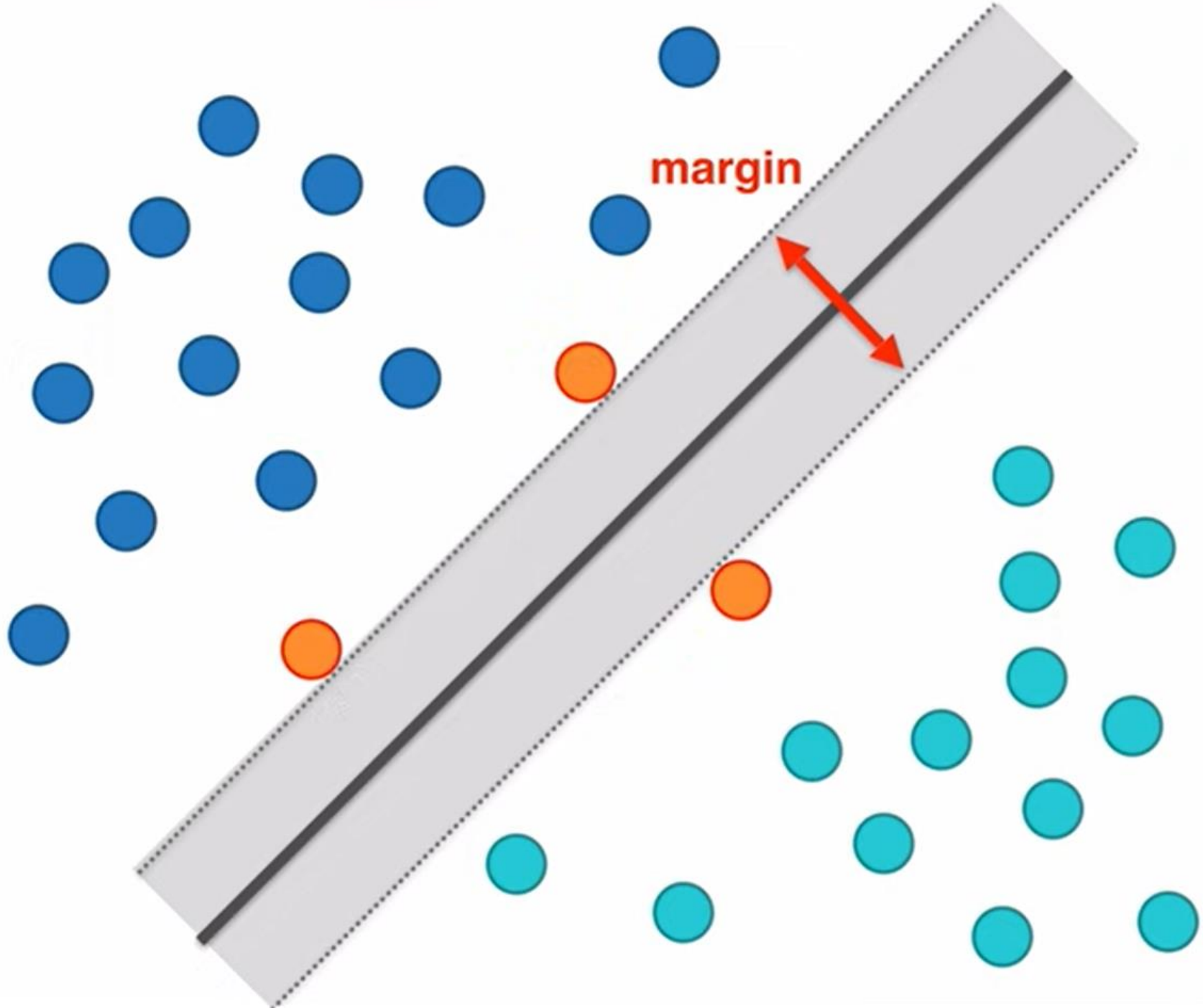
Why is this the best split?

This is the widest margin that separates the two groups



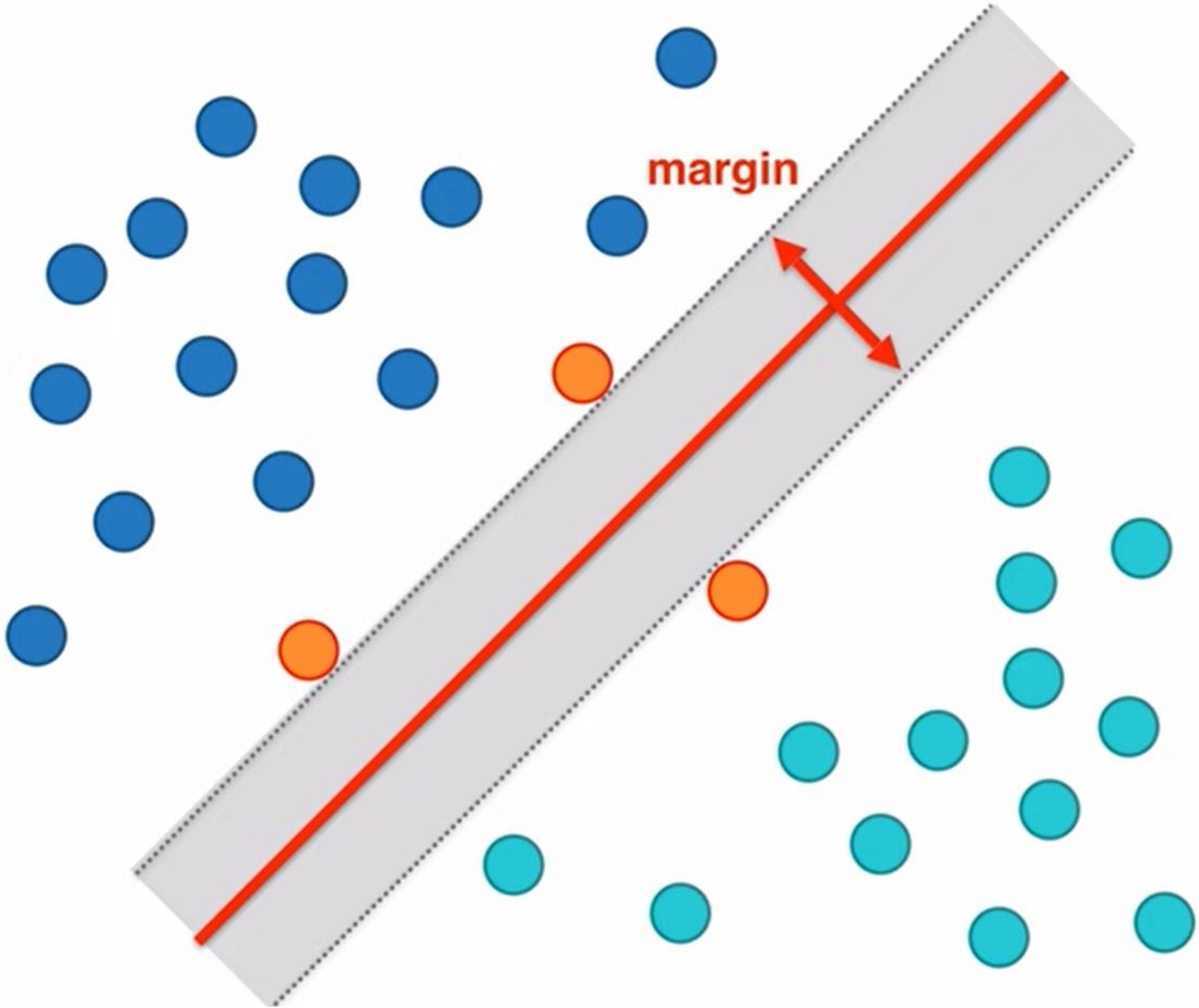
Why is this the best split?

The distance between the points and the line are as far as possible



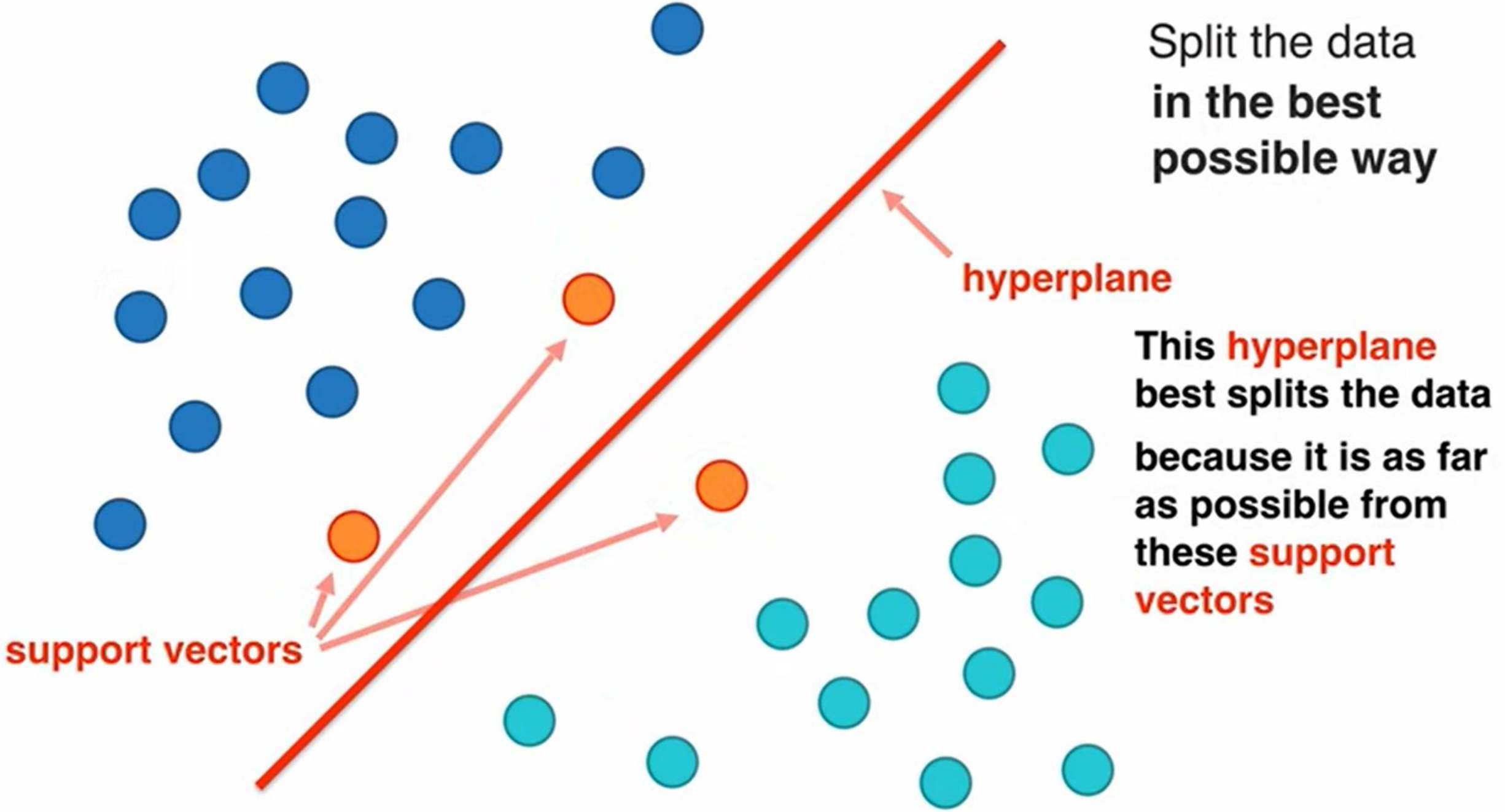
Why is this the best split?

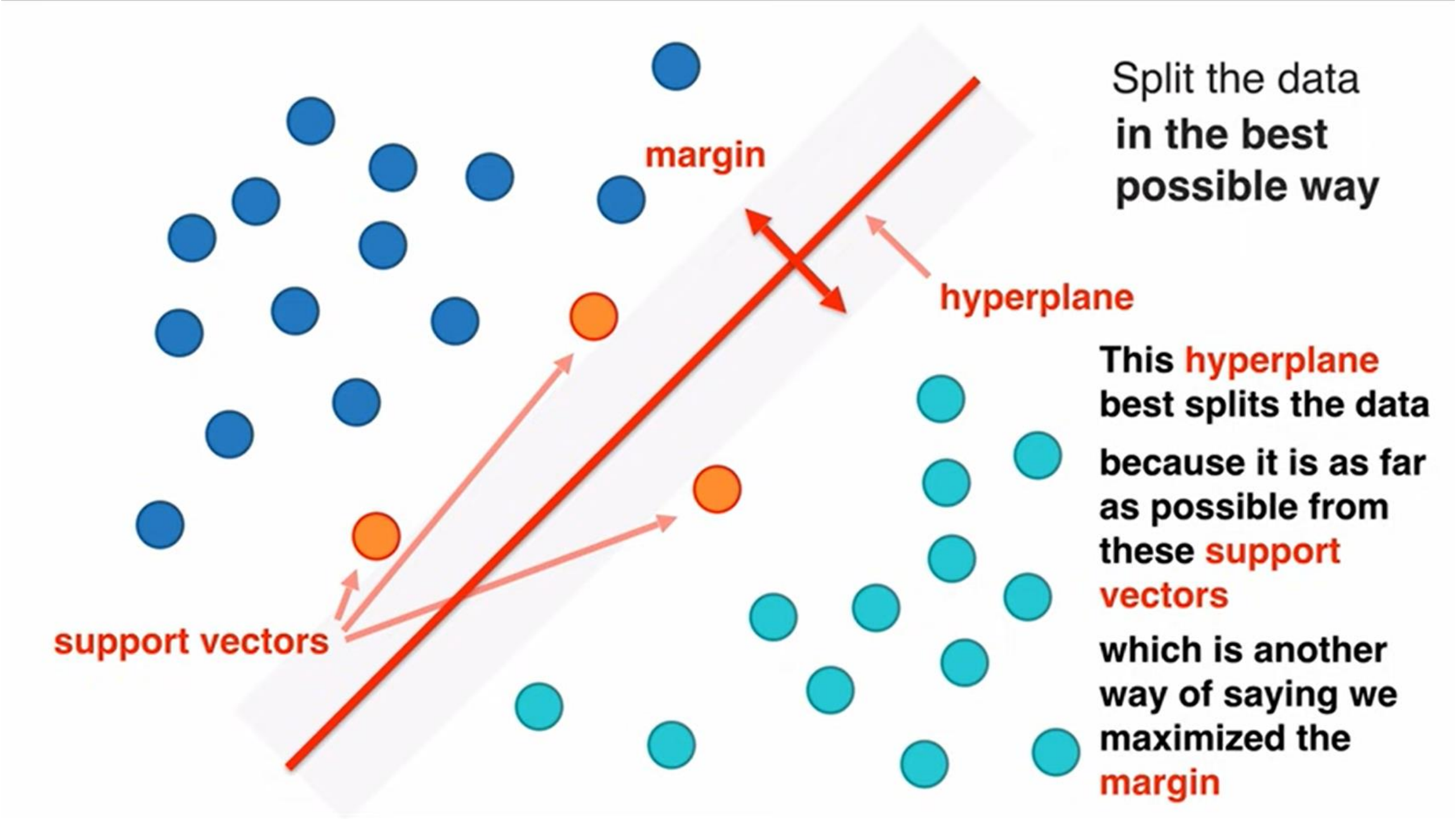
The distance between the support vectors and the line are as far as possible



Why is this the best split?

