SVM – Support Vector Machine

- SVM
- supervised classification and regression

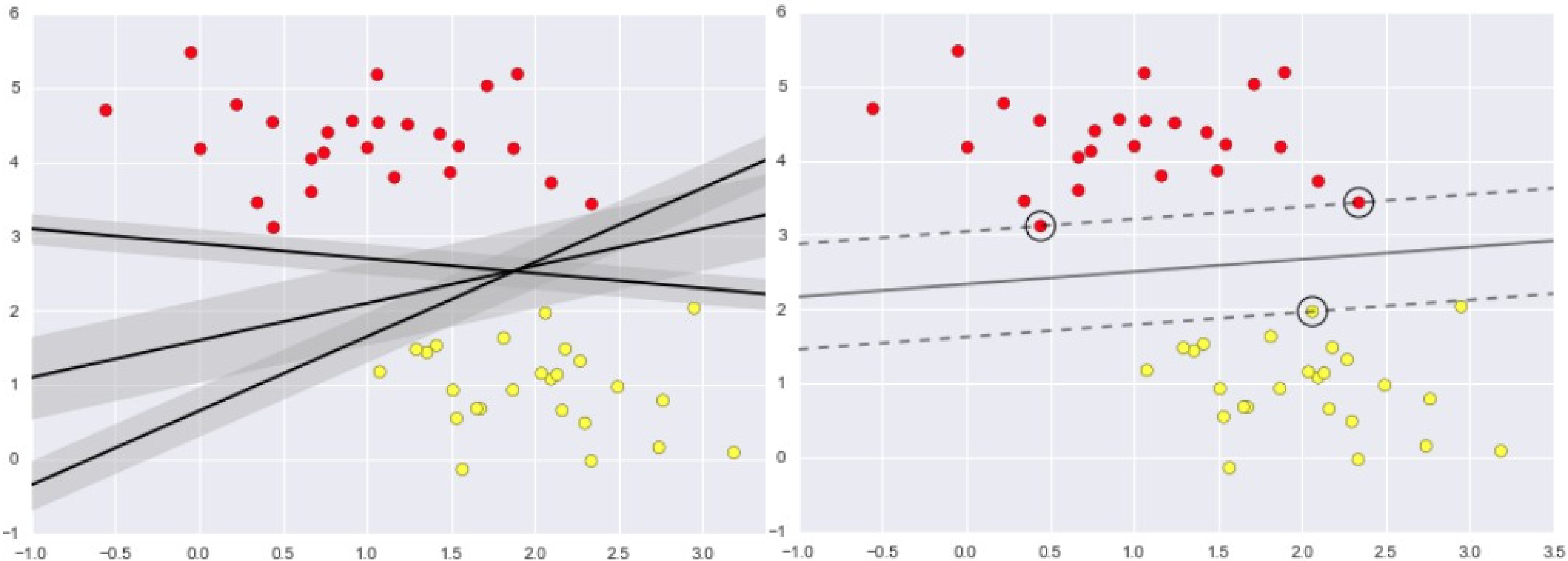
  discriminative (line or curve separating classes)

- Application to Indoor Localization
  (MLP x LVQ x SVM)

SVM Master

GitHub, Colab: [05.07-Support-Vector-Machines.ipynb]

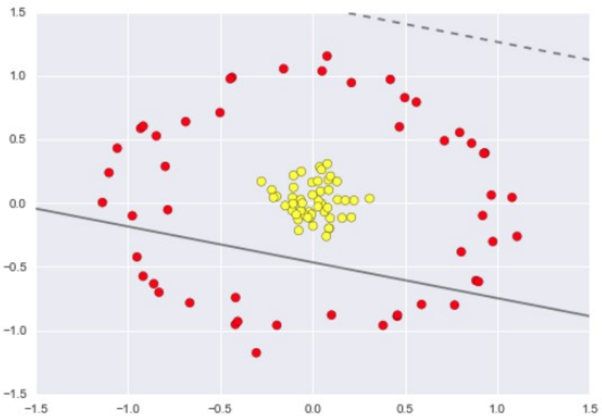
Python Data Science Handbook by Jake VanderPlas, 2018

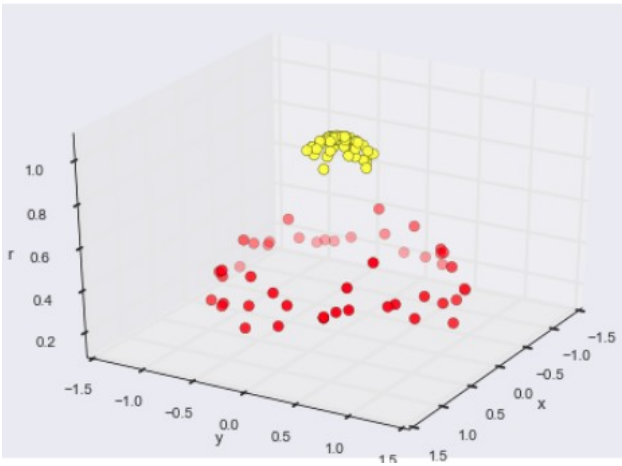


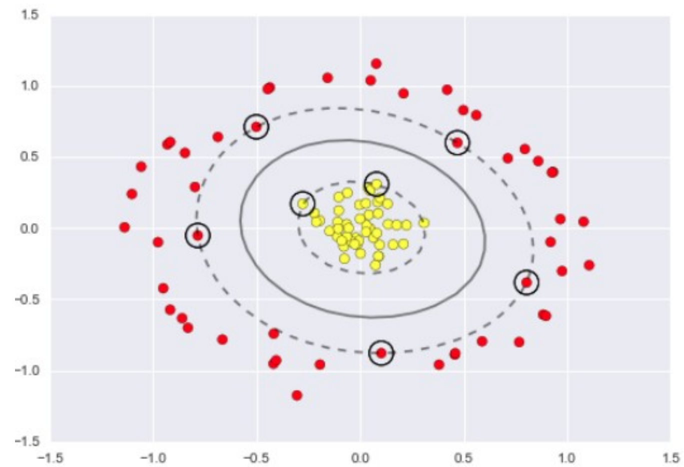
SVM Master

GitHub, Colab: [05.07-Support-Vector-Machines.ipynb]

