

Machine Learning

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DS 620
Machine Learning

Lecture 9



OUTLINE

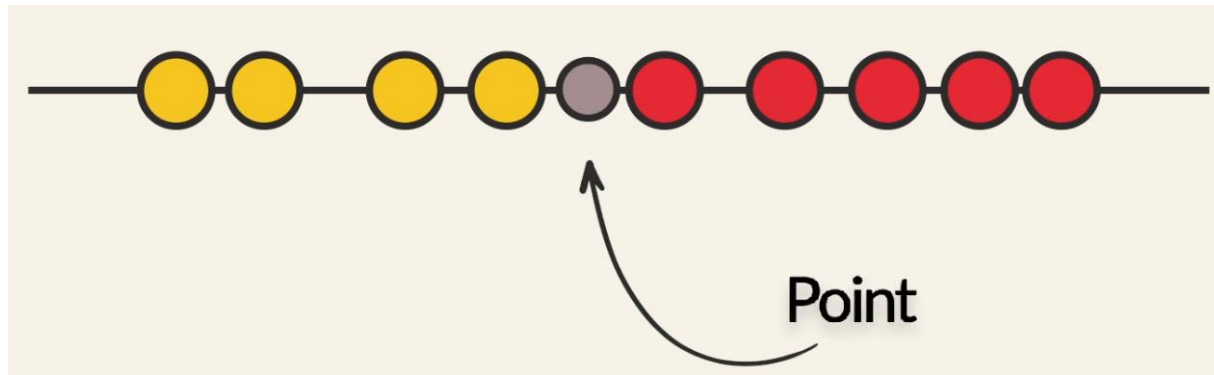
- Support vector machines (SVM)

SUPPORT VECTOR MACHINES(SVM)

- ❖ Support Vector Machines are widely used and powerful machine learning algorithms
- ❖ It is commonly used for
 - Classification and
 - Regression tasks.

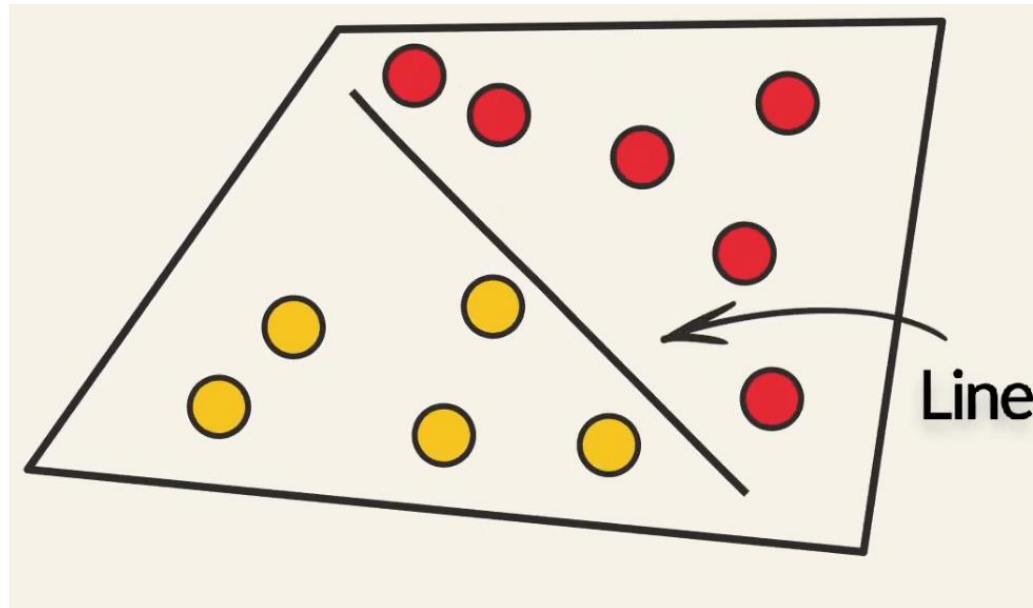
HYPERPLANE IN ONE DIMENSIONAL SPACE

❖ In one dimensional space a hyperplane is a **point**.