The distance between the support vectors and the hyperplane are as far as possible


Split the data
in the best
possible way
hyperplane
This hyperplane
best splits the data
because it is as far
as possible from
these support
vectors
support vectors

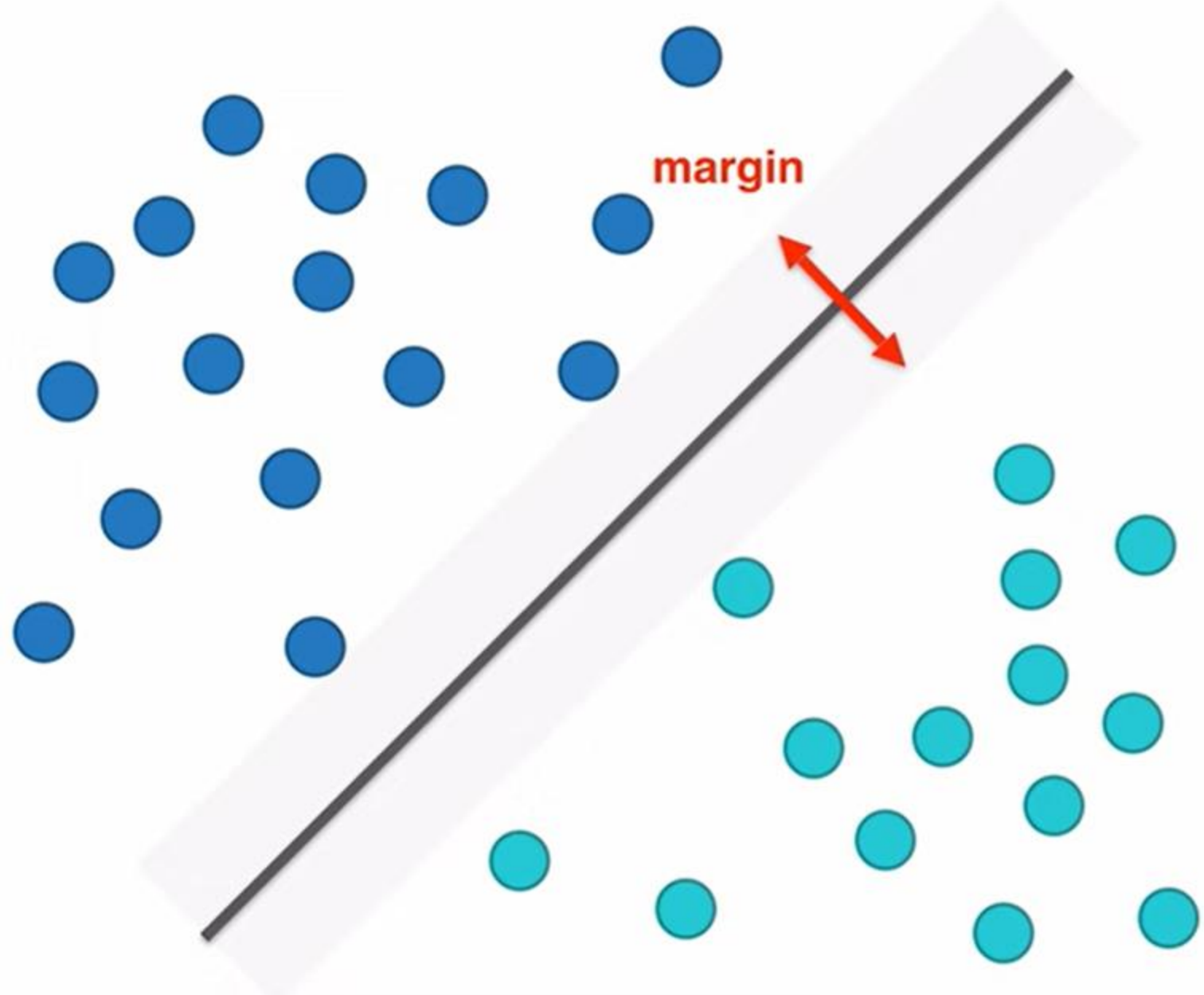


Split the data **in the best possible way**

This hyperplane best splits the data

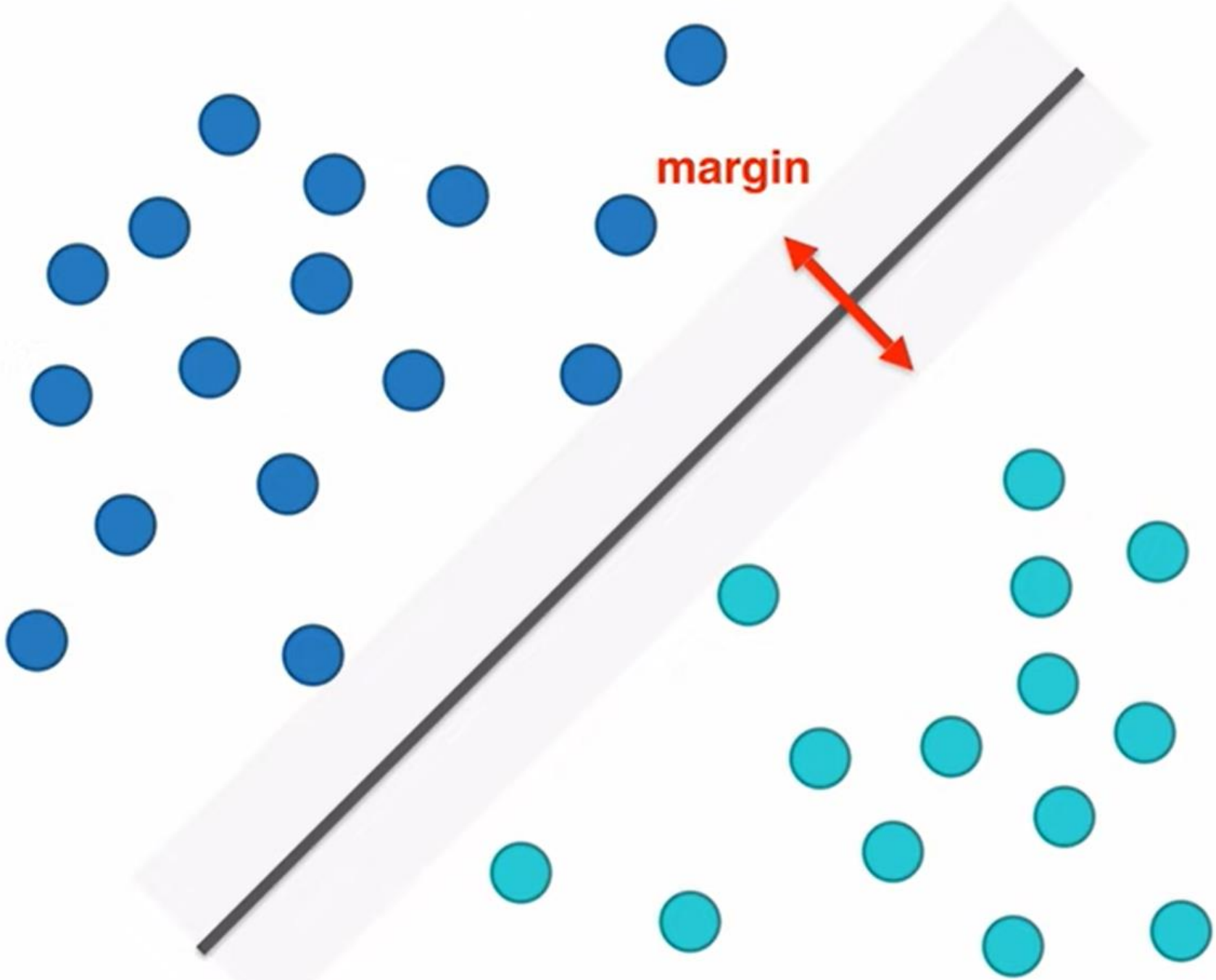
because it is as far as possible from these support vectors

which is another way of saying we maximized the margin



How do you maximize the margin?

This is a **constrained optimization** problem



How do you maximize the margin?

This is a **constrained optimization** problem

which can be solved using the **Lagrange Multipliers** technique

So now what?

Let’s apply this to a real world problem.

Cupcakes

versus

Muffins

Cupcakes

versus

Muffins

"a cupcake is just a muffin with frosting"

"a muffin is just a cupcake with random bits of stuff in it"

Cupcakes vs Muffins

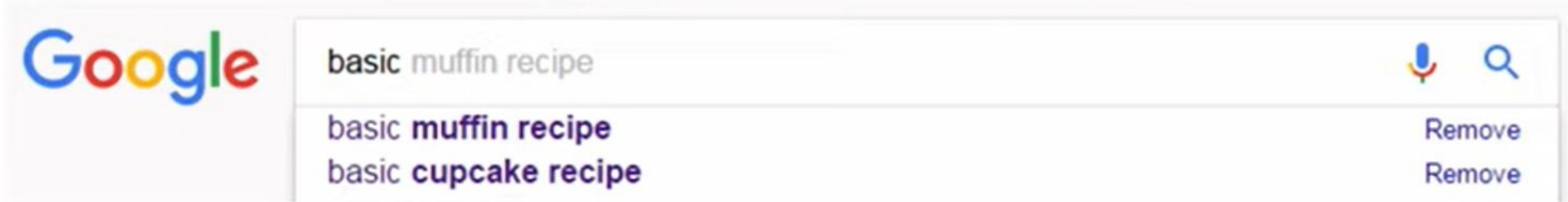
The Challenge

Classify recipes as cupcakes or muffins. When given a new recipe, determine if it's a cupcake or a muffin.

The Steps

1. Find the data
2. Apply a data science model
3. Review the results

1. Find the data



Recorded the top 10 muffin and top 10 cupcake recipes

Recipe	Flour	Sugar	Butter	Milk	Egg	Baking Powder	Salt	Vanilla
Muffin1	2 cups	1/2 cup	1/4 cup	1 cup	2 eggs	1 tbsp	1/2 tsp	1 tsp
Cupcake1	2 cups	3/4 cup	1/2 cup	1 cup	2 eggs	2 tsp	1/2 tsp	1 tsp
...	...	...	...	...	...	...	...	...

1. Find the data

Problem

Each recipe yields different amounts of batter

Solution

Amount-based

Recipe	Flour	Sugar	Other
Muffin1	2 cups	1/2 cup	…
Cupcake1	2 cups	3/4 cup	…

Percent-based

Recipe	Flour	Sugar	Other	Total Volume
Muffin1	47%	24%	…	100%
Cupcake1	42%	21%	…	100%

1. Find the data

Type	Flour	Milk	Sugar	Butter	Egg	Baking Powder	Vanilla	Salt
Muffin	55	28	3	7	5	2	0	0
Muffin	47	24	12	6	9	1	0	0
Muffin	47	23	18	6	4	1	0	0
Muffin	50	25	12	6	5	2	1	0
Muffin	55	27	3	7	5	2	1	0
Muffin	54	27	7	5	5	2	0	0
Muffin	47	26	10	10	4	1	0	0
Muffin	50	17	17	8	6	1	0	0
Muffin	50	17	17	11	4	1	0	0
Cupcake	39	0	26	19	14	1	1	0
Cupcake	34	17	20	20	5	2	1	0
Cupcake	39	13	17	19	10	1	1	0
Cupcake	38	15	23	15	8	0	1	0
Cupcake	42	18	25	9	5	1	0	0
Cupcake	36	14	21	14	11	2	1	0
Cupcake	38	15	31	8	6	1	1	0
Cupcake	36	16	24	12	9	1	1	0
Cupcake	34	17	23	11	13	0	1	0

Cupcakes vs Muffins

The Challenge

Classify recipes as cupcakes or muffins. When given a new recipe, determine if it's a cupcake or a muffin.