Python Data Science Handbook by Jake VanderPlas, 2018





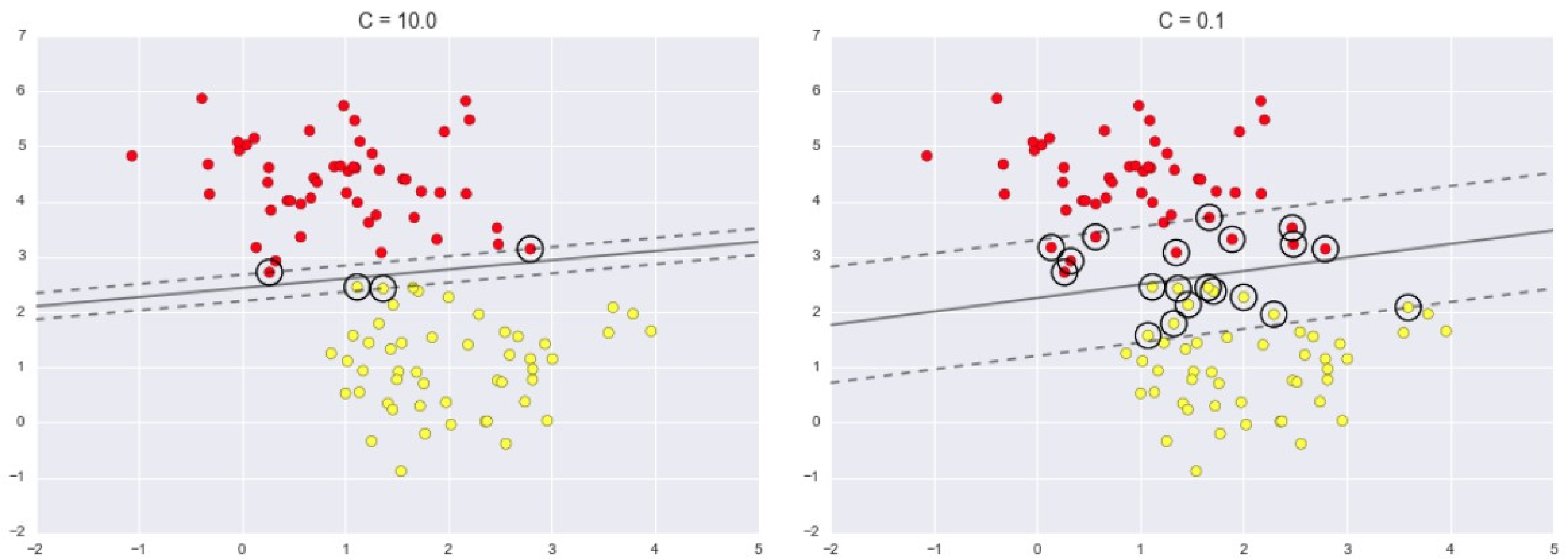


SVM Master

GitHub, Colab: [05.07-Support-Vector-Machines.ipynb]

Python Data Science Handbook by Jake VanderPlas, 2018

Softening Margins: model = SVC(kernel='linear', C=C).fit(X, y)

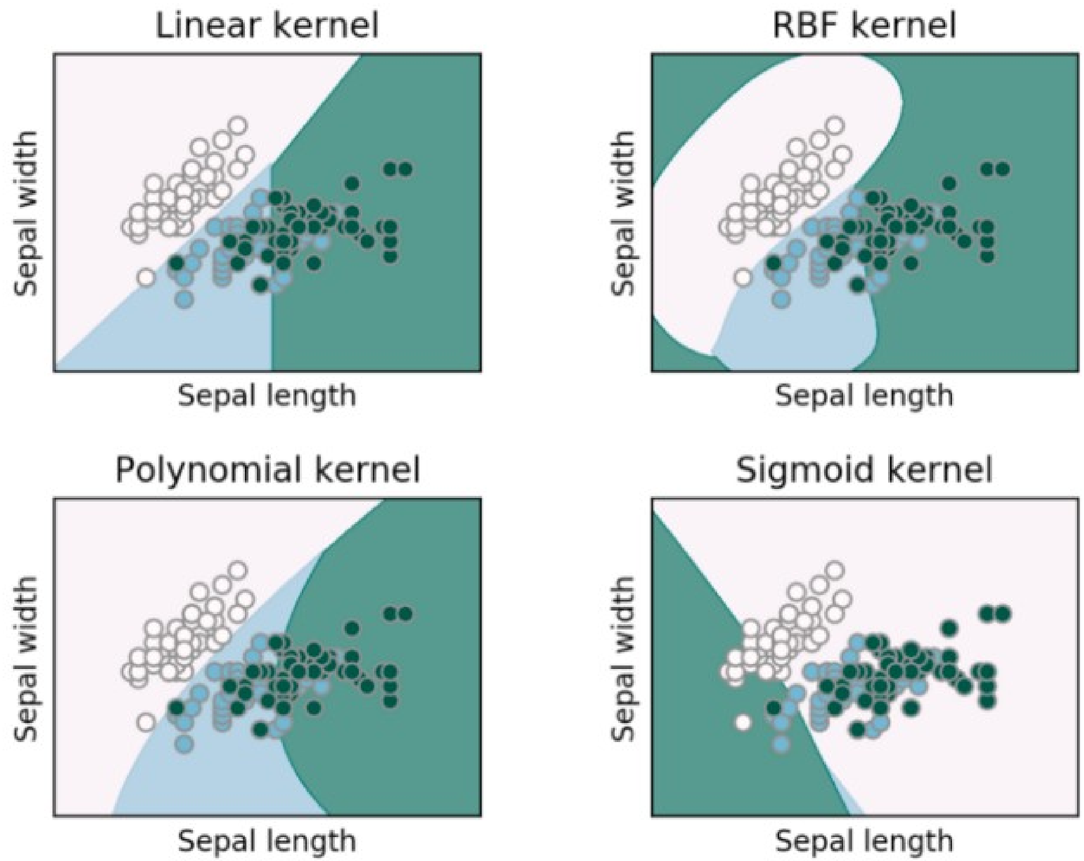


Multiclass SVM

[Multiclass Classification with Support Vector Machines (SVM), Dual Problem and Kernel Functions]

Towards data science, Hucker Marius. Jun. 8. 2020

linear = svm.SVC(kernel='linear', C=1, decision_function_shape='ovo').fit(X_train, y_train)
rbf = svm.SVC(kernel='rbf', gamma=1, C=1, decision_function_shape='ovo').fit(X_train, y_train)
poly = svm.SVC(kernel='poly', degree=3, C=1, decision_function_shape='ovo').fit(X_train, y_train)
sig = svm.SVC(kernel='sigmoid', C=1, decision_function_shape='ovo').fit(X_train, y_train)



SVM – Kernel Trick

[What is the kernel trick? Why is it important?]

