SUPPORT VECTOR MACHINES

Scholastic Video Book Series

Part 1

Linear Support Vector Machines (LSVM)

(with English Narrations)

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Support Vector Machines - #1

Liner Support Vector Machines (LSVM)

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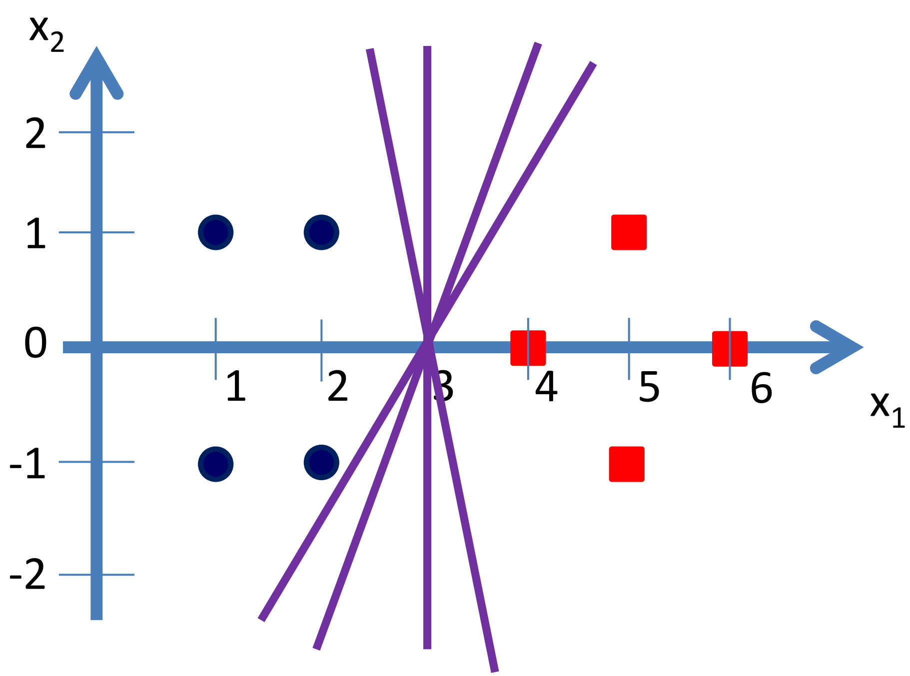
(SVM-001)

Support Vector Machines

- Support Vector Machine (SVM) algorithms are used in Classification.
- Classification can be viewed as the task of separating classes in feature space.



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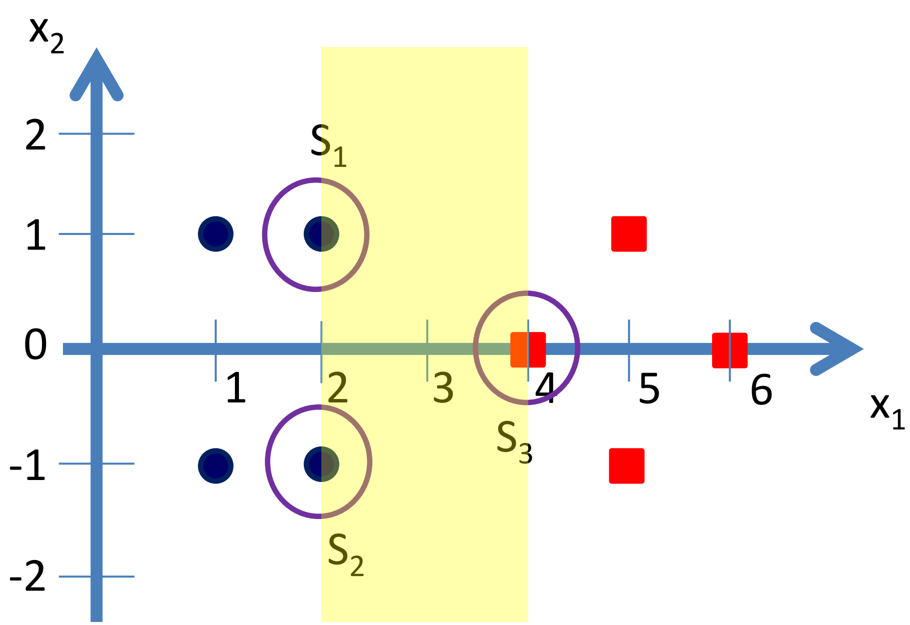
Support Vector Machines