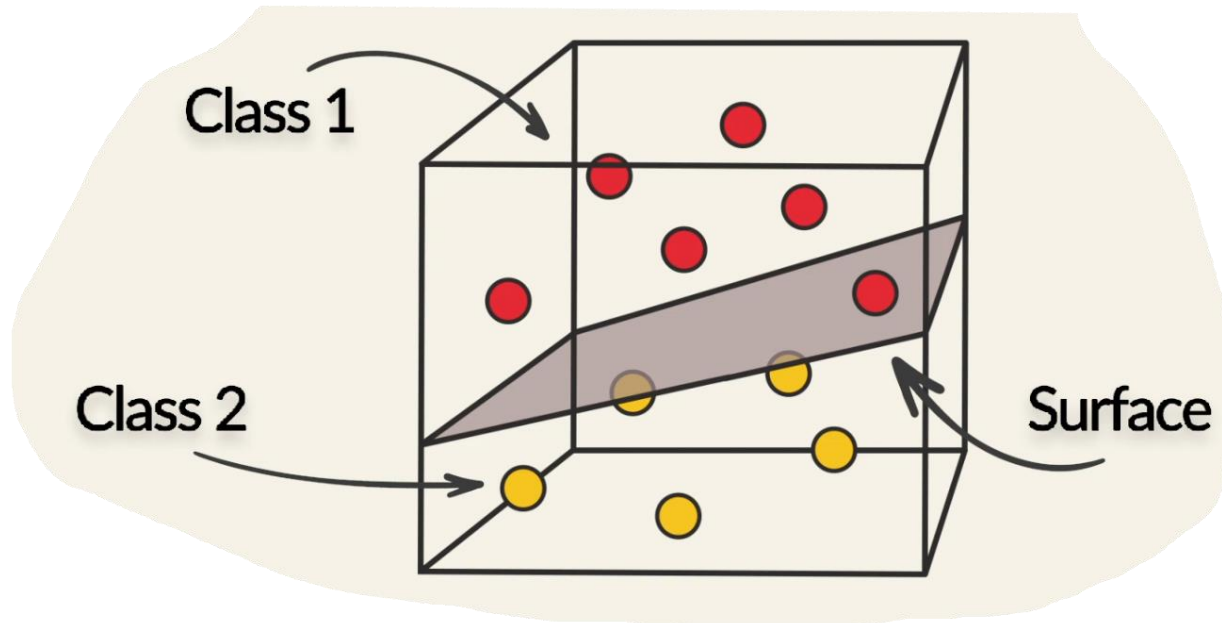
HYPERPLANE IN TWO DIMENSIONAL SPACE

❖ In two dimensional space a hyperplane is a **line**.



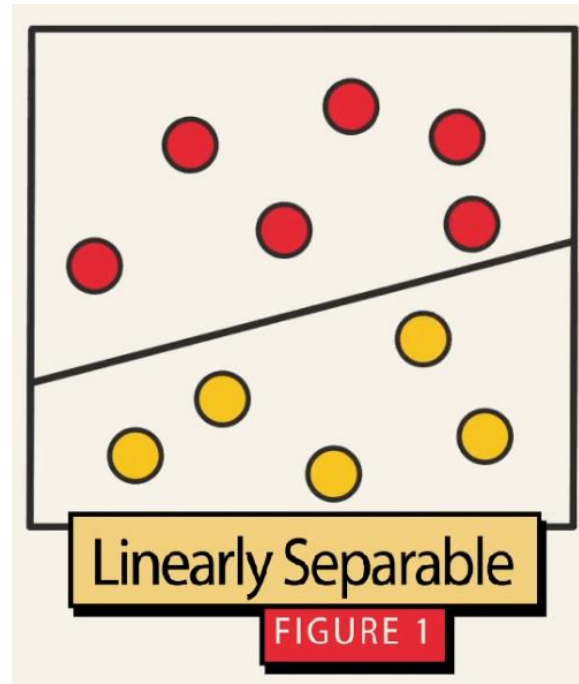
HYPERPLANE IN THREE DIMENSIONAL SPACE

- ❖ In three dimensional space the hyperplane is a **Plane/surface**.