The Steps

1. Find the data ✓
2. Apply a data science model
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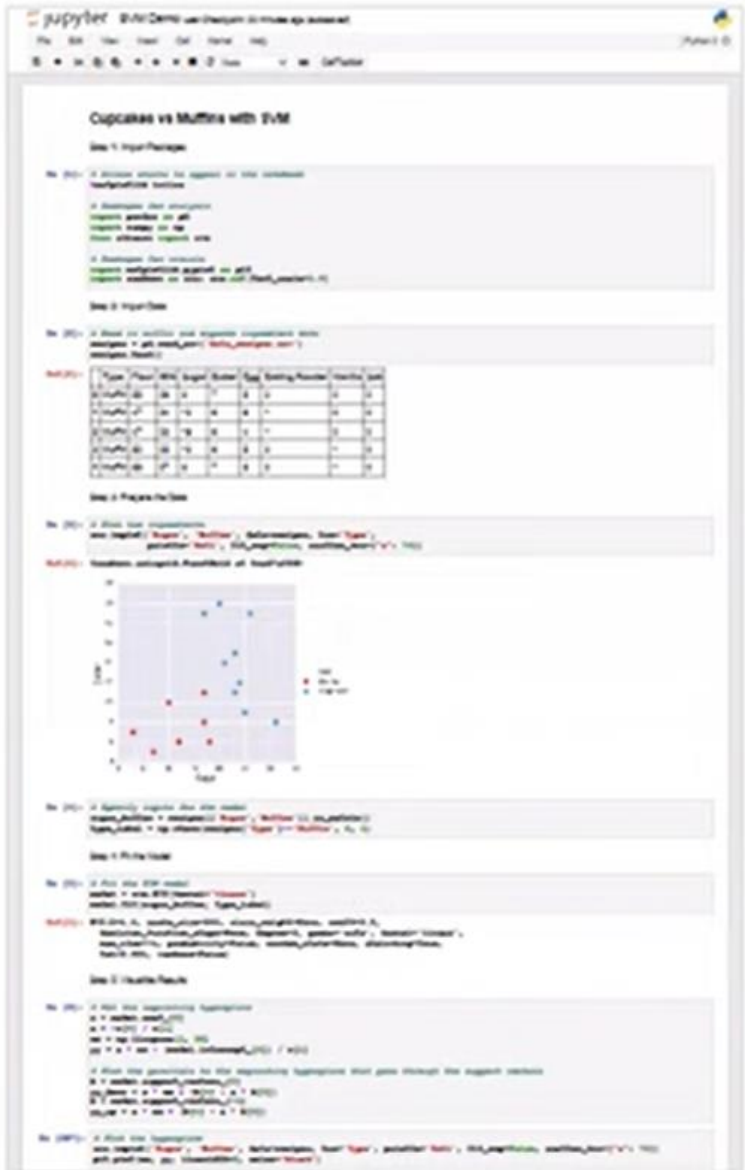
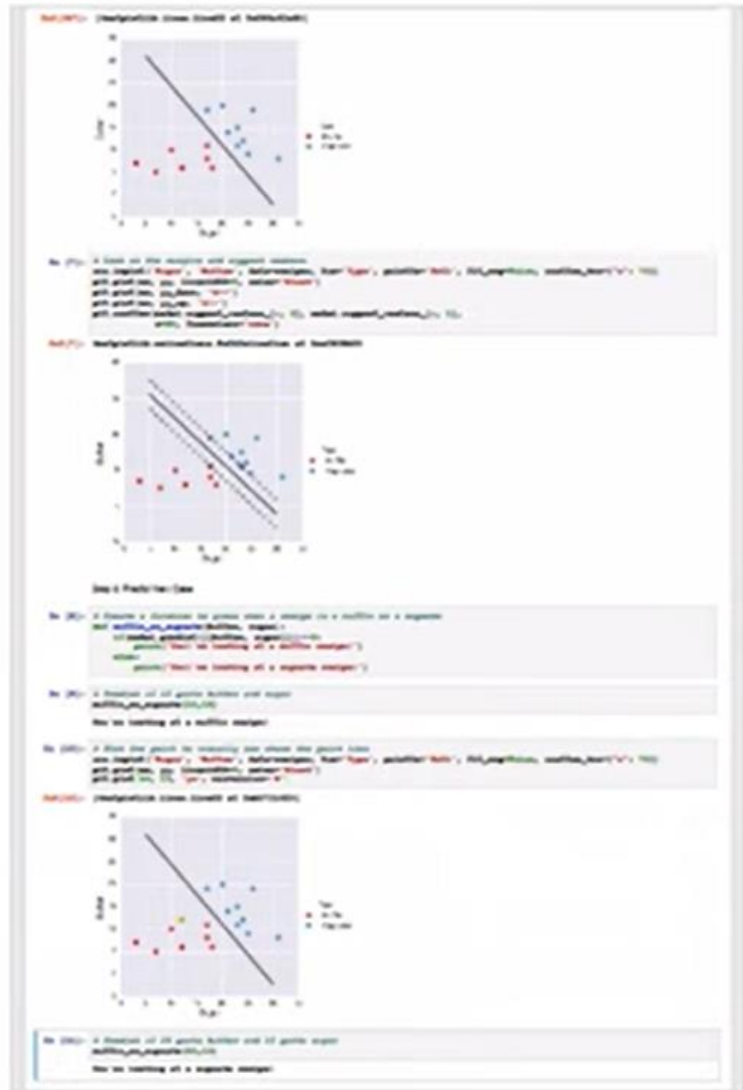
Python Script





a. Import Libraries

b. Import Data

c. Prepare the Data

d. Fit the Model

e. Visualize Results

f. Predict New Case

a. Import Libraries

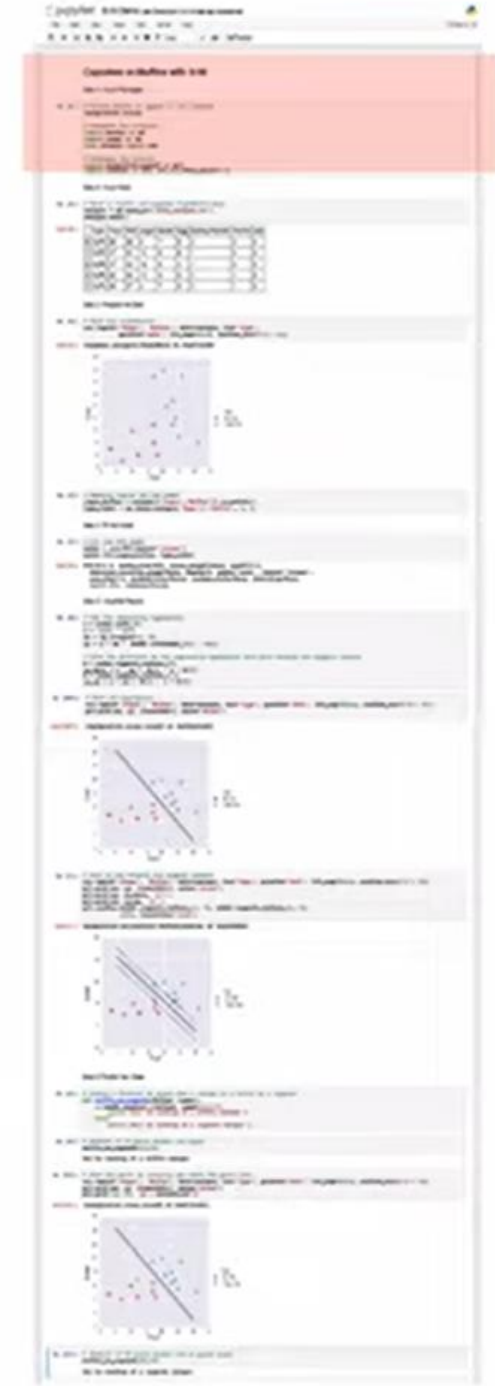
Cupcakes vs Muffins with SVM

Step 1: Import Libraries

In [13]:
```
# Allows charts to appear in the notebook
%matplotlib inline

# Libraries for analysis
import pandas as pd
import numpy as np
from sklearn import svm

# Libraries for visuals
import matplotlib.pyplot as plt
import seaborn as sns; sns.set(font_scale=1.2)
```



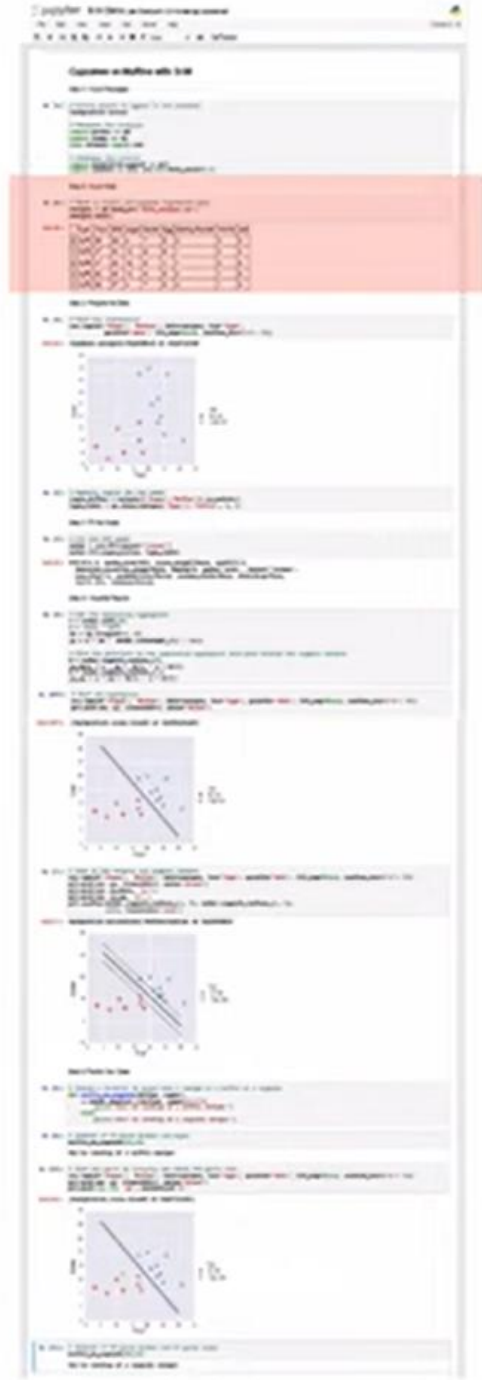
b. Import Data

Step 2: Import Data

In [2]:
```
# Read in muffin and cupcake ingredient data
recipes = pd.read_csv('data_recipes.csv')
recipes.head()
```

Out[2]:

	Type	Flour	Milk	Sugar	Butter	Egg	Baking Powder	Vanilla	Salt
0	Muffin	55	28	3	7	5	2	0	0
1	Muffin	47	24	12	6	9	1	0	0
2	Muffin	47	23	18	6	4	1	0	0
3	Muffin	50	25	12	6	5	2	1	0
4	Muffin	55	27	3	7	5	2	1	0

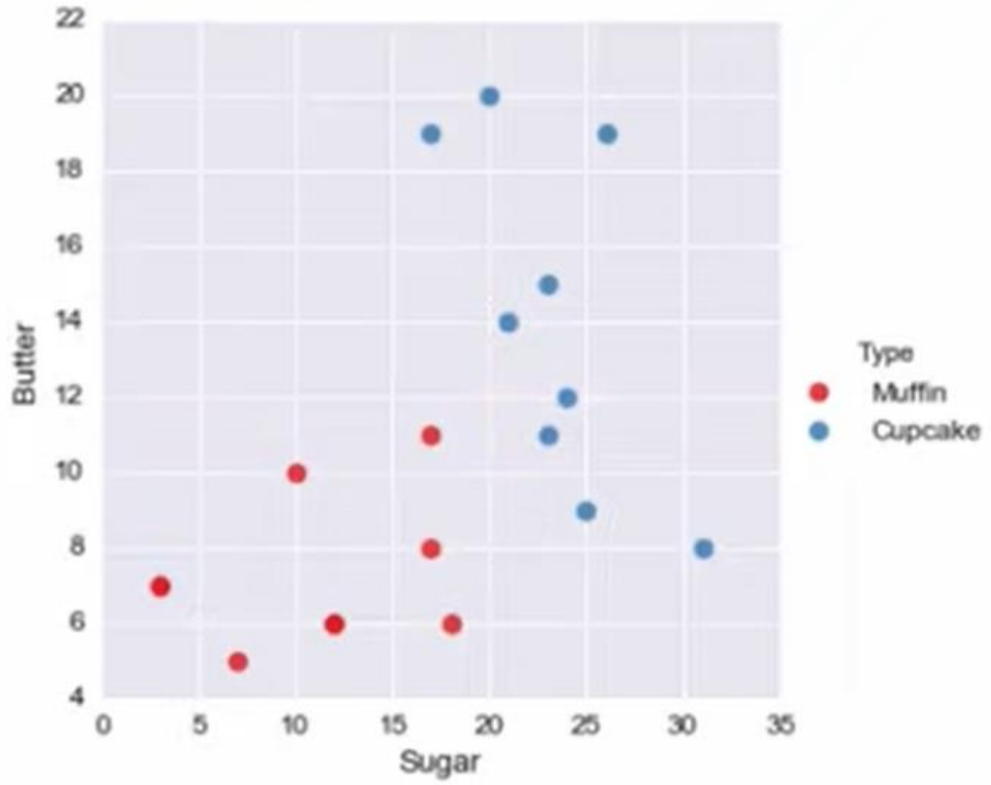


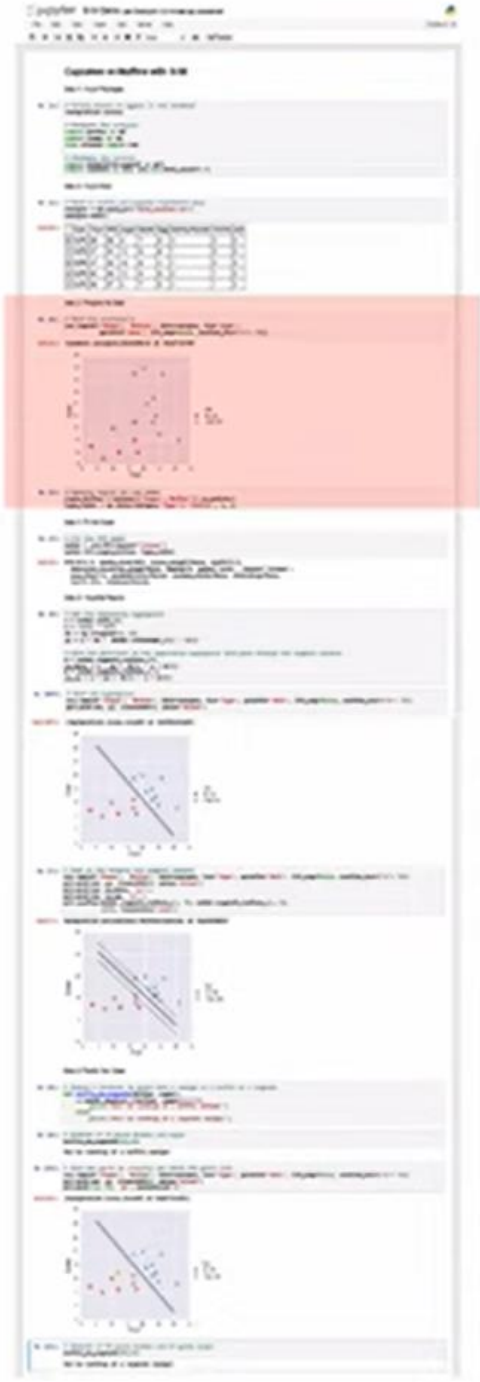
c. Prepare the Data

Step 3: Prepare the Data

In [3]:
```
# Plot two ingredients
sns.lmplot('Sugar', 'Butter', data=recipes, hue='Type',
           palette='Set1', fit_reg=False, scatter_kws={"s": 70})
```