Medium.com, Grace Zhang, Nov 11, 2018

$$\phi(\mathbf{x}) = (x_1^2, x_1x_2, x_1x_3, x_2x_1, x_2^2, x_2x_3, x_3x_1, x_3x_2, x_3^2)^T$$
$$\phi(\mathbf{y}) = (y_1^2, y_1y_2, y_1y_3, y_2y_1, y_2^2, y_2y_3, y_3y_1, y_3y_2, y_3^2)^T$$

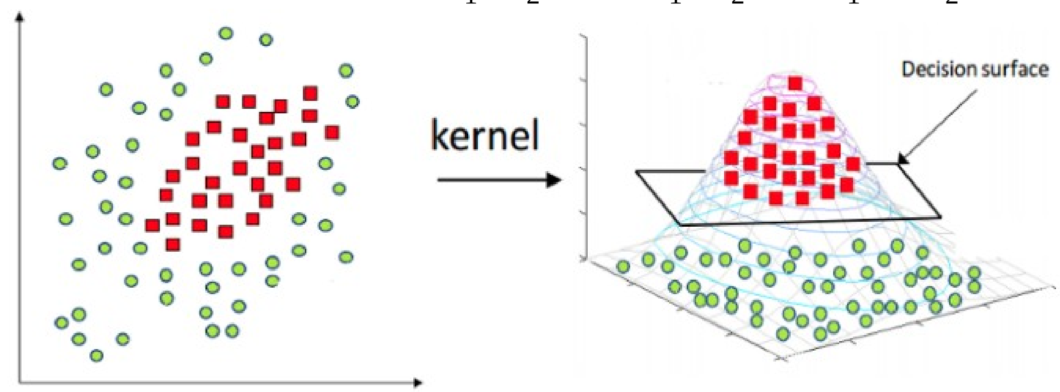
O(n²)

$$\phi(\mathbf{x})^T\phi(\mathbf{y}) = \sum_{i,j=1}^{3} x_ix_jy_iy_j$$

$(x_1, x_2) \rightarrow (x_1, x_2, \phi(x_1, x_2))$

e.g., $(x_1, x_2) \rightarrow (x_1, x_2, 1/(x_1^2 + x_2^2))$

$$\begin{aligned} k(\mathbf{x},\mathbf{y}) &= (\mathbf{x}^T\mathbf{y})^2 \\ &= (x_1y_1 + x_2y_2 + x_3y_3)^2 \\ &= \sum_{i,j=1}^{3} x_ix_jy_iy_j \end{aligned}$$



O(n).

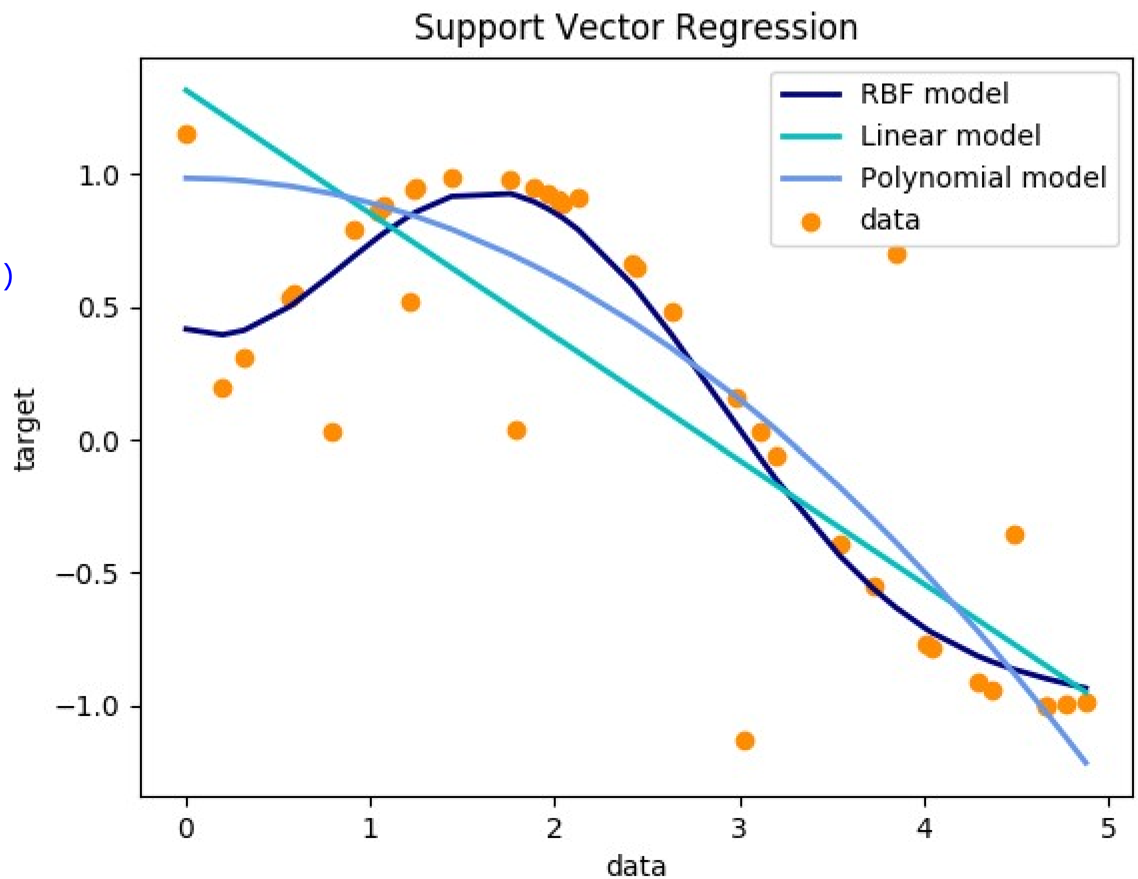
SVR – Support Vector Regression

[Support Vector Regression (SVR) using linear and non-linear kernels]