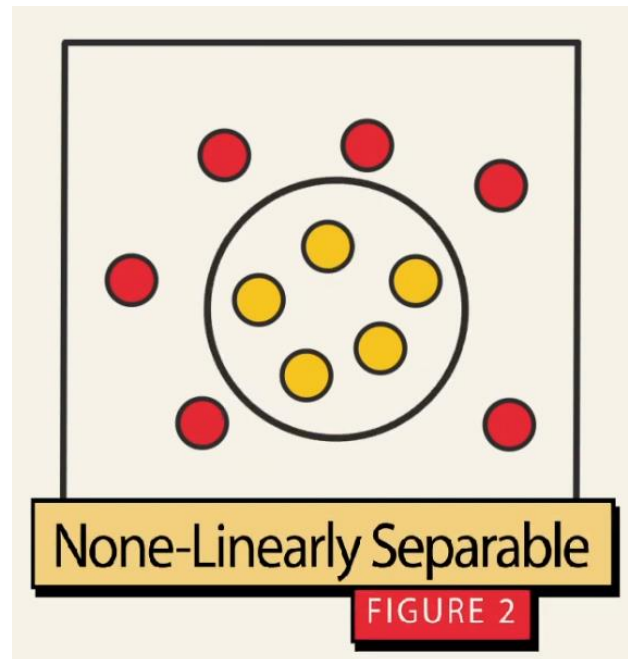
LINEARLY SEPARABLE DATA

❖ We can find a separating line between classes.



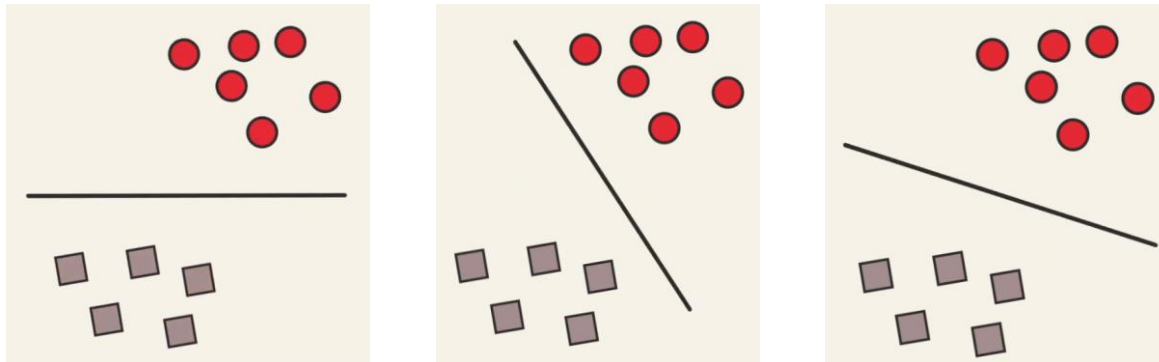
NON-LINEARLY SEPARABLE DATA

❖ We can not find a separating line between classes.



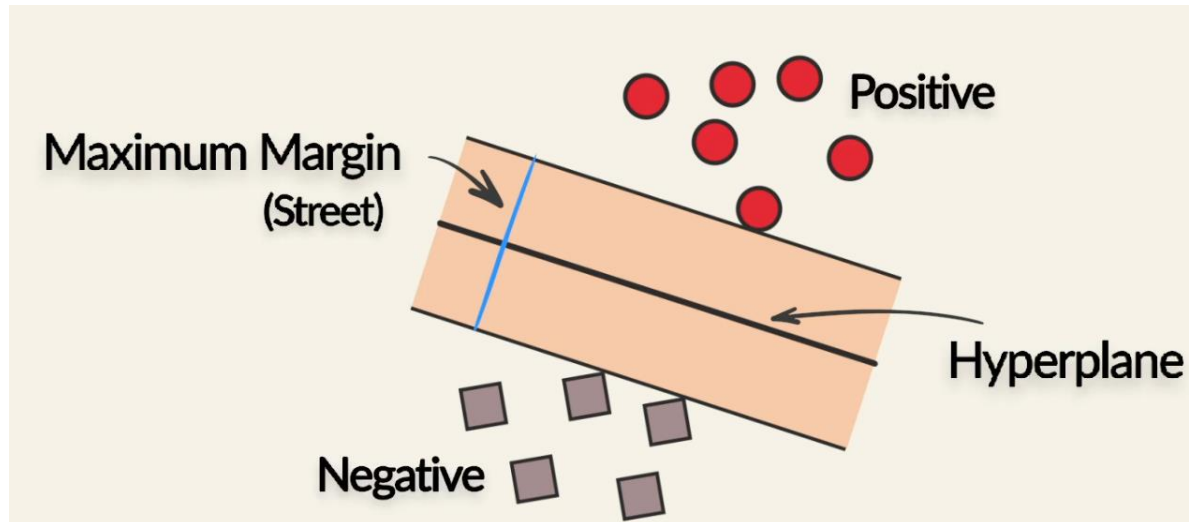
FINDING THE BEST LINE SEPARATOR

❖ Which of the following line separators gives the best classification results?