- Here we select 3 Support Vectors to start with.
- They are S_1, S_2 and S_3.



$$S_1 = \begin{pmatrix} 2 \\ 1 \end{pmatrix}$$

$$S_2 = \begin{pmatrix} 2 \\ -1 \end{pmatrix}$$

$$S_3 = \begin{pmatrix} 4 \\ 0 \end{pmatrix}$$

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Support Vector Machines

- Here we will use vectors augmented with a 1 as a bias input, and for clarity we will differentiate these with an over-tilde. That is:

$$S_1 = \begin{pmatrix} 2 \\ 1 \end{pmatrix}$$

$$S_2 = \begin{pmatrix} 2 \\ -1 \end{pmatrix}$$

$$S_3 = \begin{pmatrix} 4 \\ 0 \end{pmatrix}$$

$$\widetilde{S_1} = \begin{pmatrix} 2 \\ 1 \\ 1 \end{pmatrix}$$

$$\widetilde{S_2} = \begin{pmatrix} 2 \\ -1 \\ 1 \end{pmatrix}$$

$$\widetilde{S_3} = \begin{pmatrix} 4 \\ 0 \\ 1 \end{pmatrix}$$

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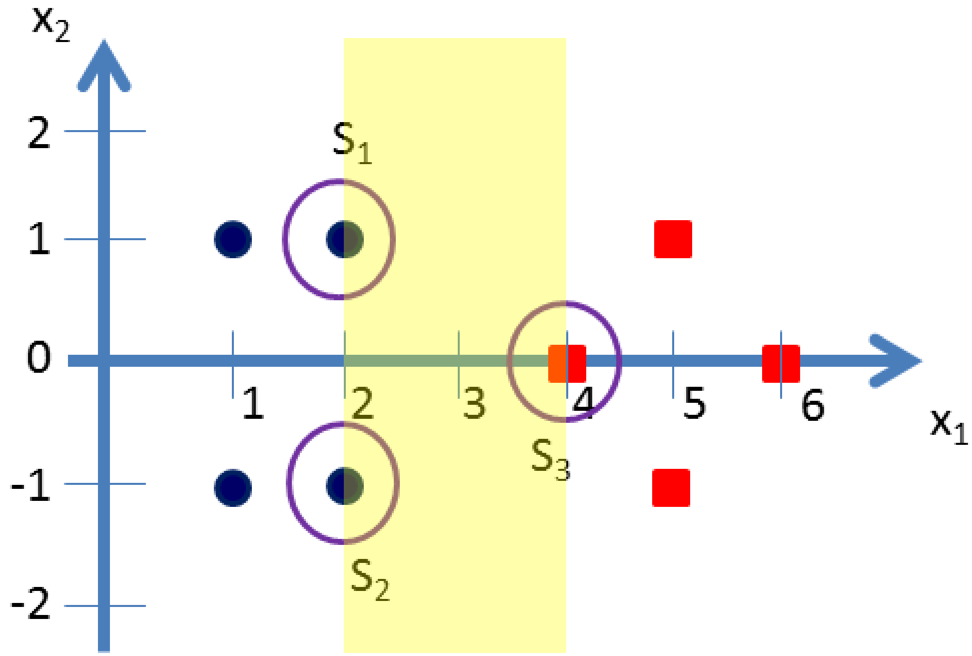

- Now we need to find 3 parameters α_1, α_2, and α_3 based on the following 3 linear equations:

$$\alpha_1 \widetilde{S_1} . \widetilde{S_1} + \alpha_2 \widetilde{S_2} . \widetilde{S_1} + \alpha_3 \widetilde{S_3} . \widetilde{S_1} = -1 \;\; (-ve \; class)$$

$$\alpha_1 \widetilde{S_1} . \widetilde{S_2} + \alpha_2 \widetilde{S_2} . \widetilde{S_2} + \alpha_3 \widetilde{S_3} . \widetilde{S_2} = -1 \; (-ve \; class)$$

$$\alpha_1 \widetilde{S_1} . \widetilde{S_3} + \alpha_2 \widetilde{S_2} . \widetilde{S_3} + \alpha_3 \widetilde{S_3} . \widetilde{S_3} = +1 \;\; (+ve \; class)$$