Scikit-learn v0.20.20

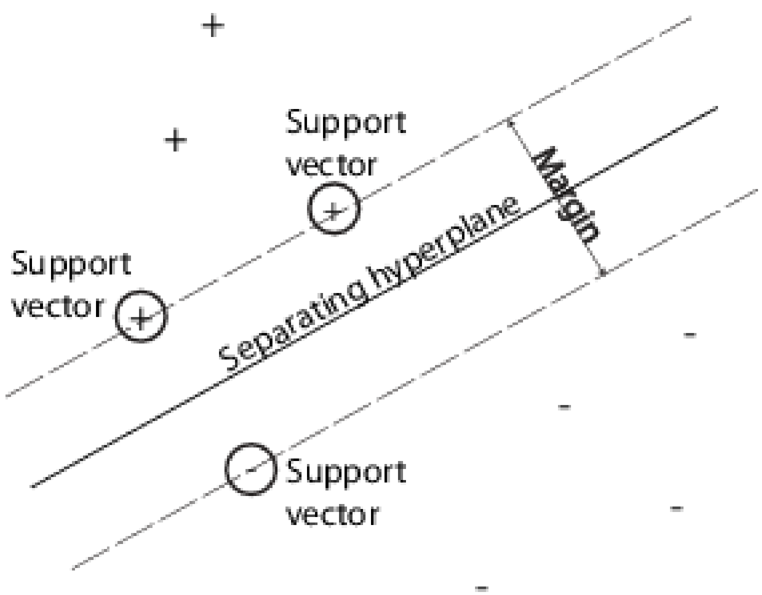
```
svr_rbf = SVR(kernel='rbf', C=1e3, gamma=0.1)
svr_lin = SVR(kernel='linear', C=1e3)
svr_poly = SVR(kernel='poly', C=1e3, degree=2)

y_rbf = svr_rbf.fit(X, y).predict(X)
y_lin = svr_lin.fit(X, y).predict(X)
y_poly = svr_poly.fit(X, y).predict(X)
```