MAXIMUM MARGIN CLASSIFIER

- ❖ SVM can help us to choose the best hyperplane that maximizes the margin between classes.(Maximum Margin Classifier)



SUPPORT VECTOR MACHINES(SVM)

❖ Support Vector Machines are a type of **supervised learning algorithm** that works by finding an optimal hyperplane in a high-dimensional feature space to separate different classes of data points.

SUPPORT VECTOR MACHINES(SVM)

- ❖ The hyperplane is chosen in such a way that it **maximizes the margin**, i.e., the distance between the hyperplane and the nearest data points of each class.
- ❖ The data points that are closest to the hyperplane are called support vectors.

SUPPORT VECTOR MACHINES(SVM)

- ❖ By maximizing the margin,
 - We can achieve better generalization on unseen data, and
 - Improve the algorithm's ability to handle noise and outliers.

LINEAR SVM

- ❖ In linear SVM, the goal is to find the best hyperplane that separates the data points of different classes.
- ❖ The hyperplane can be represented by the equation:
$$w \cdot x + b = 0,$$
- ❖ where w represents the weights vector, x is the input feature vector, and b is the bias term.

LINEAR SVM

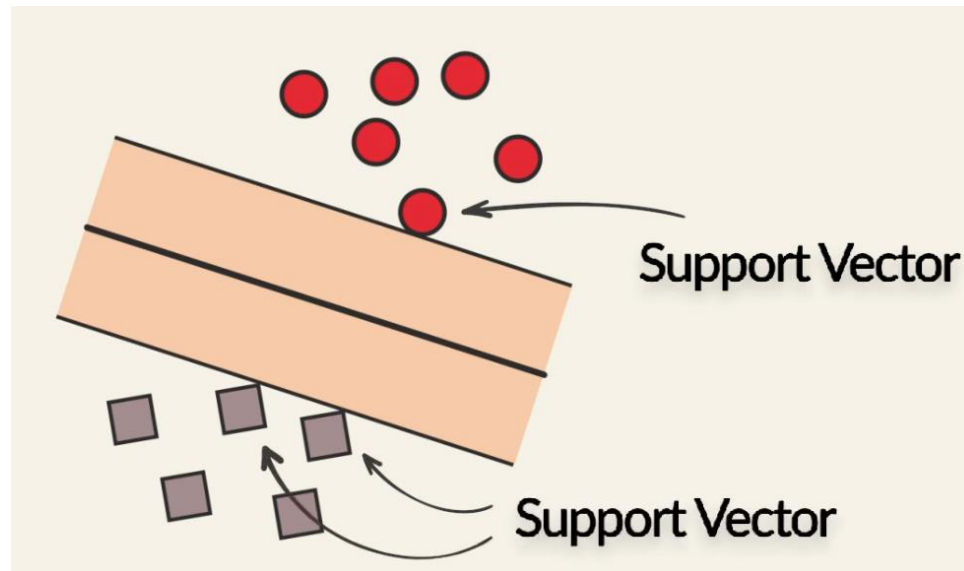
- ❖ The objective of SVM is to find the optimal $\mathbf{w}$ and $\mathbf{b}$ values that maximize the margin while correctly classifying the training data.
- ❖ To achieve this, we formulate an optimization problem that minimizes the objective function subject to certain constraints.

LINEAR SVM

- ❖ To handle non-linearly separable data, we can introduce a slack variable ξ that allows for some misclassification of training samples.
- ❖ This leads to the formulation of the soft-margin SVM, where the objective function includes a penalty term for misclassifications.