Out[3]: <seaborn.axisgrid.FacetGrid at 0xad7af28>





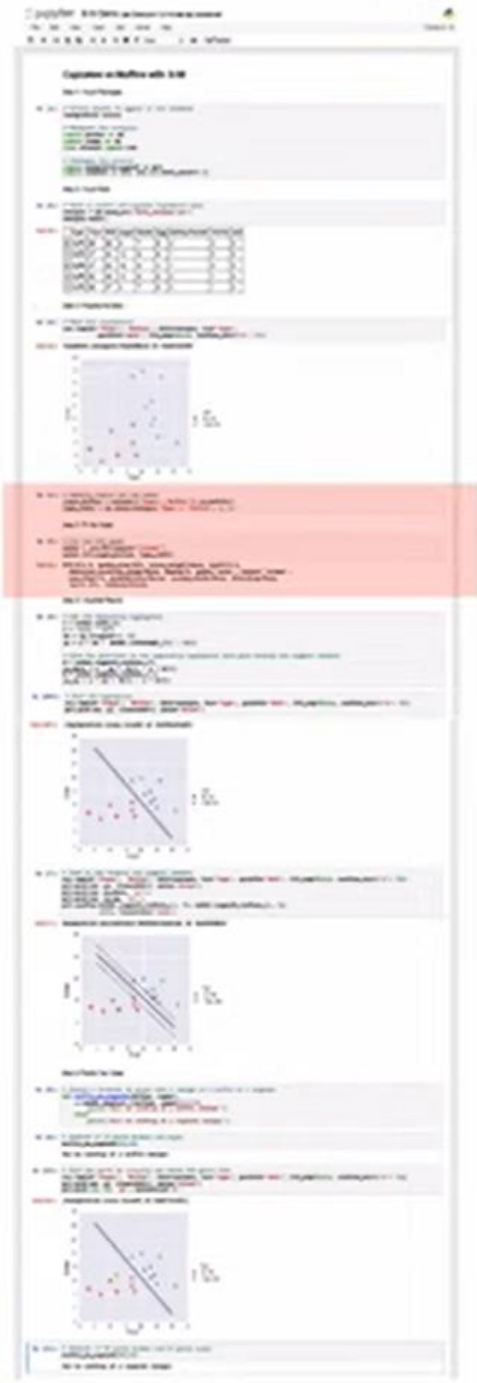
d. Fit the Model

Step 4: Fit the Model

In [4]:
```
# Specify inputs for the model
sugar_butter = recipes[['Sugar','Butter']].as_matrix()
type_label = np.where(recipes['Type']=='Muffin', 0, 1)
```

In [5]:
```
# Fit the SVM model
model = svm.SVC(kernel='linear')
model.fit(sugar_butter, type_label)
```

Out[5]:
```
SVC(C=1.0, cache_size=200, class_weight=None, coef0=0.0,
  decision_function_shape=None, degree=3, gamma='auto', kernel='linear',
  max_iter=-1, probability=False, random_state=None, shrinking=True,
  tol=0.001, verbose=False)
```



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Out[5]:
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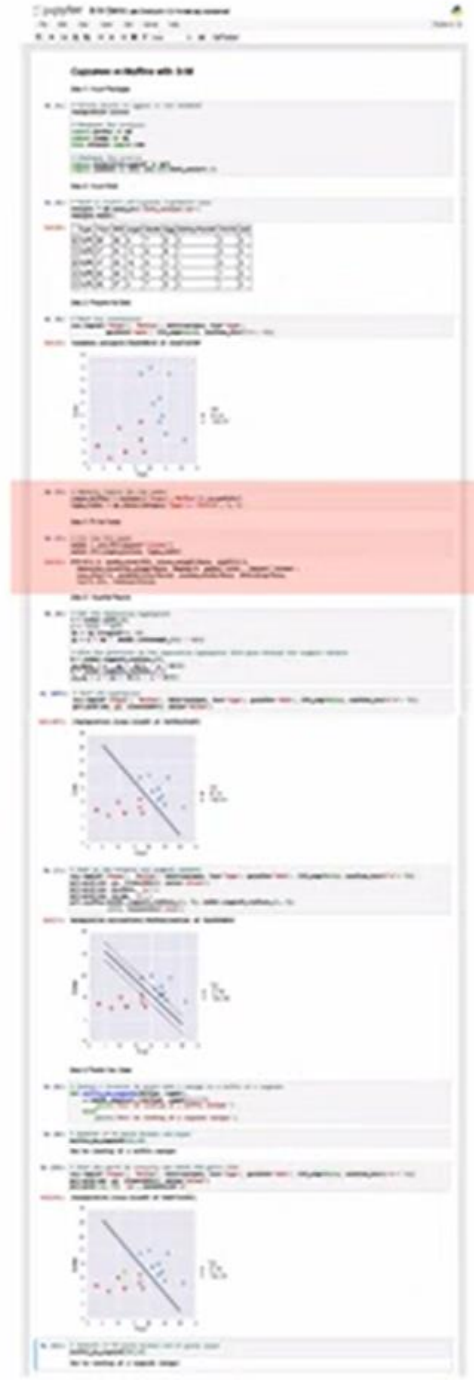
  max_iter=-1, probability=False, random_state=None, shrinking=True,
  tol=0.001, verbose=False)
```

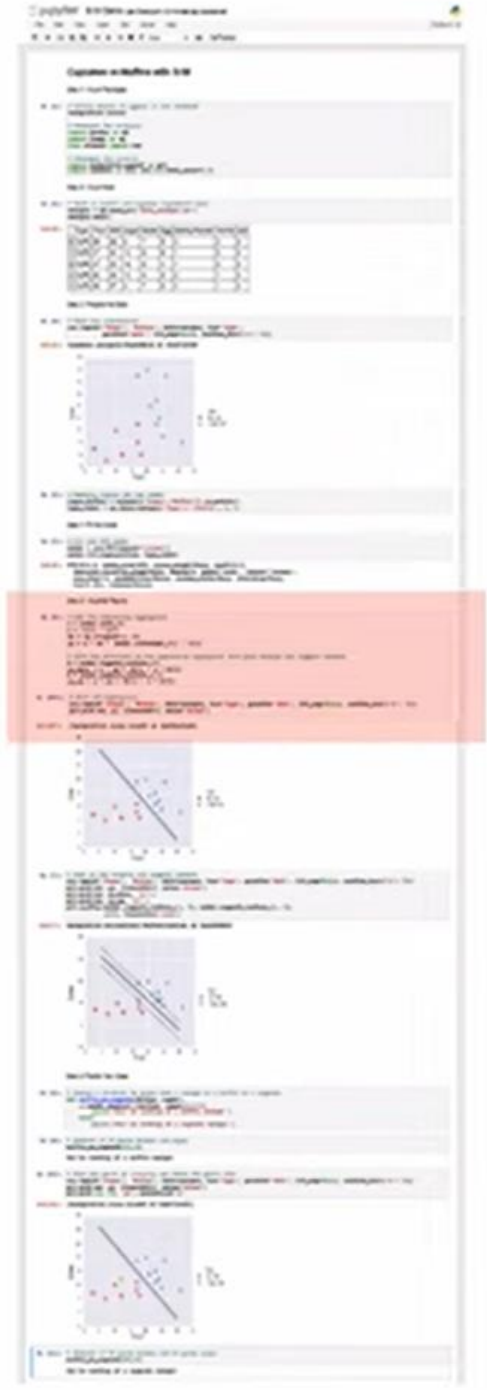


e. Visualize Results

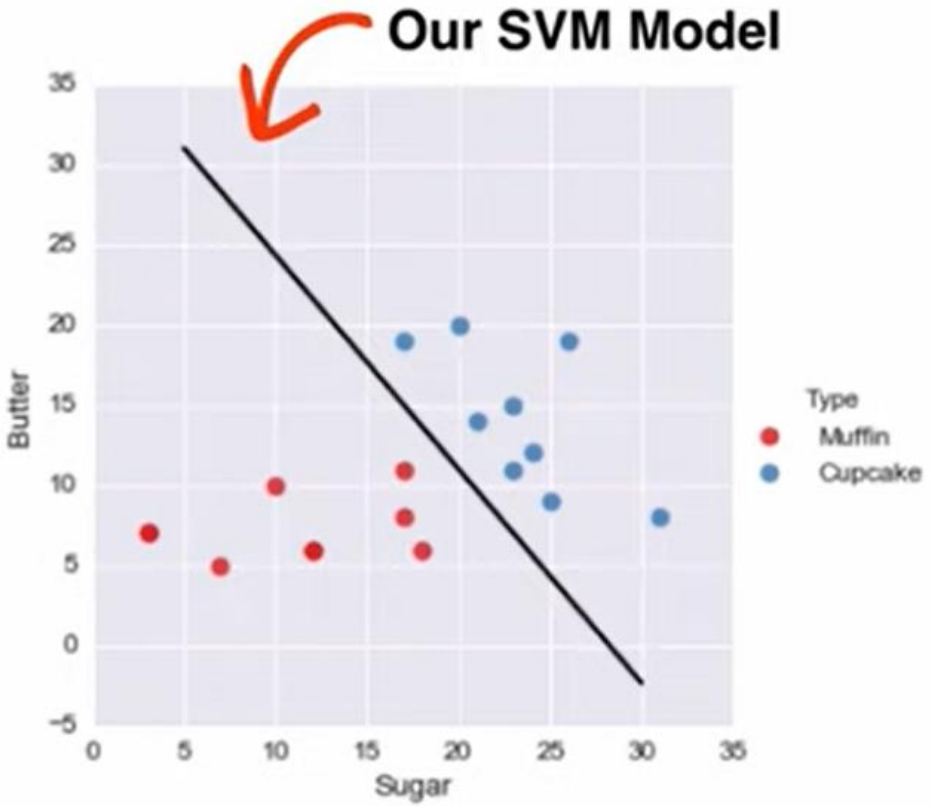
Step 5: Visualize Results

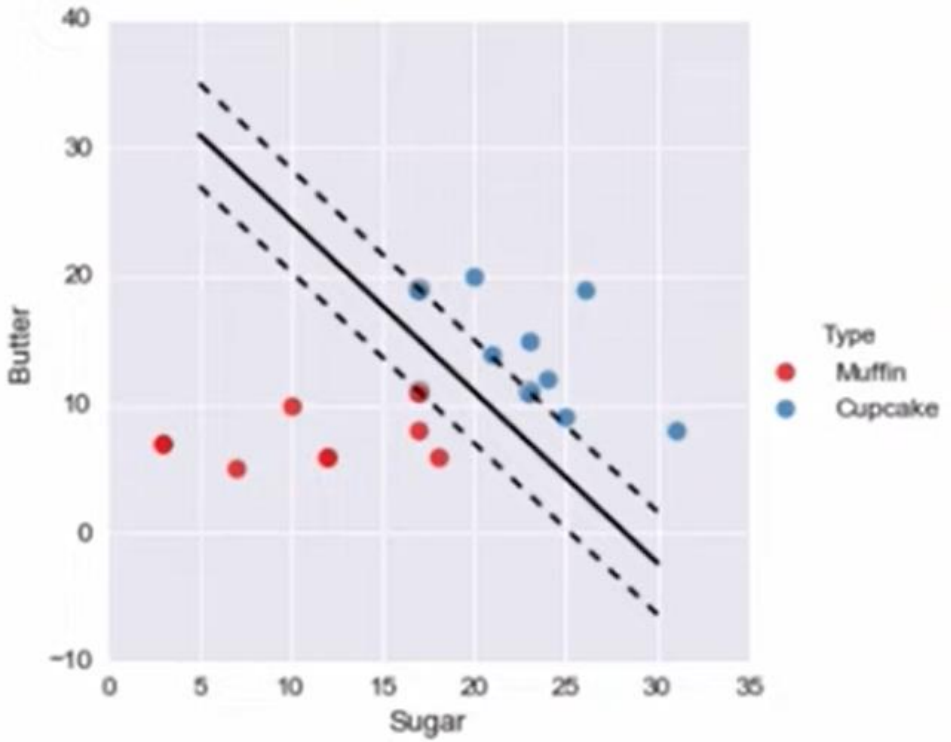
In [6]:
```
# Get the separating hyperplane
w = model.coef_[0]
a = -w[0] / w[1]
xx = np.linspace(5, 30)
yy = a * xx - (model.intercept_[0]) / w[1]