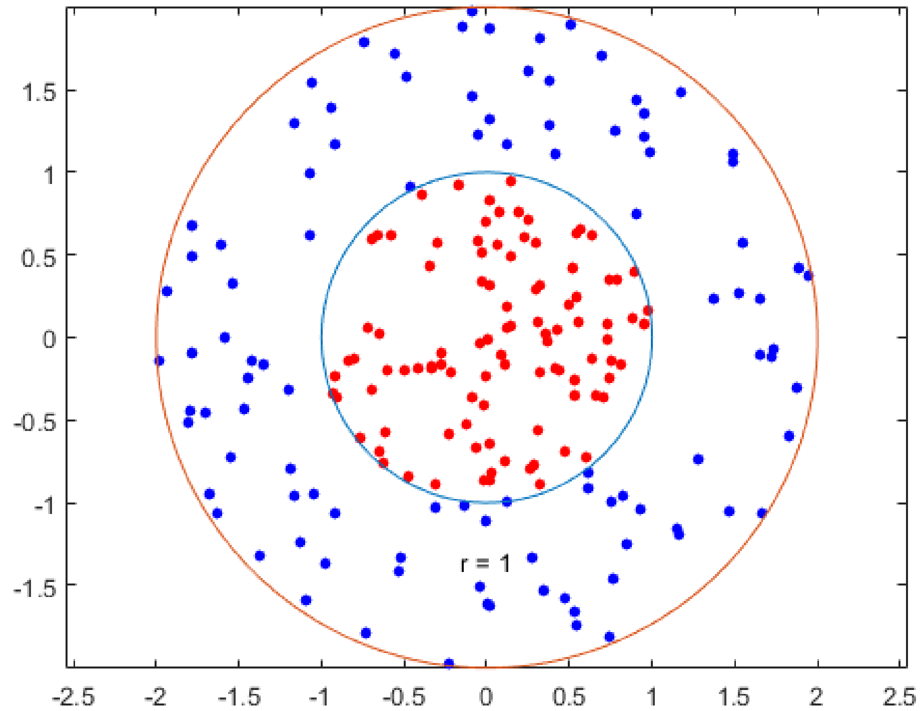
SVM – Support Vector Machine

Linear Separable Classes



Optimality –
Maximum margin to the Separating Hyperplane

Non Linear Separable Classes

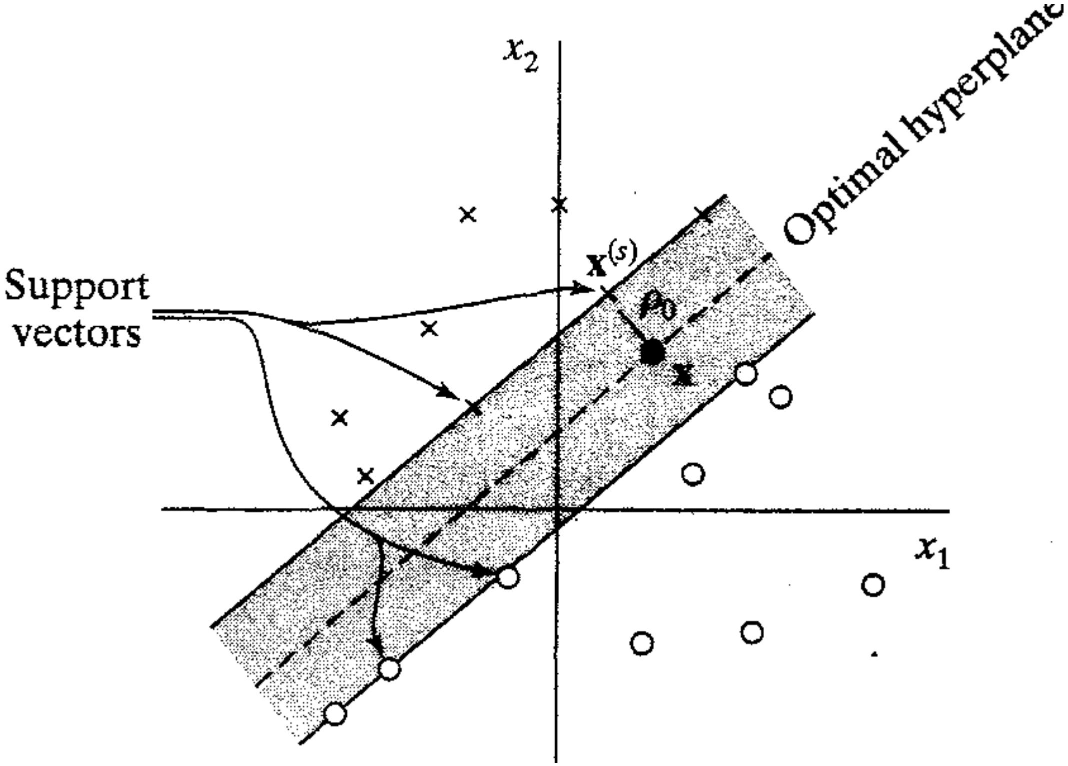


Features transformation –
Linear in the output space!