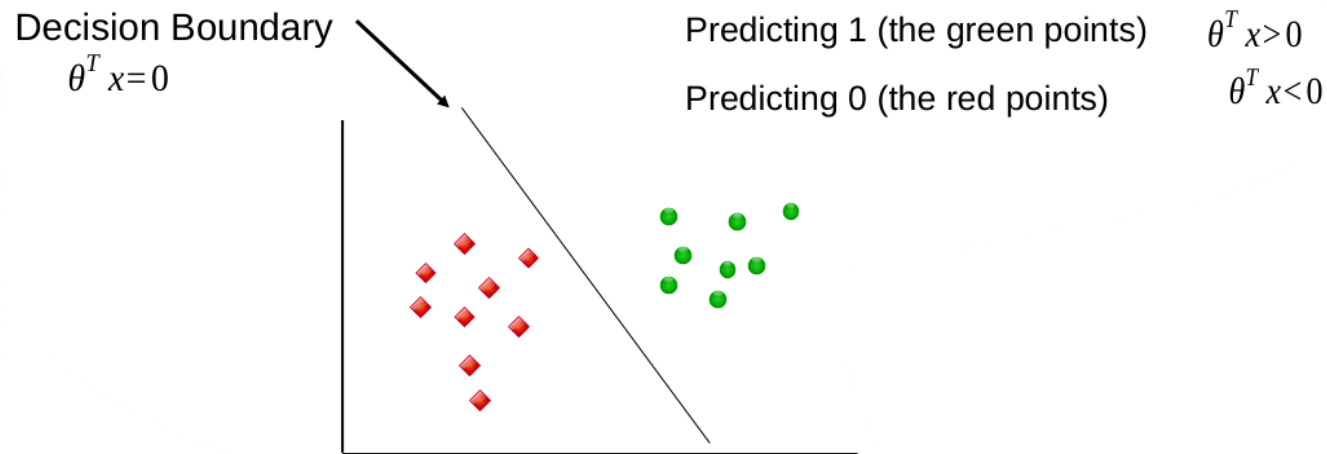
SUPPORT VECTORS

- ❖ Support vectors are the data points that lie closest to the hyperplane. (The most difficult data points to classify)



CLASSIFICATION

- ❖ Binary Classification can be view as the task of separating classes in feature spaces.
- ❖ For a hypothesis $h_{\theta}(x) = \theta^T x$



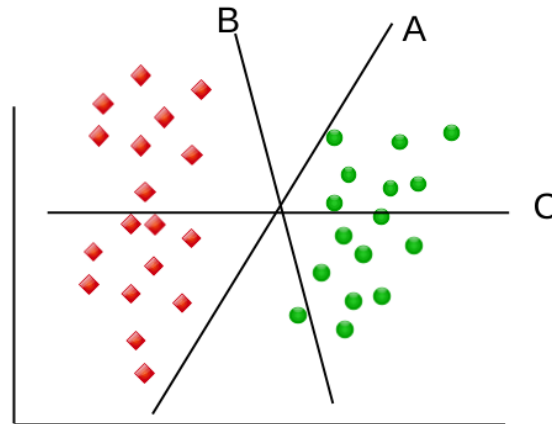
- ❖ The goal of Classifier is to train a model that assigns a new **unseen object** into a specific category.
- ❖ It places the object **above or below the separator hyperplane**

CLASSIFICATION

- ❖ Classification is the process of categorizing the two classes with a hyperplane.
- ❖ How can we Identify the (best) hyperplane

Scenario 1

Identify the right hyper-plane

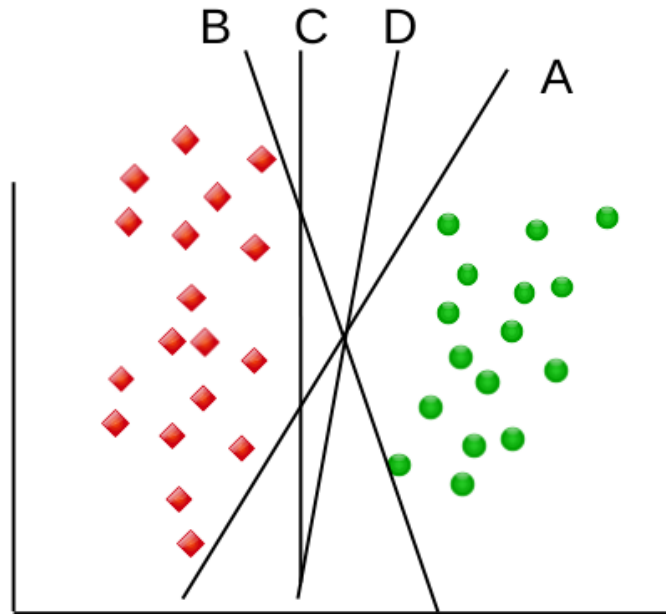


MULTIPLE CORRECT HYPERPLANES

❖ What if we have more than one hyperplane?