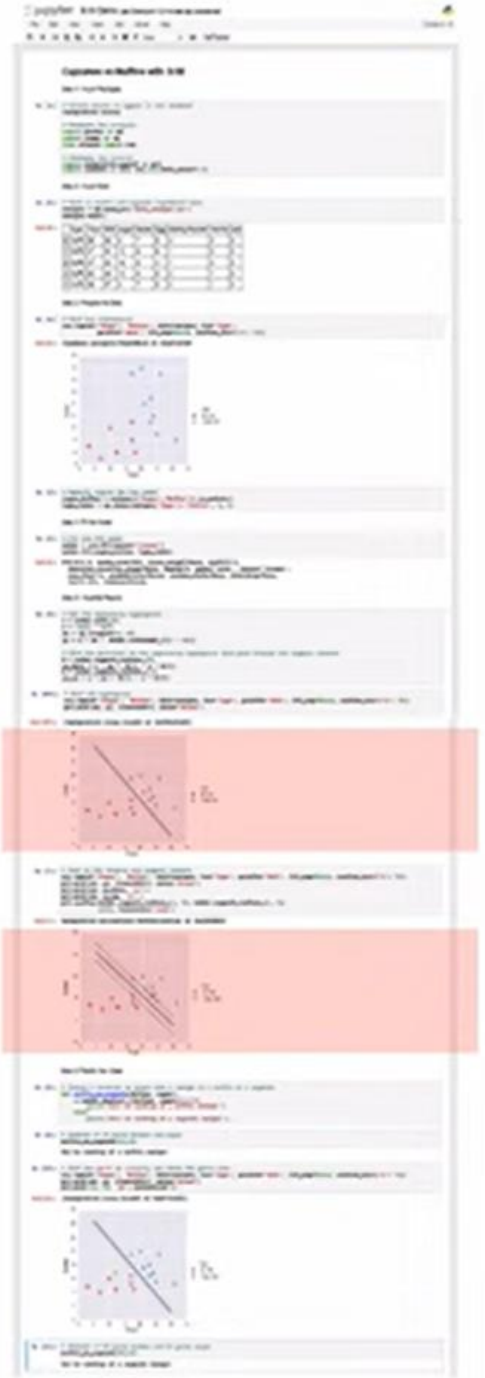
# Plot the parallels to the separating hyperplane
# that pass through the support vectors
b = model.support_vectors_[0]
yy_down = a * xx + (b[1] - a * b[0])
b = model.support_vectors_[-1]
yy_up = a * xx + (b[1] - a * b[0])
```



e. Visualize Results







Cupcakes vs Muffins

The Challenge

Classify recipes as cupcakes or muffins. When given a new recipe, determine if it's a cupcake or a muffin.

The Steps

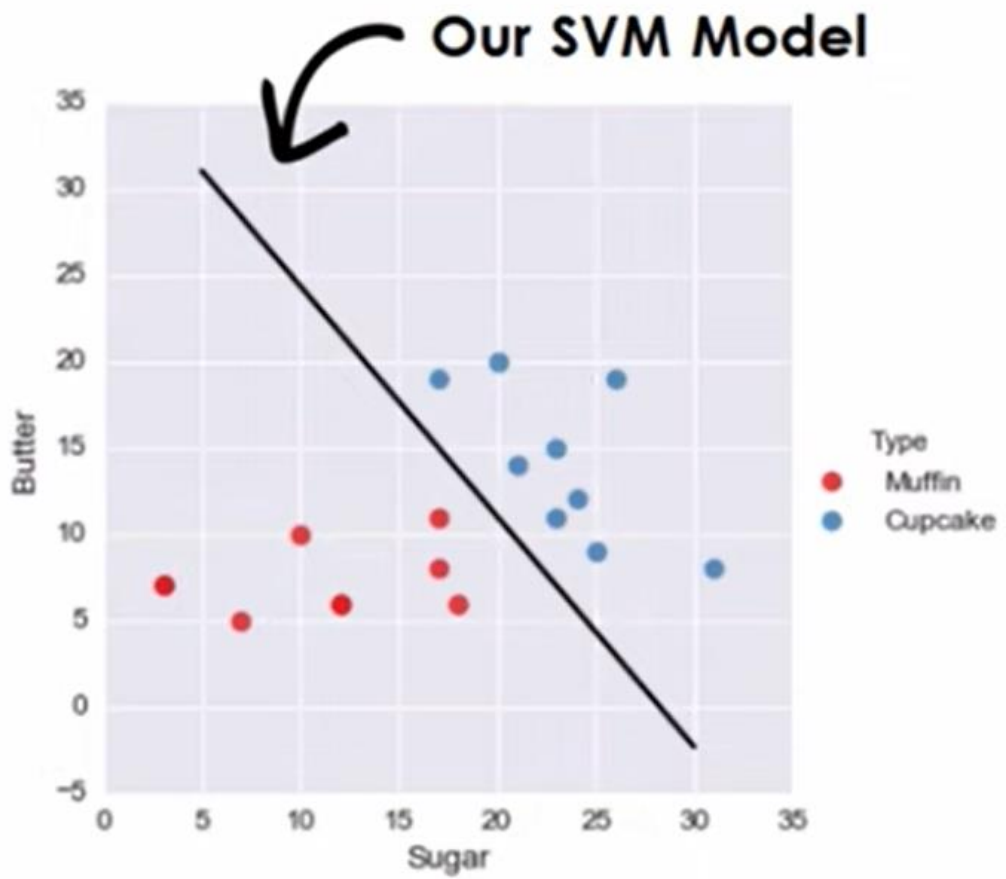
1. Find the data ✓
2. Apply a data science model ✓
3. Review the results

3. Review the Results

The Challenge

Classify recipes as cupcakes or muffins. ✓

When given a new recipe, determine if it's a cupcake or a muffin.

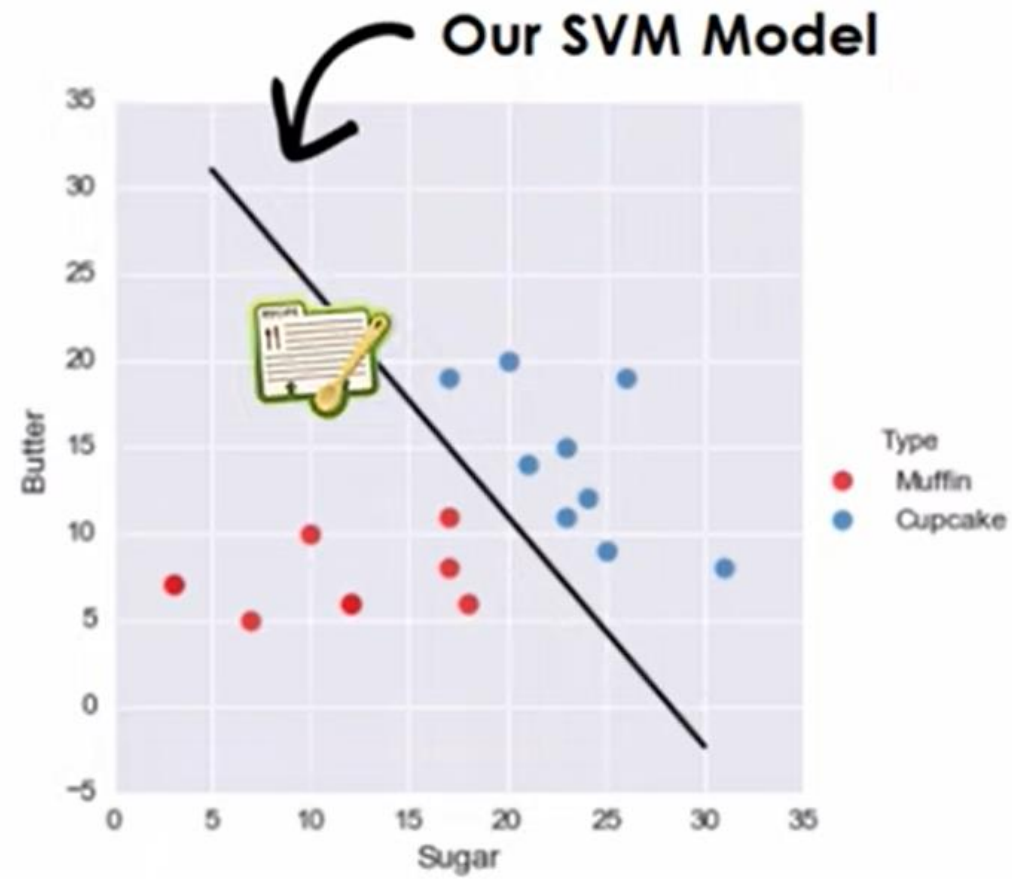


3. Review the Results

The Challenge

Classify recipes as cupcakes or muffins. ✓

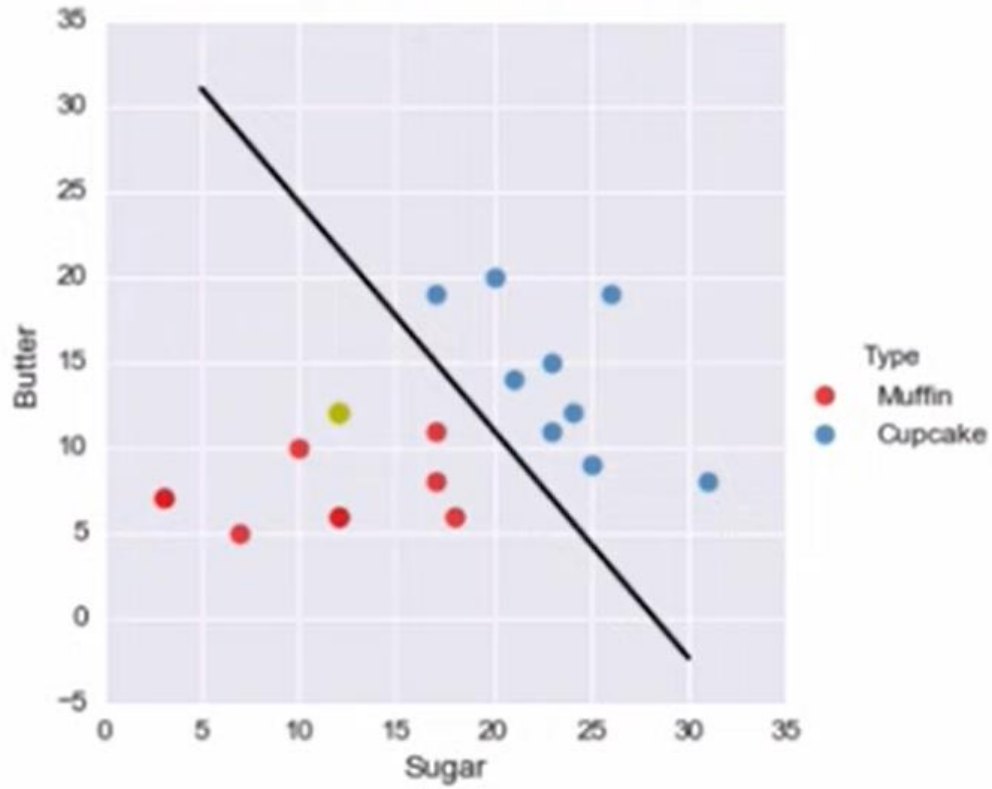
When given a new recipe, determine if it's a cupcake or a muffin.

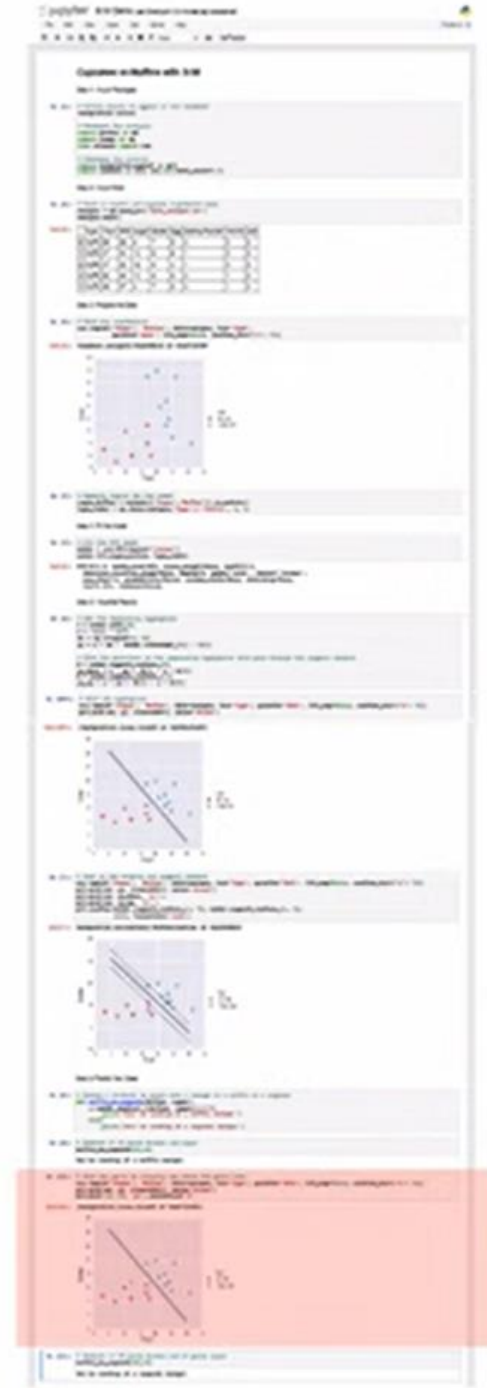


f. Predict New Case

In [10]:
```
# Plot the point to visually see where the point lies
sns.lmplot('Sugar', 'Butter', data=recipes, hue='Type',
           palette='Set1', fit_reg=False, scatter_kws={"s": 70})
plt.plot(xx, yy, linewidth=2, color='black')
plt.plot(12, 12, 'yo', markersize='9')
```

Out[10]: [<matplotlib.lines.Line2D at 0xb075160>]





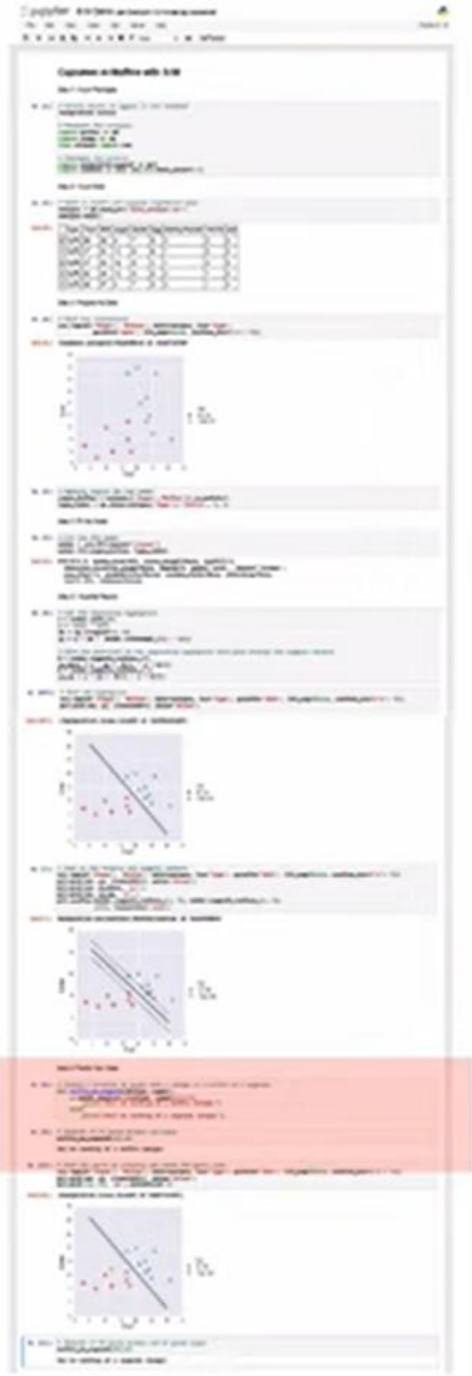
f. Predict New Case

Step 6: Predict New Case

In [8]:
```
# Create a function to guess when a recipe is a muffin
# or a cupcake using the SVM model we created
def muffin_or_cupcake(butter, sugar):
    if(model.predict([[butter, sugar]]))==0:
        print('You\'re looking at a muffin recipe!')
    else:
        print('You\'re looking at a cupcake recipe!')
```

In [9]:
```
# Predict if 12 parts butter and sugar
muffin_or_cupcake(12,12)
```