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$$\alpha_1\widetilde{S_1}.\widetilde{S_1}+\alpha_2\widetilde{S_2}.\widetilde{S_1}+\alpha_3\widetilde{S_3}.\widetilde{S_1}=-1\ \ (-ve\ class)$$

$$\alpha_1\widetilde{S_1}.\widetilde{S_2}+\alpha_2\widetilde{S_2}.\widetilde{S_2}+\alpha_3\widetilde{S_3}.\widetilde{S_2}=-1\ (-ve\ class)$$

$$\alpha_1\widetilde{S_1}.\widetilde{S_3}+\alpha_2\widetilde{S_2}.\widetilde{S_3}+\alpha_3\widetilde{S_3}.\widetilde{S_3}=+1\ \ (+ve\ class)$$

- Let's substitute the values for $\widetilde{S}_1$, $\widetilde{S}_2$ and $\widetilde{S}_3$ in the above equations.

$$\widetilde{S_1}=\begin{pmatrix}2\\1\\1\end{pmatrix}\qquad \widetilde{S_2}=\begin{pmatrix}2\\-1\\1\end{pmatrix}\qquad \widetilde{S_3}=\begin{pmatrix}4\\0\\1\end{pmatrix}$$

$$\alpha_1\begin{pmatrix}2\\1\\1\end{pmatrix}.\begin{pmatrix}2\\1\\1\end{pmatrix}+\alpha_2\begin{pmatrix}2\\-1\\1\end{pmatrix}.\begin{pmatrix}2\\1\\1\end{pmatrix}+\alpha_3\begin{pmatrix}4\\0\\1\end{pmatrix}.\begin{pmatrix}2\\1\\1\end{pmatrix}=-1$$

$$\alpha_1\begin{pmatrix}2\\1\\1\end{pmatrix}.\begin{pmatrix}2\\-1\\1\end{pmatrix}+\alpha_2\begin{pmatrix}2\\-1\\1\end{pmatrix}.\begin{pmatrix}2\\-1\\1\end{pmatrix}+\alpha_3\begin{pmatrix}4\\0\\1\end{pmatrix}.\begin{pmatrix}2\\-1\\1\end{pmatrix}=-1$$

$$\alpha_1\begin{pmatrix}2\\1\\1\end{pmatrix}.\begin{pmatrix}4\\0\\1\end{pmatrix}+\alpha_2\begin{pmatrix}2\\-1\\1\end{pmatrix}.\begin{pmatrix}4\\0\\1\end{pmatrix}+\alpha_3\begin{pmatrix}4\\0\\1\end{pmatrix}.\begin{pmatrix}4\\0\\1\end{pmatrix}=+1$$

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$$\alpha_1 \begin{pmatrix}2\\1\\1\end{pmatrix}.\begin{pmatrix}2\\1\\1\end{pmatrix} + \alpha_2 \begin{pmatrix}2\\-1\\1\end{pmatrix}.\begin{pmatrix}2\\1\\1\end{pmatrix} + \alpha_3 \begin{pmatrix}4\\0\\1\end{pmatrix}.\begin{pmatrix}2\\1\\1\end{pmatrix} = -1$$

$$\alpha_1 \begin{pmatrix}2\\1\\1\end{pmatrix}.\begin{pmatrix}2\\-1\\1\end{pmatrix} + \alpha_2 \begin{pmatrix}2\\-1\\1\end{pmatrix}.\begin{pmatrix}2\\-1\\1\end{pmatrix} + \alpha_3 \begin{pmatrix}4\\0\\1\end{pmatrix}.\begin{pmatrix}2\\-1\\1\end{pmatrix} = -1$$

$$\alpha_1 \begin{pmatrix}2\\1\\1\end{pmatrix}.\begin{pmatrix}4\\0\\1\end{pmatrix} + \alpha_2 \begin{pmatrix}2\\-1\\1\end{pmatrix}.\begin{pmatrix}4\\0\\1\end{pmatrix} + \alpha_3 \begin{pmatrix}4\\0\\1\end{pmatrix}.\begin{pmatrix}4\\0\\1\end{pmatrix} = +1$$

- After simplification we get:

$$6\alpha_1 + 4\alpha_2 + 9\alpha_3 = -1$$

$$4\alpha_1 + 6\alpha_2 + 9\alpha_3 = -1$$

$$9\alpha_1 + 9\alpha_2 + 17\alpha_3 = +1$$

- Simplifying the above 3 simultaneous equations we get: α_1=α_2= -3.25 and α_3= 3.5.