K(x,y) = <φ(x),φ(y)>

SVM – Support Vector Machine

Linear Separable Classes



Classes

$$\mathbf{w}^T\mathbf{x}_i + b \geq 0 \qquad \text{for } d_i = +1$$

$$\mathbf{w}^T\mathbf{x}_i + b < 0 \qquad \text{for } d_i = -1$$

Optimal hyperplane

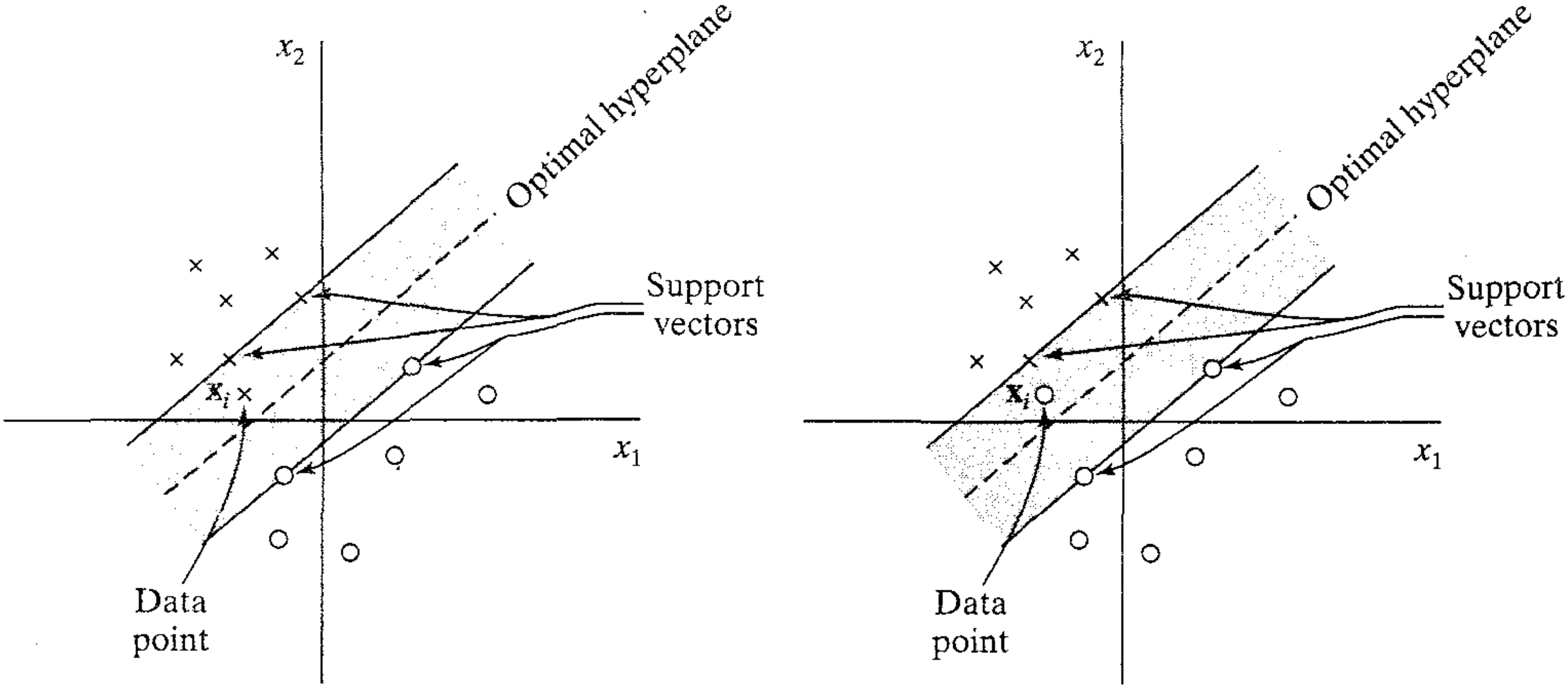
$$\mathbf{w}_o^T\mathbf{x} + b_o = 0$$

Distance to the optimal hyperplane

$$g(\mathbf{x}) = \mathbf{w}_o^T\mathbf{x} + b_o$$

Optimality –
Maximum margin to the Separating Hyperplane

SVM for non separable patterns



SVM for pattern recognition – feature space

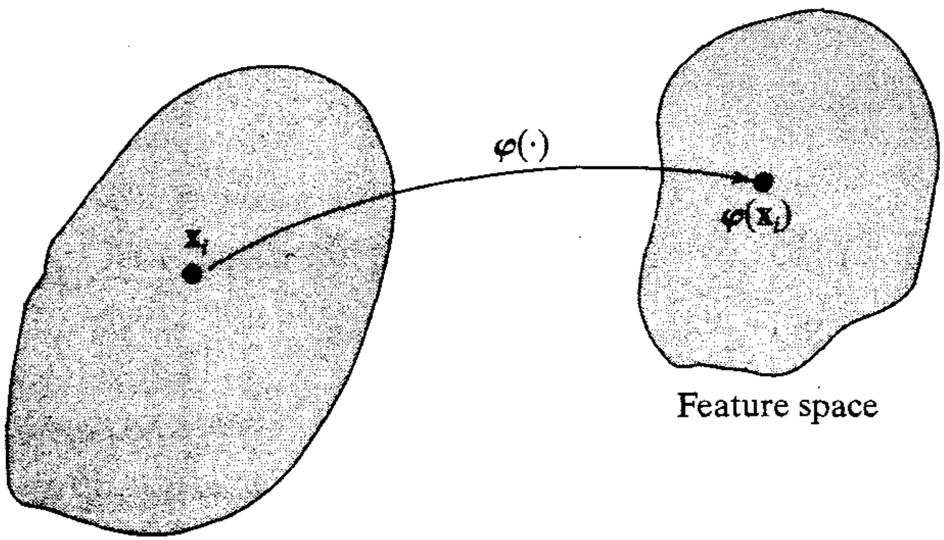
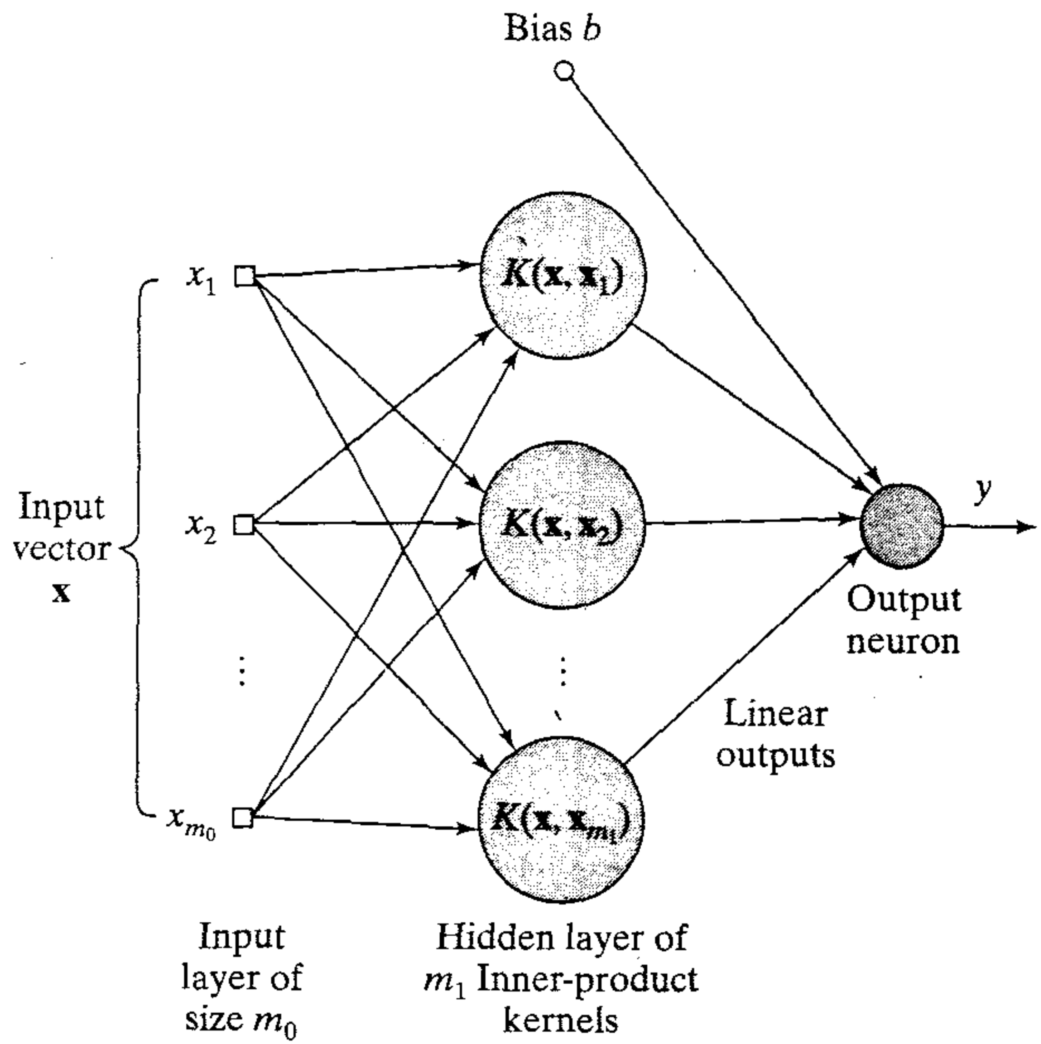


TABLE 6.1 Summary of Inner-Product Kernels

Type of support vector machine	Inner product kernel $K(\mathbf{x}, \mathbf{x}_i)$, $i = 1, 2, \ldots, N$
Polynomial learning machine	$(\mathbf{x}^T\mathbf{x}_i + 1)^p$
Radial-basis function network	$\exp\left(-\frac{1}{2\sigma^2}\|\mathbf{x} - \mathbf{x}_i\|^2\right)$
Two-layer perceptron	$\tanh(\beta_0\mathbf{x}^T\mathbf{x}_i + \beta_1)$