```
You're looking at a muffin recipe!
```



Cupcakes

versus

Muffins

Cupcakes and muffins can be classified using Support Vector Machines!

Basic case ✓

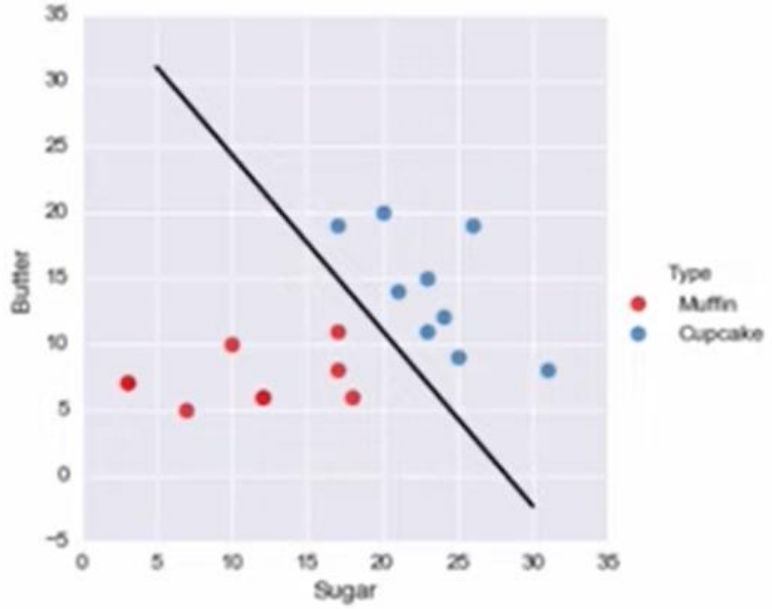
Up next: How to make SVM even more powerful

Agenda

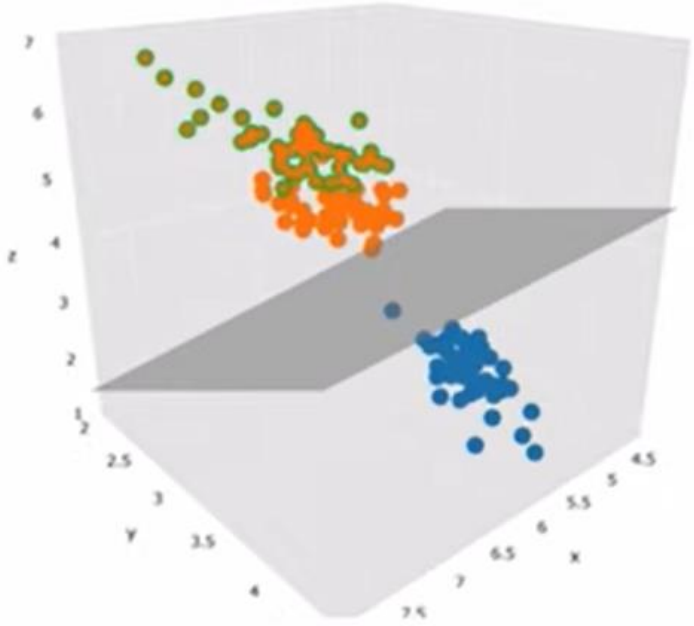
1. SVM Basics
   - Visual introduction
   - Example in Python
2. **Additional Complexities**
   - Higher dimensions
   - Multiple classes
   - C parameter
   - Kernel trick
3. Closing Remarks
   - Pros and cons
   - Other techniques

Higher Dimensions: Visual

2D: Separate with Line



3D: Separate with Plane



4D+: Separate with Hyperplane

Hard to Visualize

Higher Dimensions: Code

- Hard to visualize, but easy to code

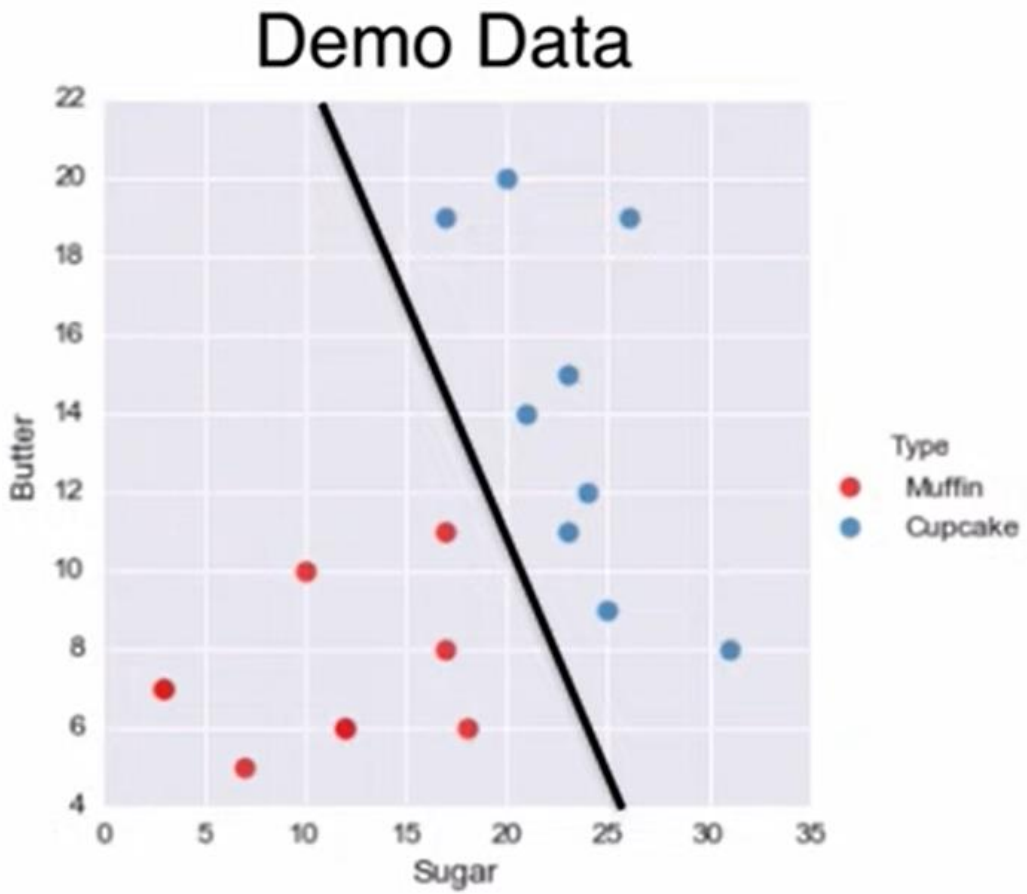
```
# Fit SVM model for sugar & butter
model = svm.SVC(kernel='linear')
model.fit(sugar_butter, type_label)
```

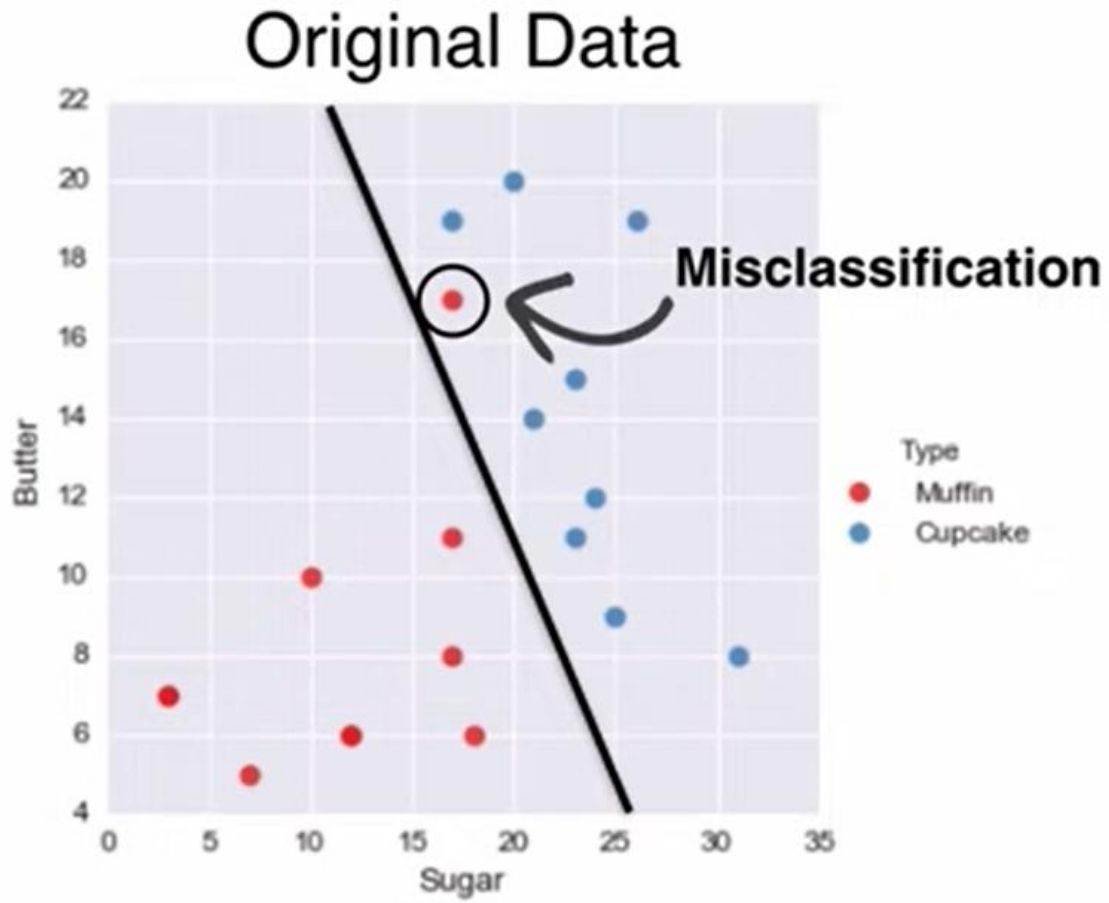
```
[ 3,  7],
[12,  6],
[18,  6],
[12,  6],
[ 3,  7], ...
```

all_ingredients

```
[55, 28,  3,  7,  5,  2,  0,  0],
[47, 24, 12,  6,  9,  1,  0,  0],
[47, 23, 18,  6,  4,  1,  0,  0],
[50, 25, 12,  6,  5,  2,  1,  0],
[55, 27,  3,  7,  5,  2,  1,  0], ...
```

C Parameter: Visual





C Parameter: Code

The C parameter allows you to decide how much you want to penalize misclassified points

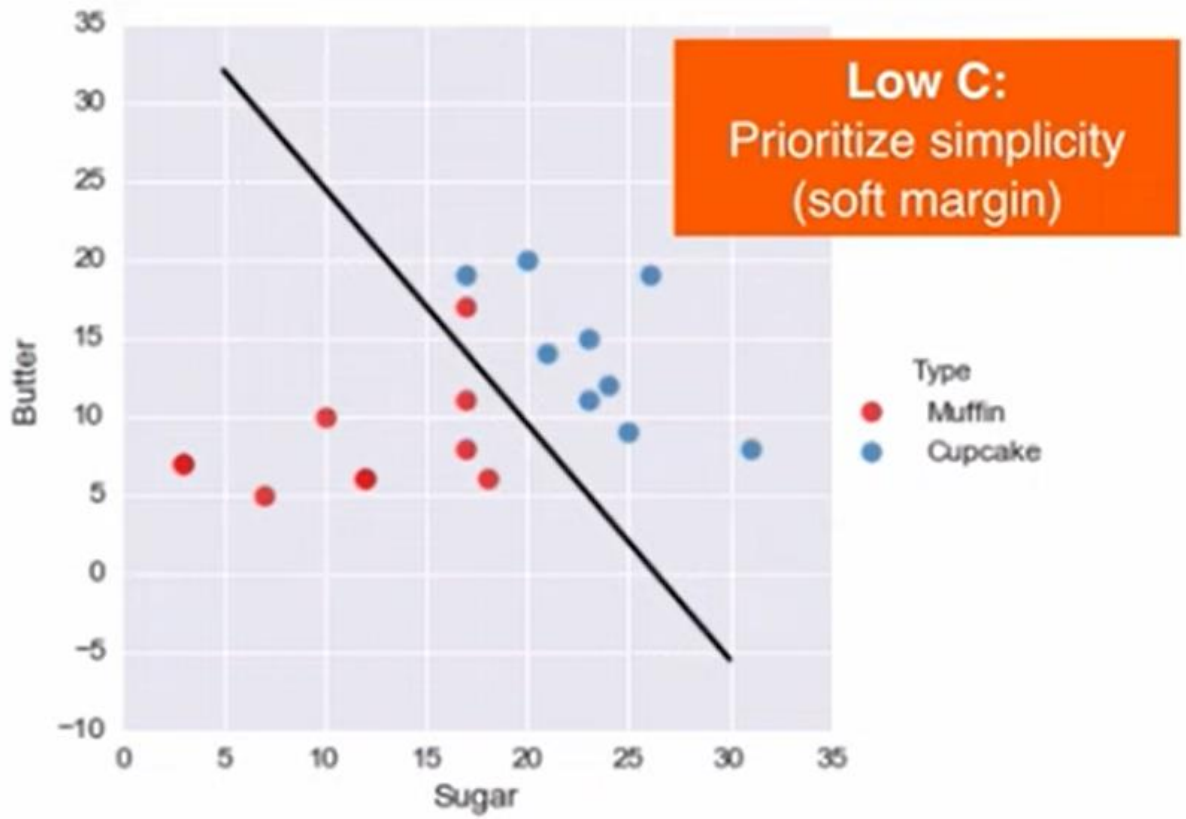
```
In [5]: # Fit the SVM model
        model = svm.SVC(kernel='linear')
        model.fit(sugar_butter, type_label)