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$\alpha_1 = \alpha_2 = -3.25$ and $\alpha_3 = 3.5$

$$\widetilde{S_1} = \begin{pmatrix} 2 \\ 1 \\ 1 \end{pmatrix} \quad \widetilde{S_2} = \begin{pmatrix} 2 \\ -1 \\ 1 \end{pmatrix} \quad \widetilde{S_3} = \begin{pmatrix} 4 \\ 0 \\ 1 \end{pmatrix}$$

- The hyper plane that discriminates the positive class from the negative class is give by:

$$\widetilde{w} = \sum_i \alpha_i \widetilde{S}_i$$

- Substituting the values we get:

$$\widetilde{w} = \alpha_1 \begin{pmatrix} 2 \\ 1 \\ 1 \end{pmatrix} + \alpha_2 \begin{pmatrix} 2 \\ -1 \\ 1 \end{pmatrix} + \alpha_3 \begin{pmatrix} 4 \\ 0 \\ 1 \end{pmatrix}$$

$$\widetilde{w} = (-3.25).\begin{pmatrix} 2 \\ 1 \\ 1 \end{pmatrix} + (-3.25).\begin{pmatrix} 2 \\ -1 \\ 1 \end{pmatrix} + (3.5).\begin{pmatrix} 4 \\ 0 \\ 1 \end{pmatrix} = \begin{pmatrix} 1 \\ 0 \\ -3 \end{pmatrix}$$

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$$\tilde{w} = (-3.25).\begin{pmatrix}2\\1\\1\end{pmatrix} + (-3.25).\begin{pmatrix}2\\-1\\1\end{pmatrix} + (3.5).\begin{pmatrix}4\\0\\1\end{pmatrix} = \begin{pmatrix}1\\0\\-3\end{pmatrix}$$

- Our vectors are augmented with a bias.
- Hence we can equate the entry in $\tilde{w}$ as the hyper plane with an offset b.
- Therefore the separating hyper plane equation $y = wx + b$ with $w = \begin{pmatrix}1\\0\end{pmatrix}$ and offset $b = -3$.

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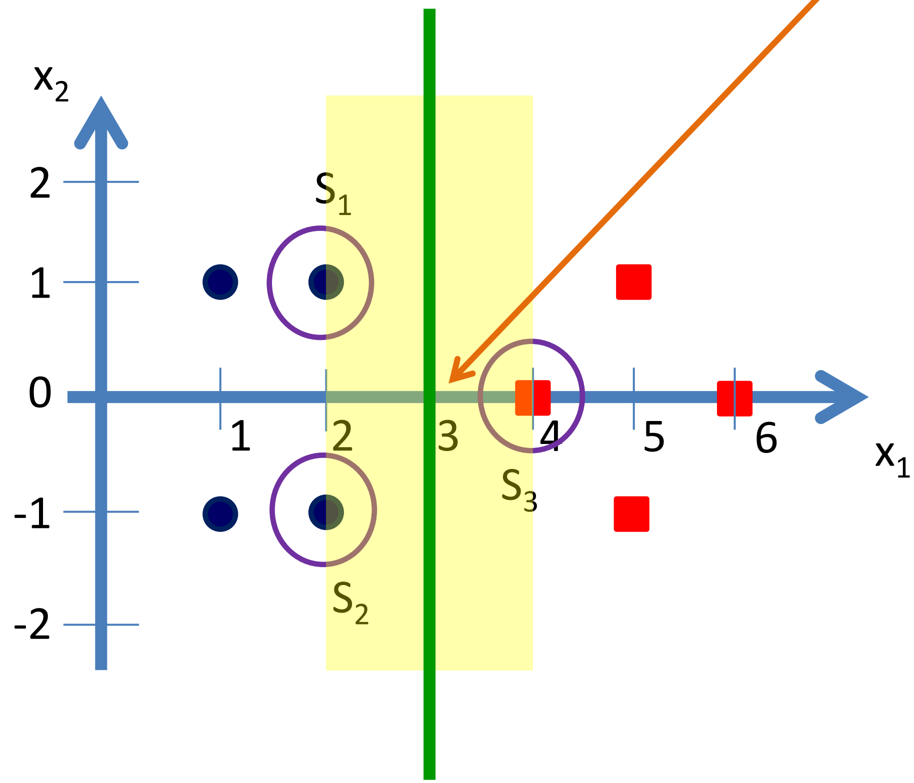
Support Vector Machines

- $y = wx + b$ with $w = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$ and offset $b = -3$.