Architecture of a SVM



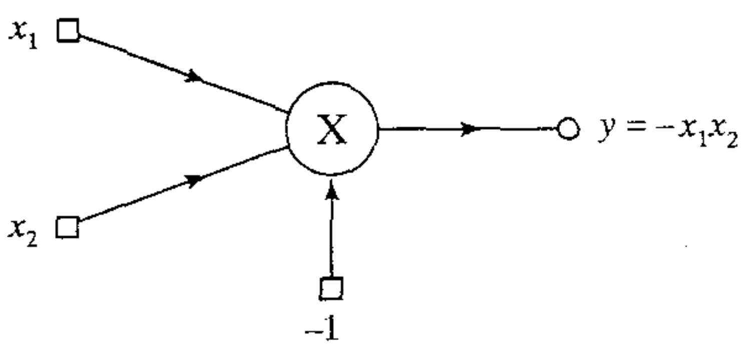
X-Or using SVM

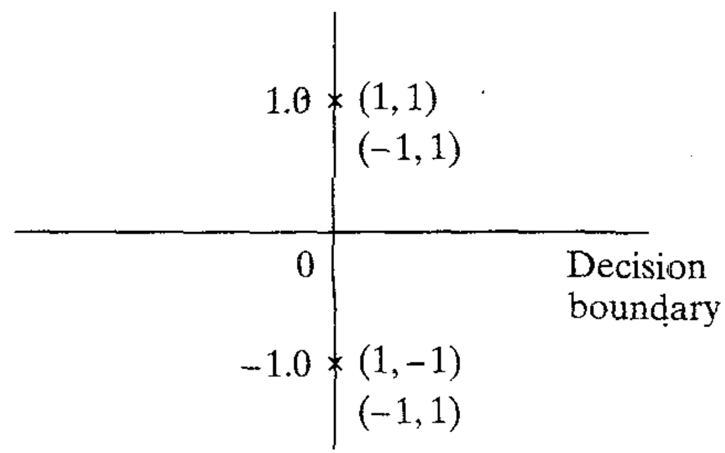
TABLE 6.2 XOR Problem	
Input vector, $\mathbf{x}$	Desired response, d
$(-1,-1)$	-1
$(-1,+1)$	$+1$
$(+1,-1)$	$+1$
$(+1,+1)$	-1

$$K(\mathbf{x}, \mathbf{x}_i) = (1 + \mathbf{x}^T\mathbf{x}_i)^2$$

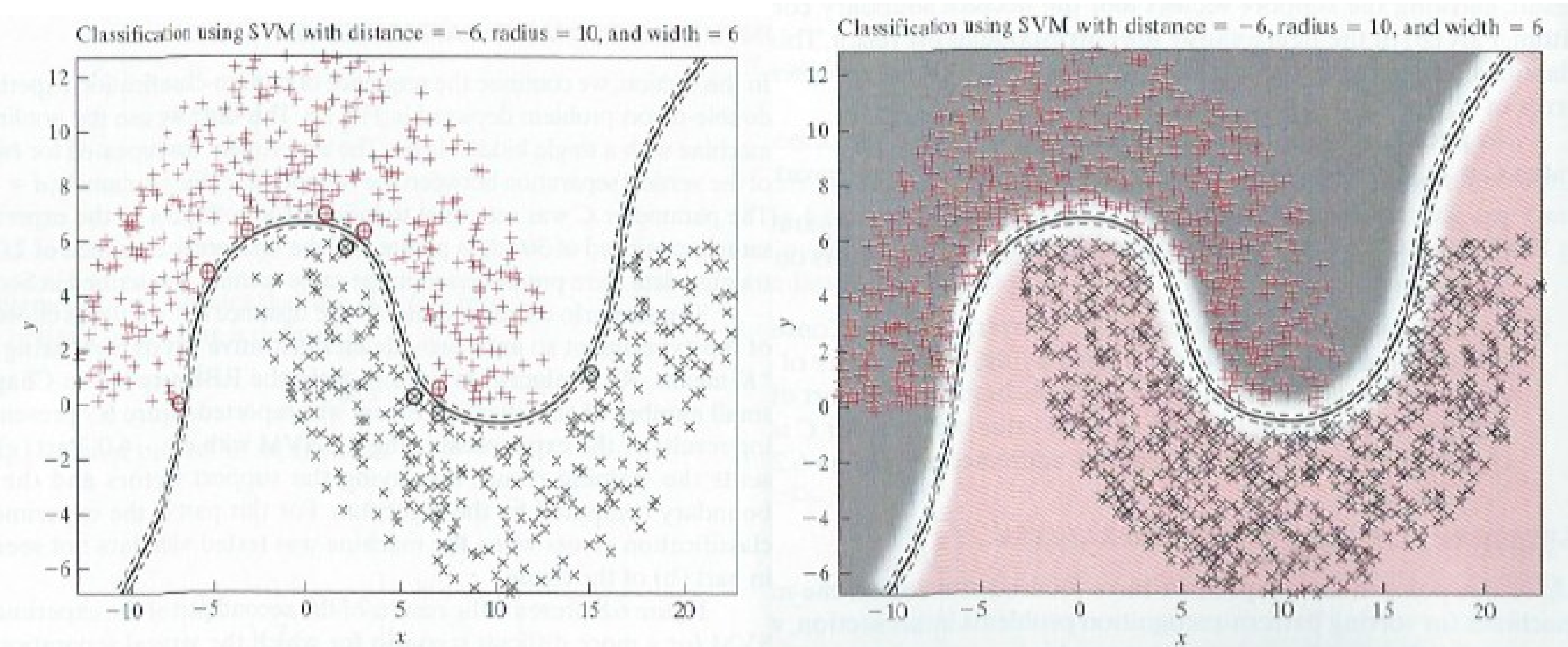
$$K(\mathbf{x}, \mathbf{x}_i) = 1 + x_1^2x_{i1}^2 + 2x_1x_2x_{i1}x_{i2} + x_2^2x_{i2}^2 + 2x_1x_{i1} + 2x_2x_{i2}$$

$$\boldsymbol{\varphi}(\mathbf{x}) = \left[1, x_1^2, \sqrt{2}x_1x_2, x_2^2, \sqrt{2}x_1, \sqrt{2}x_2\right]^T$$