Out[5]: SVC(C=1.0, cache_size=200, class_weight=None, coef0=0.0,
          decision_function_shape=None, degree=3, gamma='auto', kernel='linear',
          max_iter=-1, probability=False, random_state=None, shrinking=True,
          tol=0.001, verbose=False)
```

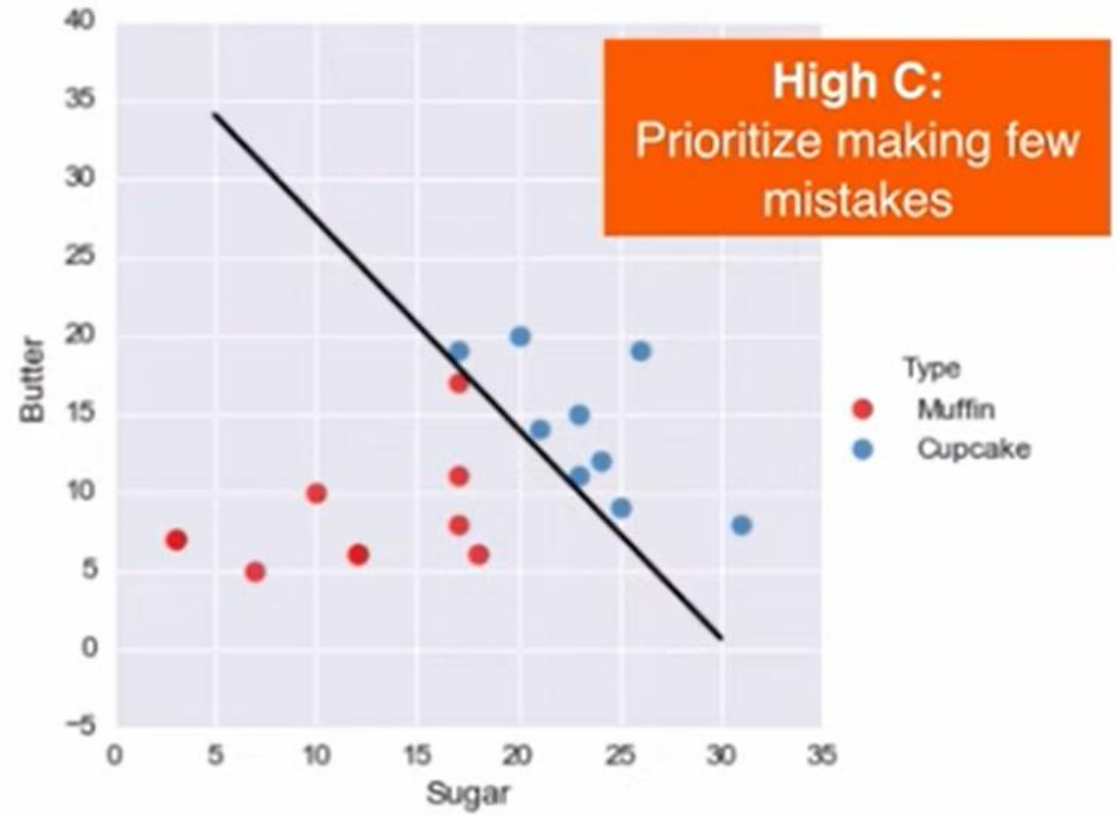
Default Value

C Parameter: Comparison

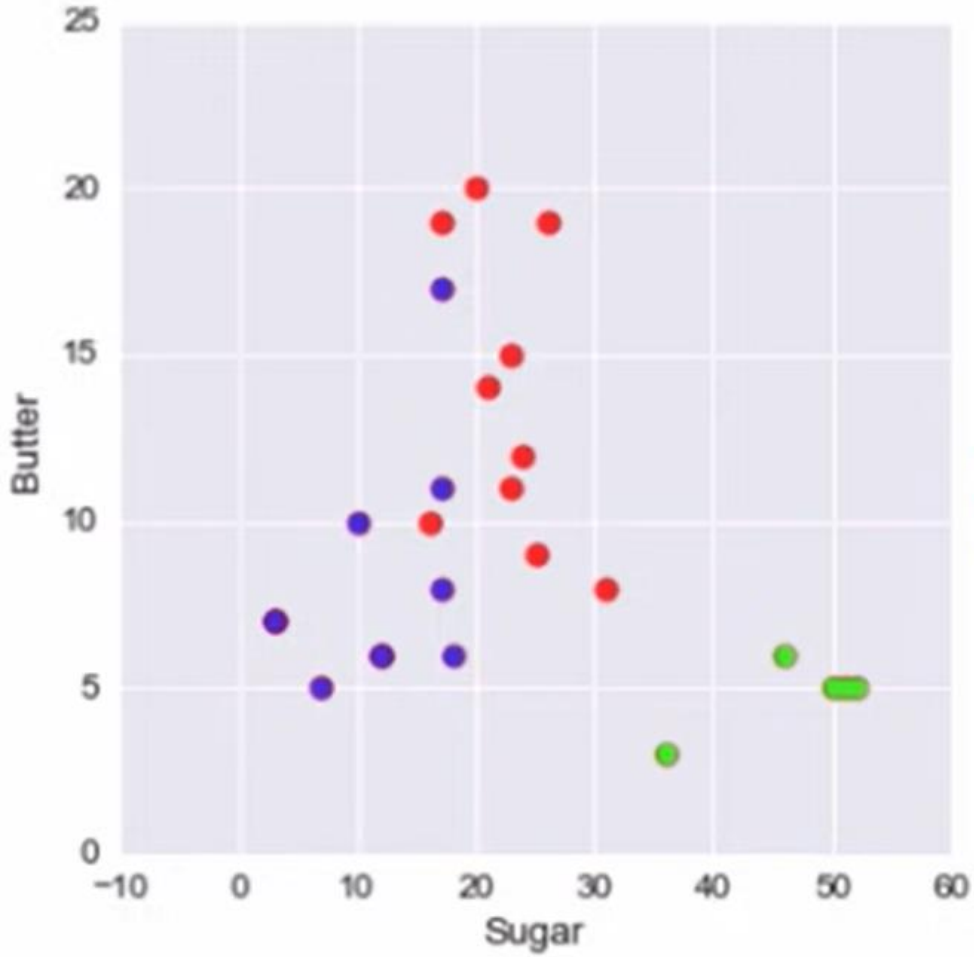
```
# Fit the SVM model with a LOW C
model = svm.SVC(kernel='linear', C=2**-5)
model.fit(sugar_butter, type_label)
```

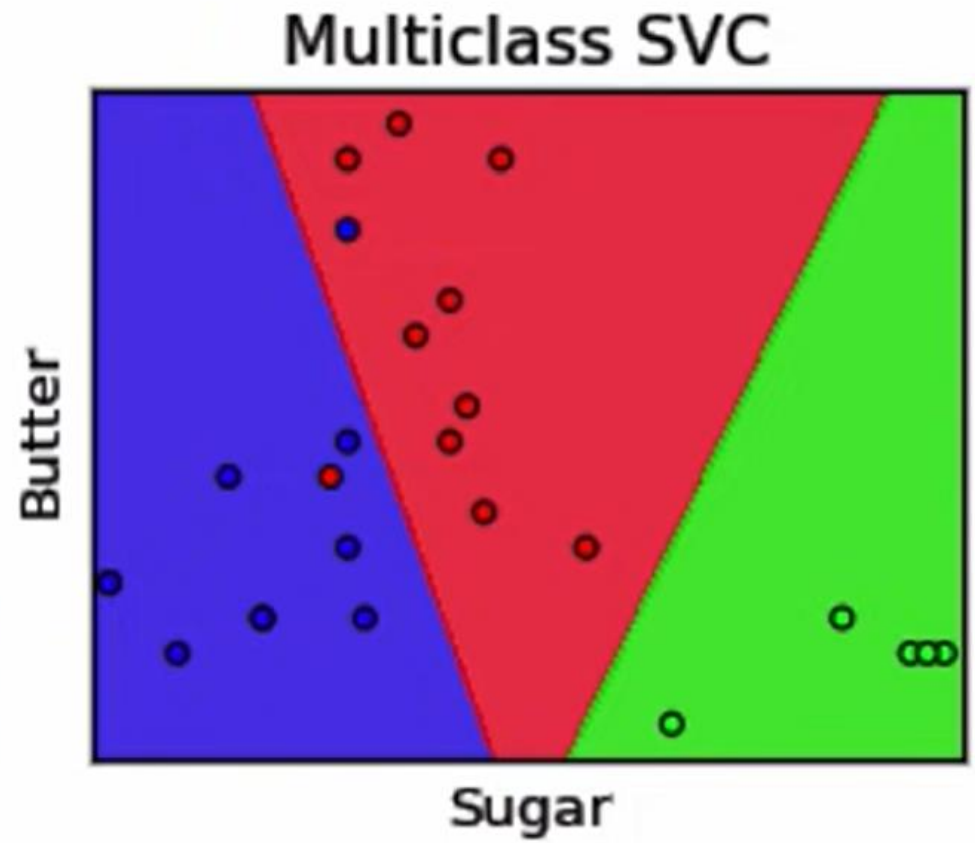



```
# Fit the SVM model with a HIGH C
model = svm.SVC(kernel='linear', C=2**5)
model.fit(sugar_butter, type_label)
```



Multiple Classes: Visual





Multiple Classes: Code

Original Code
(2 classes)

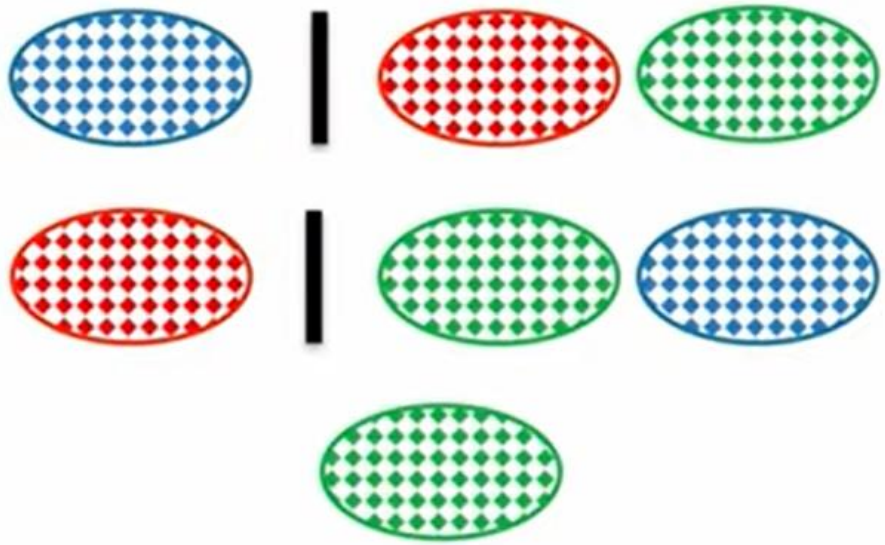
```
# Fit the SVM model
model = svm.SVC(kernel='linear')
model.fit(sugar_butter, type_label)
```

Updated Code
(3+ classes)