- This is the expected decision surface of the LSVM.

Support Vector Machines – Programme Code Example 1

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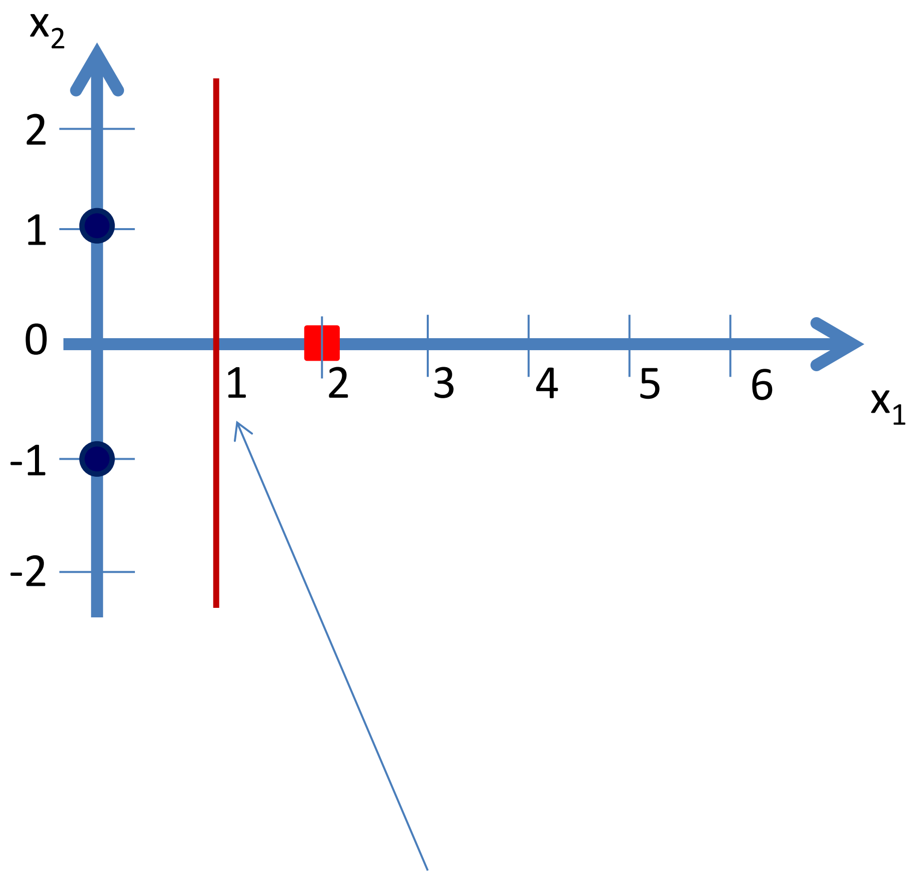
```
% 3 support vector version

s1 = [ 0 -1 1 ];
s2 = [ 0 1 1 ];
s3 = [ 2 0 1 ];

A = [ sum(s1.*s1) sum(s2.*s1) sum(s3.*s1) ;
sum(s1.*s2) sum(s2.*s2) sum(s3.*s2) ;
sum(s1.*s3) sum(s2.*s3) sum(s3.*s3) ]
Y = [ -1 -1 +1 ]
X = Y/A

p = X(1)
q = X(2)
r = X(3)

W = [ p*s1 + q*s2 + r*s3 ]
```



When you run you should get: $\tilde{w}$ = [1 0 -1]. This is a vertical line passing through x1=1.

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Support Vector Machines - Programme Code Examples 2