Scenario 2

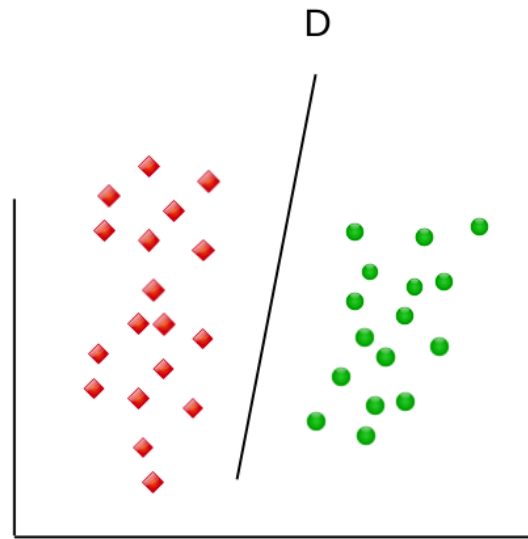
Identify the right hyper-plane



We have 4 hyper-planes A, B, C, and D. All are separating the classes well

MAXIMUM MARGIN CLASSIFIER (MMC)

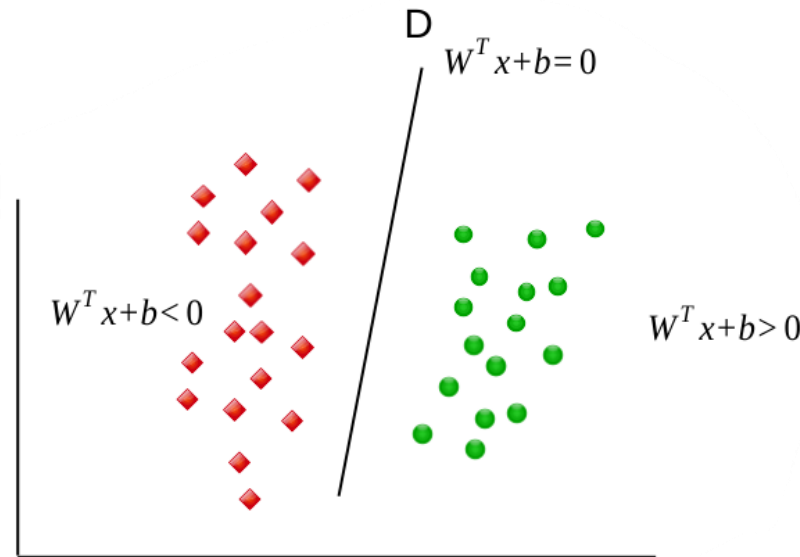
- ❖ D stays as far as possible from both classes.
- ❖ By being **right in the middle of the two classes**, it is less “risky” to misclassify the unseen data, thus generalizes well on test data



MAXIMUM MARGIN CLASSIFIER (MMC)