```
# Fit the SVM model for more than 2 classes
model = svm.SVC(kernel='linear', decision_function_shape='ovr')
model.fit(sugar_butter, type_label)
```

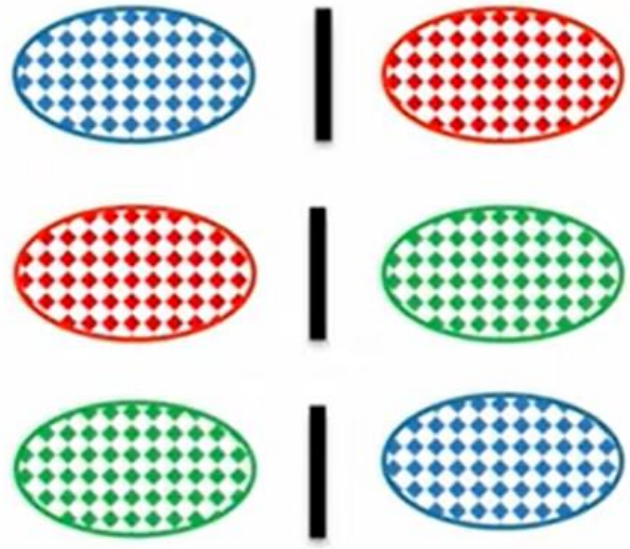
Multiple Classes: Comparison

OVR: One vs Rest



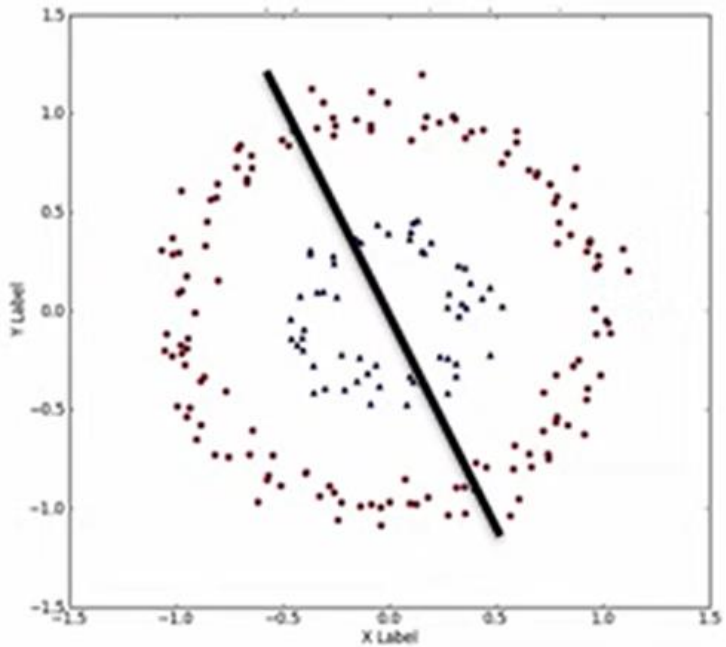
Pros: Fewer classifications
Cons: Classes may be imbalanced

OVO: One vs One

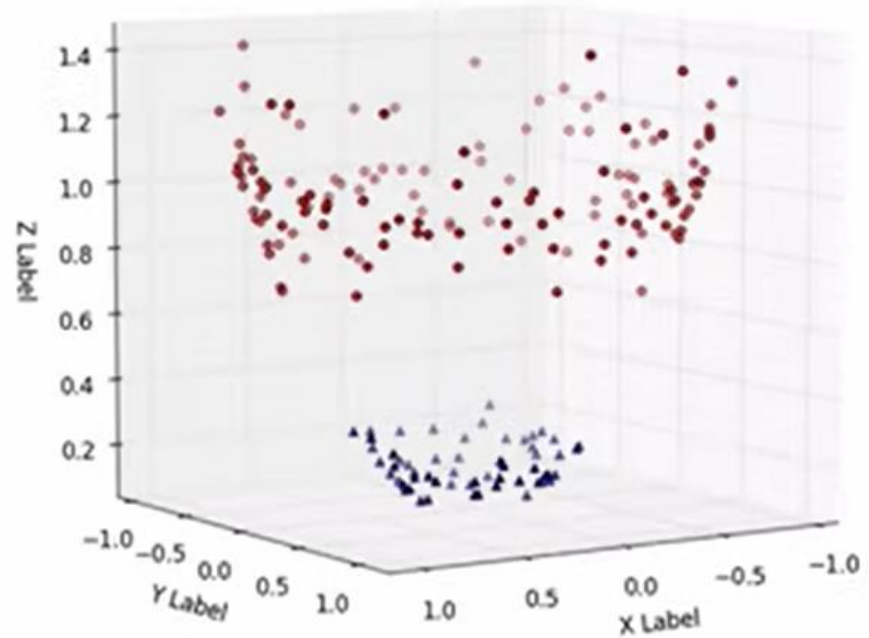


Pros: Less sensitive to imbalance
Cons: More classifications

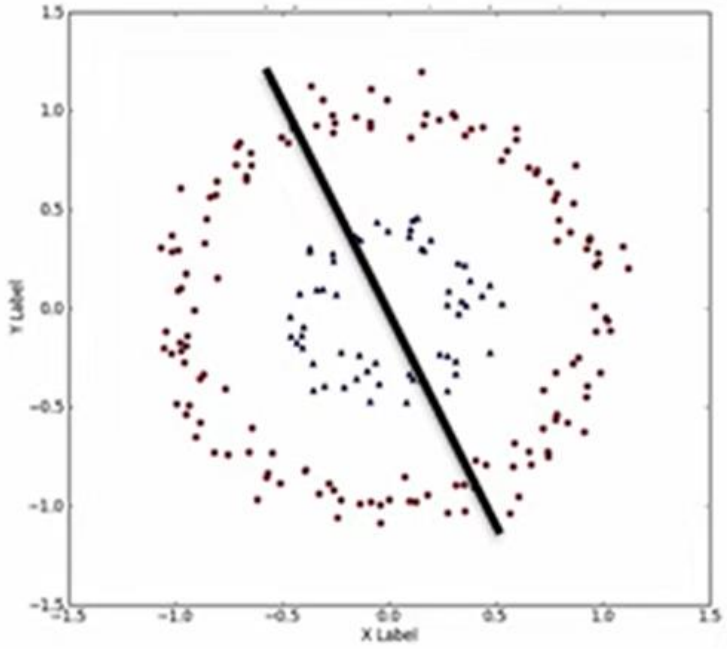
Kernel Trick: Visual



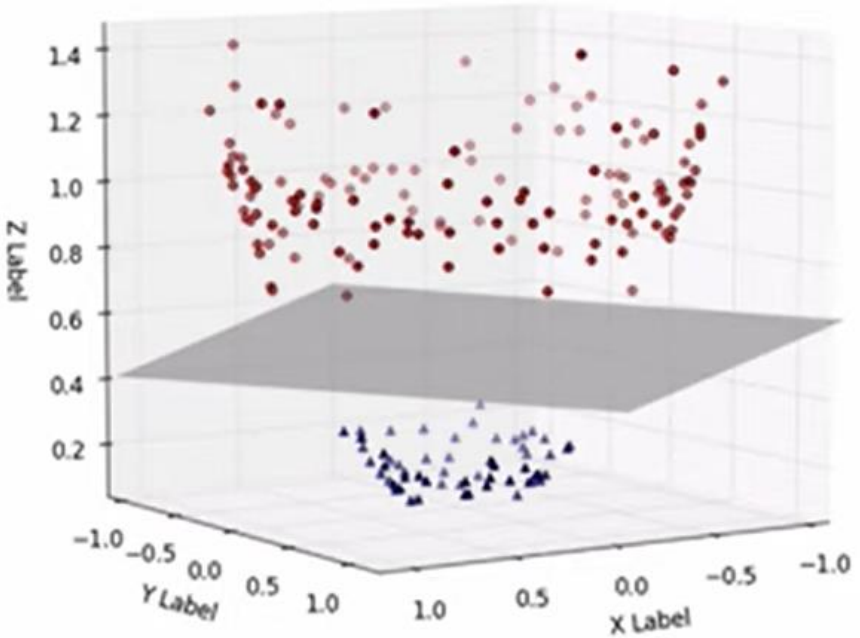
Kernel



Kernel Trick: Visual



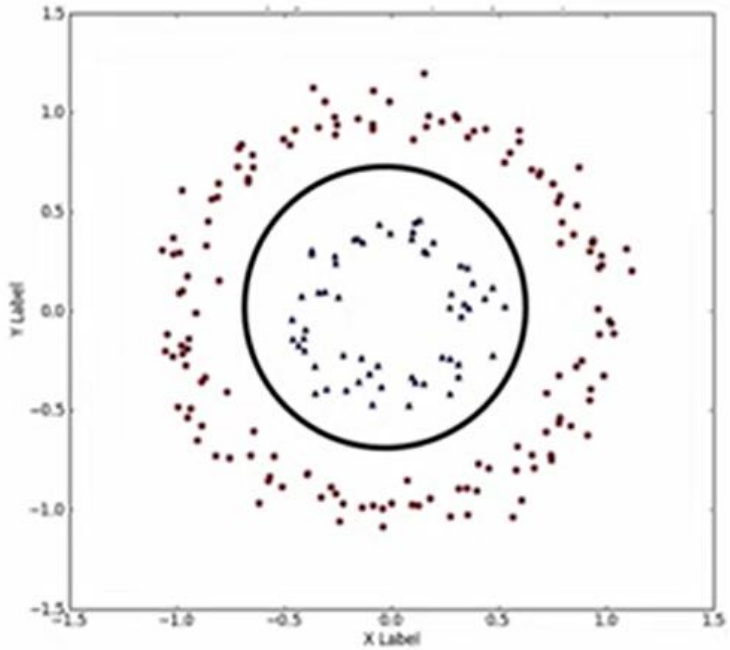
Kernel



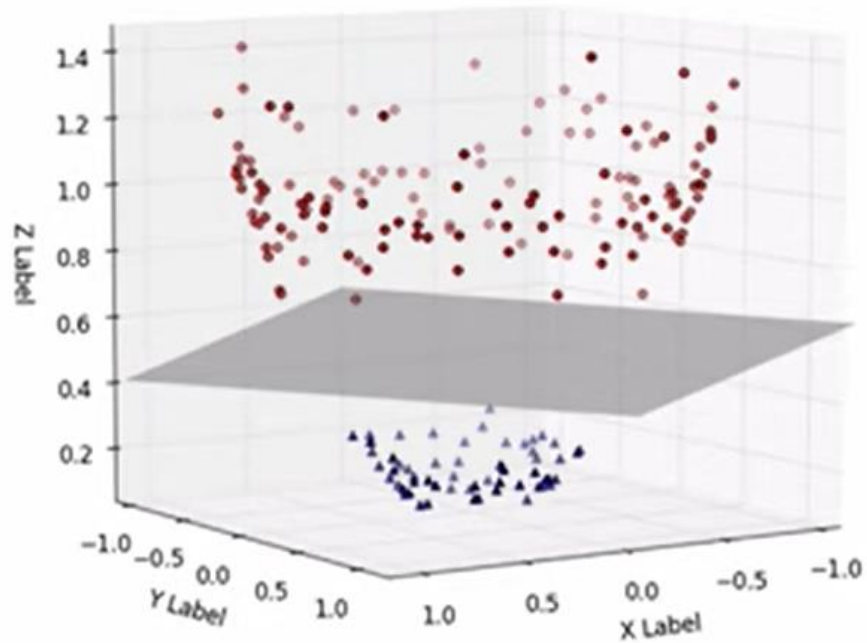
Kernel Options

- Linear
- Radial Basis Function
- Polynomial
- Sigmoid

Kernel Trick: Visual



Kernel



Kernel Options

- Linear
- Radial Basis Function
- Polynomial
- Sigmoid

Kernel Trick: Code

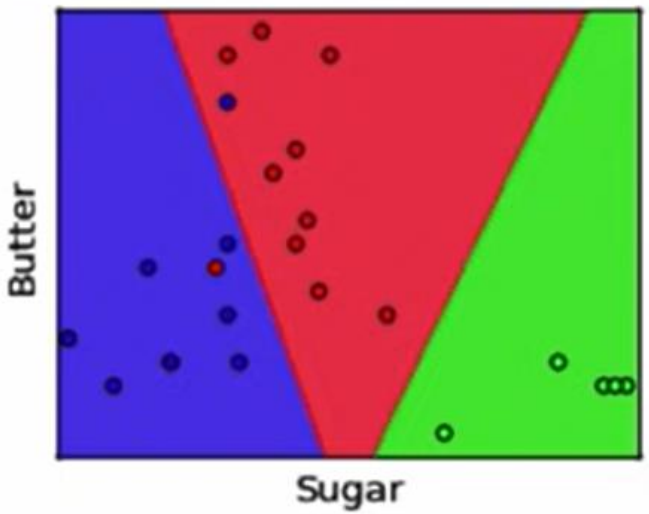
Original Code (linear)

```
# Fit basic SVC model (linear kernel)
model = svm.SVC(kernel='linear')
model.fit(sugar_butter, type_label)
```

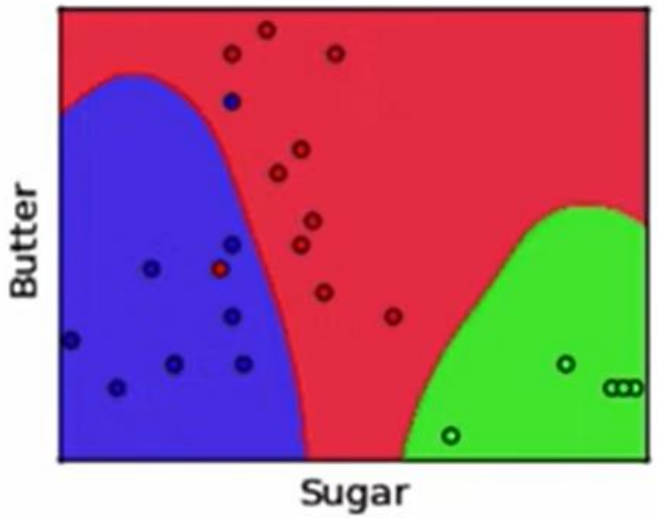
Updated Code (RBF)

```
# Fit the SVC model with radial kernel
model = svm.SVC(kernel='rbf', C=1, gamma=2**-5)
model.fit(sugar_butter, type_label)
```

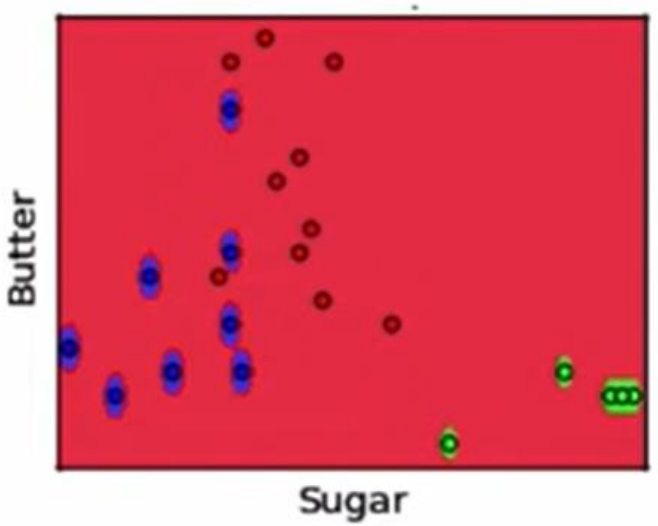
Kernel Trick: Comparison



Kernel: Linear
C: 1



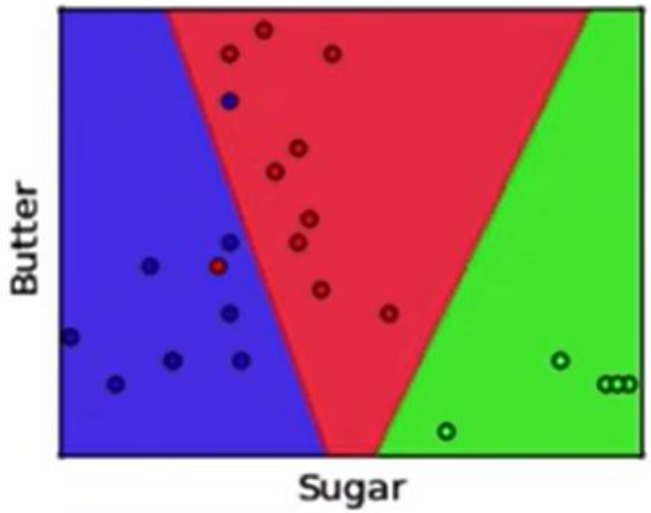
Kernel: RBF
C: 1
Gamma: 2^-5



Kernel: RBF
C: 1
Gamma: 2^1

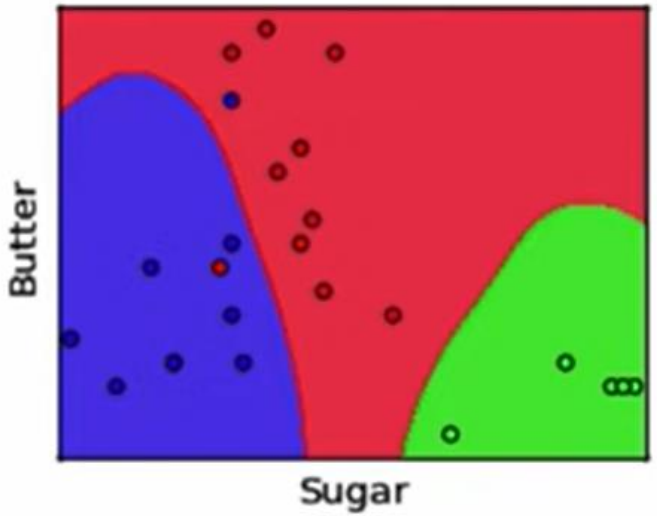
- Muffin
- Cupcake
- Scone

Kernel Trick: Comparison



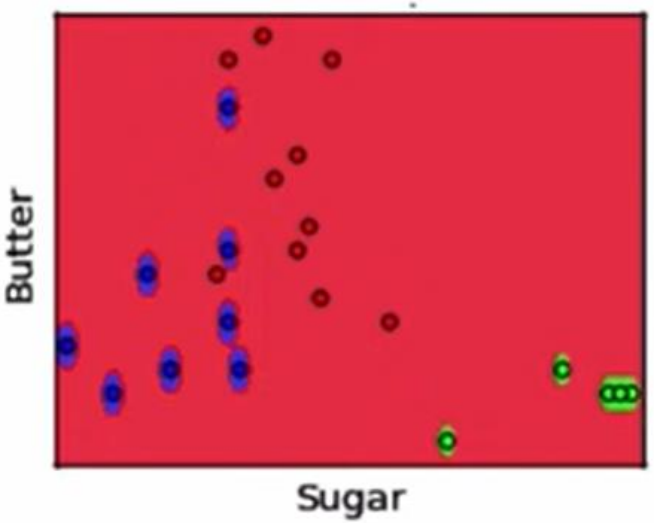
Kernel: Linear
C: 1

Muffin
Cupcake
Scone



Kernel: RBF
C: 1
Gamma: 2^-5

Small Gamma:
Less complexity



Kernel: RBF
C: 1
Gamma: 2^1

Large Gamma:
More complexity

Agenda

1. SVM Basics
   - Visual introduction
   - Example in Python
2. Additional Complexities
   - Higher dimensions
   - Multiple classes
   - C parameter
   - Kernel trick
3. Closing Remarks
   - Pros and cons
   - Other techniques

Pros and Cons of SVM

- **Pros**
  - Good at dealing with high dimensional data
  - Works well on small data sets
- **Cons**
  - Picking the right kernel and parameters can be computationally intensive

Classification Techniques

- **SVM is one of many classification techniques**
  - Logistic Regression
  - K Nearest Neighbors
  - Decision Trees
  - Naïve Bayes
  - Neural Networks

- **Advice: try multiple techniques on your data set**