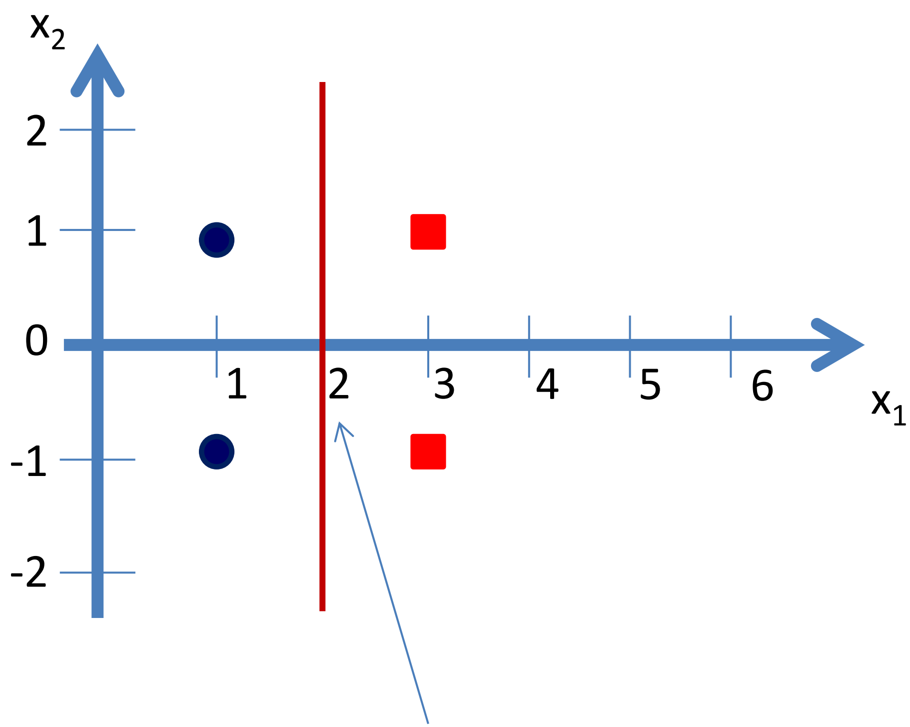
```
% 4 support vector version

s1 = [ 1 1 1 ];
s2 = [ 1 −1 1 ];
s3 = [ 3 −1 1 ];
s4 = [ 3 1 0 ];

A = [ sum(s1.∗s1) sum(s2.∗s1) sum(s3.∗s1) sum(s4.∗s1);
   sum(s1.∗s2) sum(s2.∗s2) sum(s3.∗s2) sum(s4.∗s1);
   sum(s1.∗s3) sum(s2.∗s3) sum(s3.∗s3) sum(s4.∗s3);
   sum(s1.∗s4) sum(s2.∗s4) sum(s3.∗s4) sum(s4.∗s4);]
Y = [ −1 −1 +1 +1 ]
X = Y/A

p = X(1)
q = X(2)
r = X(3)
s = X(4)

W = [ p∗s1 + q∗s2 + r∗s3 + s∗s4 ]
```



When you run you should get: $\widetilde{w}$ = [1 0 -2]. This is a vertical line passing through x1=2.

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Support Vector Machines - Programme Code Example 3

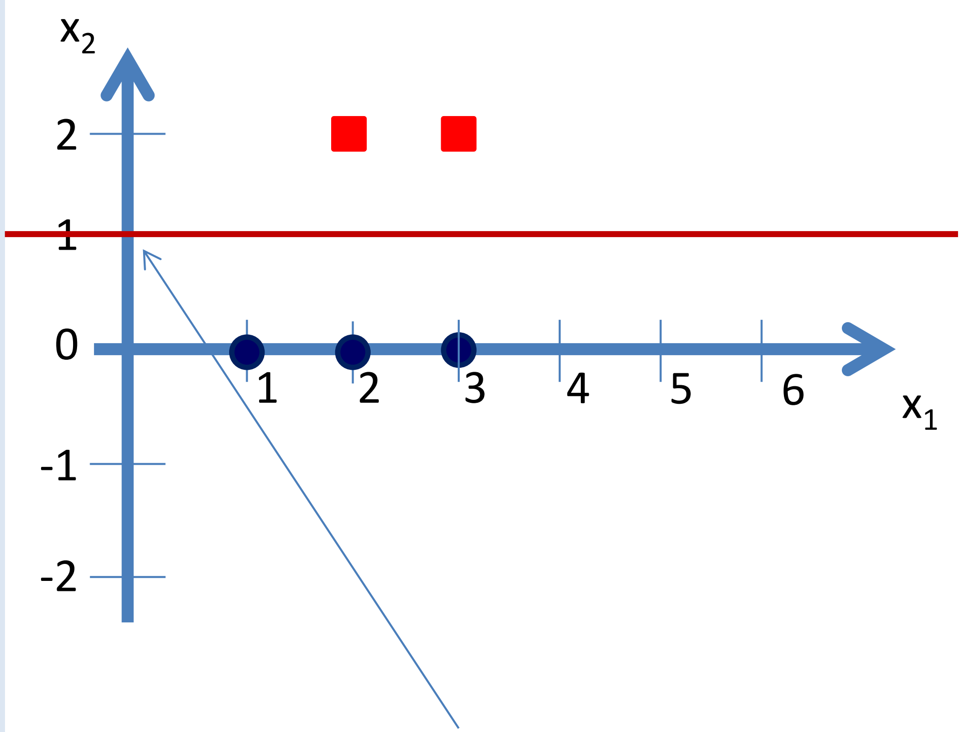
```
% 5 support vector version

s1 = [ 1 0 1 ];
s2 = [ 2 0 1 ];
s3 = [ 3 0 1 ];
s4 = [ 2 2 1 ];
s5 = [ 3 2 1 ];

A = [ sum(s1.*s1) sum(s2.*s1) sum(s3.*s1) sum(s4.*s1) sum(s5.*s1);
   sum(s1.*s2) sum(s2.*s2) sum(s3.*s2) sum(s4.*s2) sum(s5.*s2);
   sum(s1.*s3) sum(s2.*s3) sum(s3.*s3) sum(s4.*s3) sum(s5.*s3);
   sum(s1.*s4) sum(s2.*s4) sum(s3.*s4) sum(s4.*s4) sum(s5.*s4);
   sum(s1.*s5) sum(s2.*s5) sum(s3.*s5) sum(s4.*s5) sum(s5.*s5)]
Y = [ −1 −1 −1 +1 +1 ]
X = Y/A

p = X(1)
q = X(2)
r = X(3)
s = X(4)
t = X(5)

W = [ p*s1 + q*s2 + r*s3 + s*s4 + t*s5 ]
```