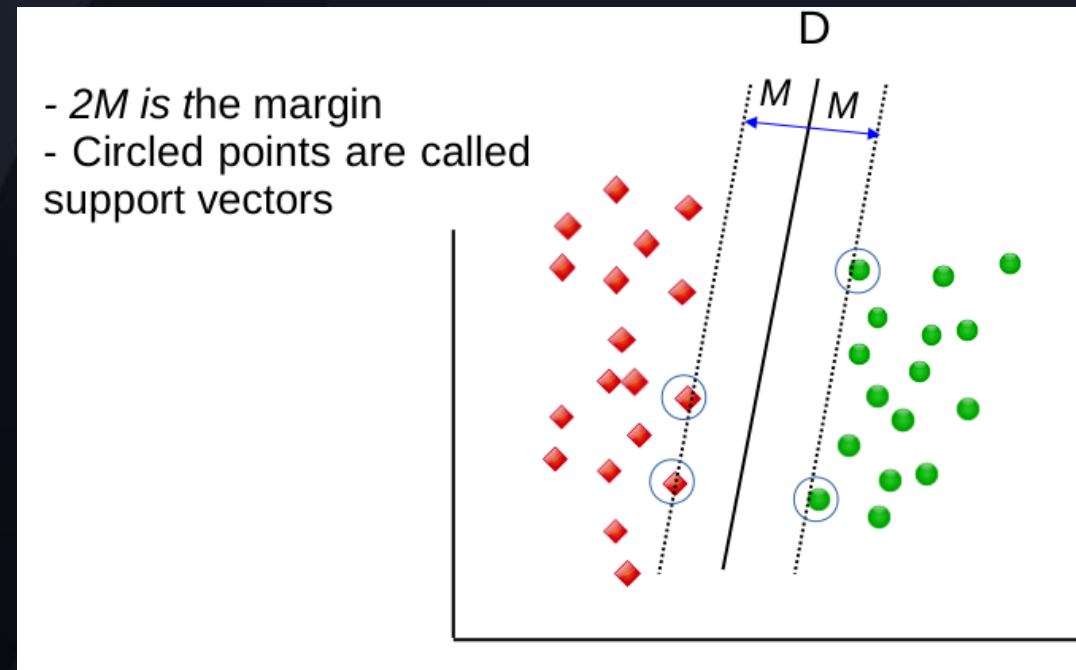
❖ MMC tries to find the best separator hyperplane. Here is a simple version of What MMC (as a kind of SVMs) do:

1. Find hyperplanes that correctly classify the training data.
2. Among all such hyperplanes, pick the one that has the greatest distance to the closest points.



MAXIMUM MARGIN CLASSIFIER (MMC)

- ❖ The closest points that identify this hyper-plane are known as **support vectors**.
- ❖ The region around the line is known as the Margin.
 - Only support vectors matter, other training examples are ignored.
 - Data that can be separated by a hyper-plane is known as **Linearly separable** data
 - The hyperplane that classifies the linear separable data acts as a linear classifier.

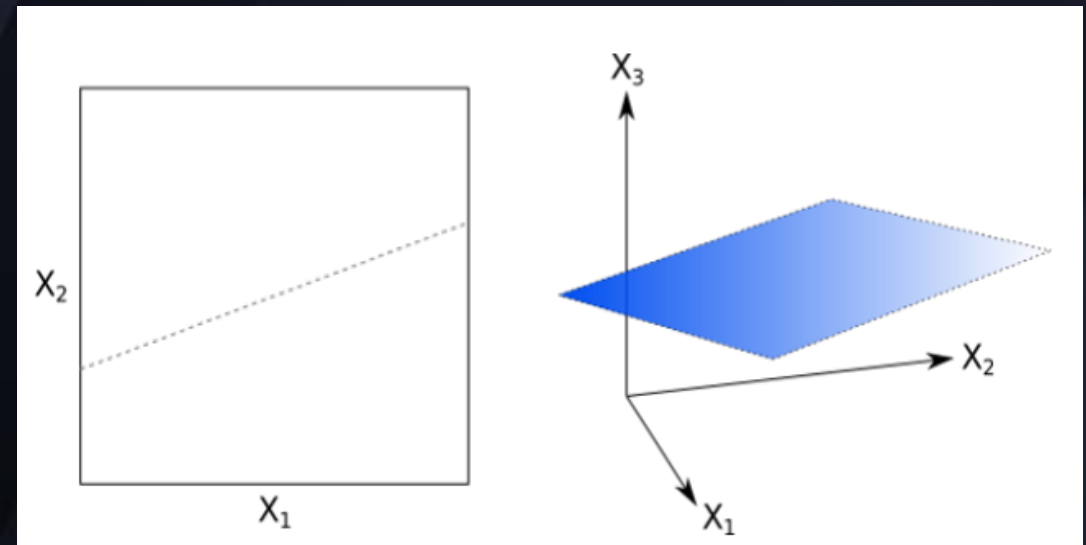


SUPPORT VECTOR CLASSIFIER

- ❖ SVC is a classifier formally defined by a separating hyperplane $W^T X + b = 0$
- ❖ A hyperplane is a subspace of one dimension less than its ambient space.
- ❖ This means a hyperplane of two dimension space is one dimension separator (line).
- ❖ A hyperplane of three dimension space is two dimension separator (plane).