When you run you should get: $\tilde{w}$ = [0 1 -1]. This is a horizontal line passing through x2=1.

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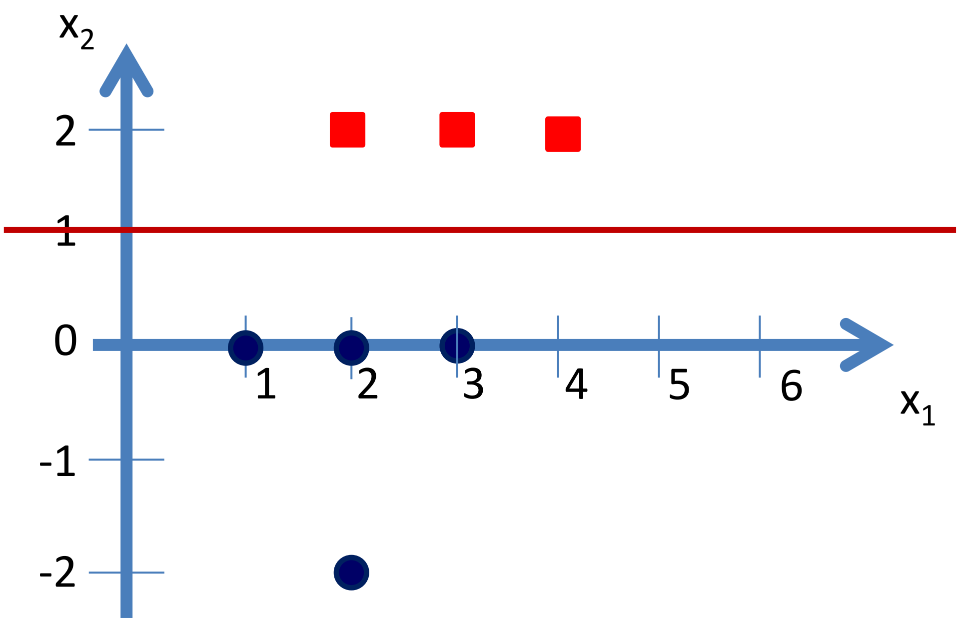
Support Vector Machines – Classification Examples

- Let′s take the 5 support vector version
- $\widetilde{w}$ = [0 1 -1]. This is a horizontal line passing through x2=1.
- Let's classify the point (x1,x2)=(4,2).
- $w.x = \binom{0}{1}.\binom{4}{2} = 2 > 1$
- Hence this point belongs to the red class
- Let's classify the point (x1,x2)=(2,-2).
- $w.x = \binom{0}{1}.\binom{2}{-2} = -2 < 1$
- Hence this point belongs to the blue class
- We can do the same for any new point.



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Support Vector Machines - #1

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END of the Book

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