SUPPORT VECTOR CLASSIFIER

- ❖ Elements above the hyperplane satisfy $w^T x + b > 0$
- ❖ Elements below the hyperplane satisfy $w^T x + b < 0$
- ❖ The weight vector W represents the orientation of the hyperplane and b represent the bias.



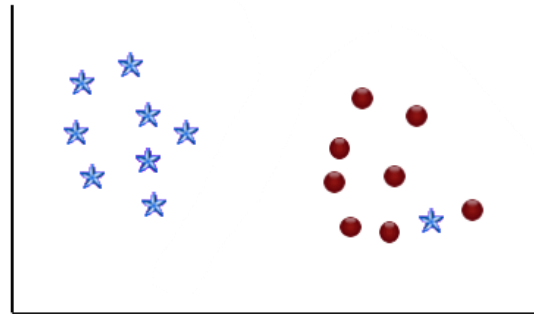
2D space separated by line (left).
3D space separated by plane (right)

ALLOWING FOR ERRORS

- ❖ Look at the case indicated in scenario 3,
- ❖ How can we define the class separator?

Scenario 3

How can you find the right hyperplane ?

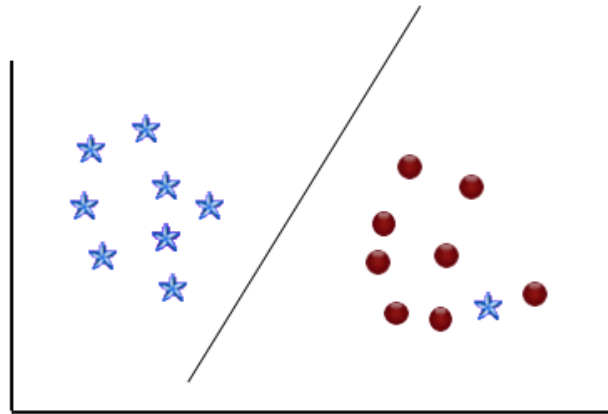


ALLOWING FOR ERRORS

- ❖ SVC has a feature to ignore outliers and find the hyperplane that has maximum margin.
- ❖ i.e SVC (hence SVM) is robust against outliers

Scenario 3

How can you find the right hyperplane ?

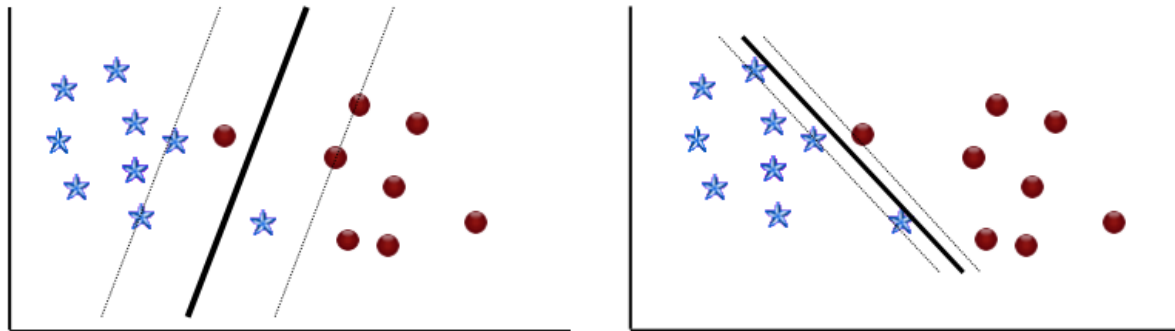


SOFT MARGIN CLASSIFIER

- ❖ For scenario 4, which separator is better.
- ❖ Will you maximize the margin and allow misclassified instance?
- ❖ Or
- ❖ Will you choose to correctly classify with narrow margin ?

Scenario 4

Which one is the best ?



Soft margin Classifier

ALLOWING FOR ERRORS



SUMMARY

- Support vector machines



Thank You

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