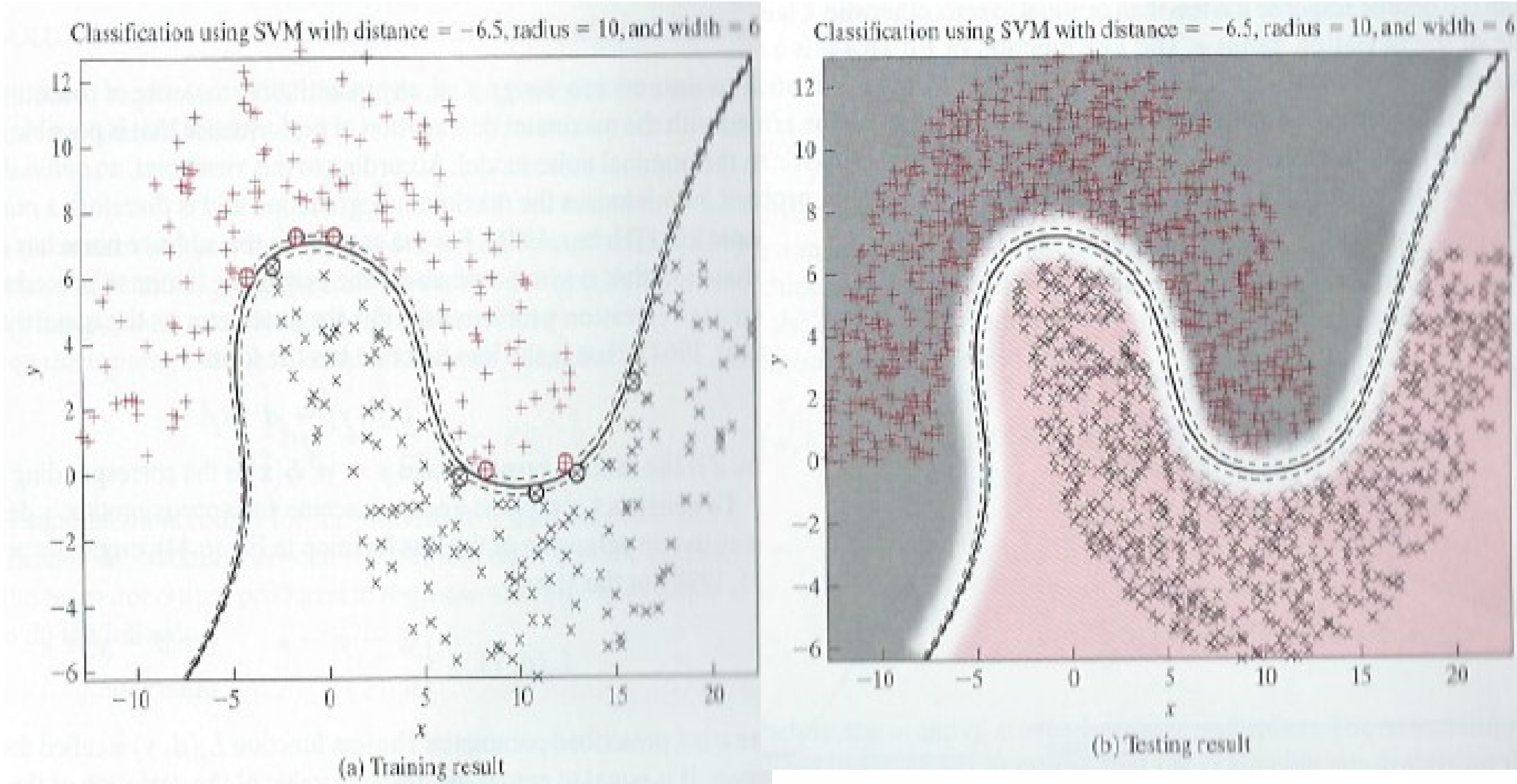


SVM ‘Double Moon’ classification



(a) Training result (b) Testing result

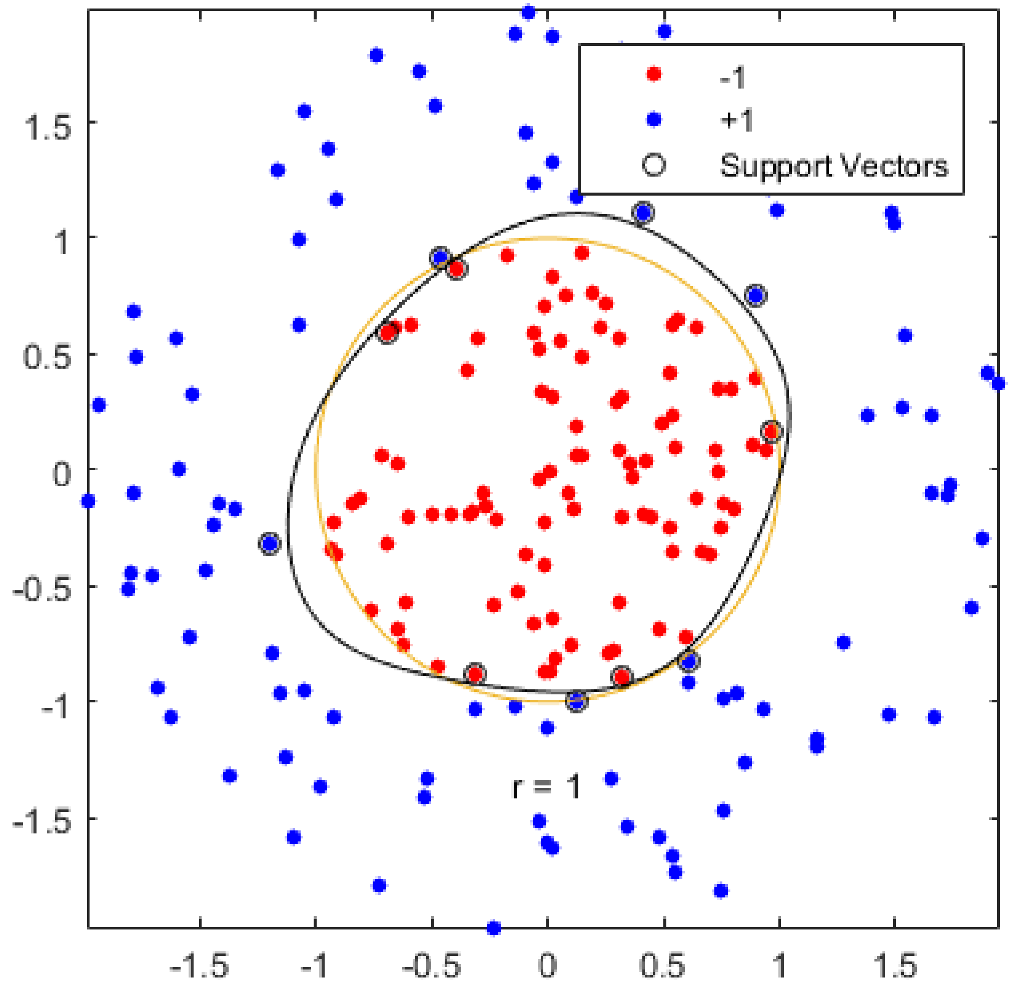
SVM ‘Double Moon’ classification



Train the SVM Classifier

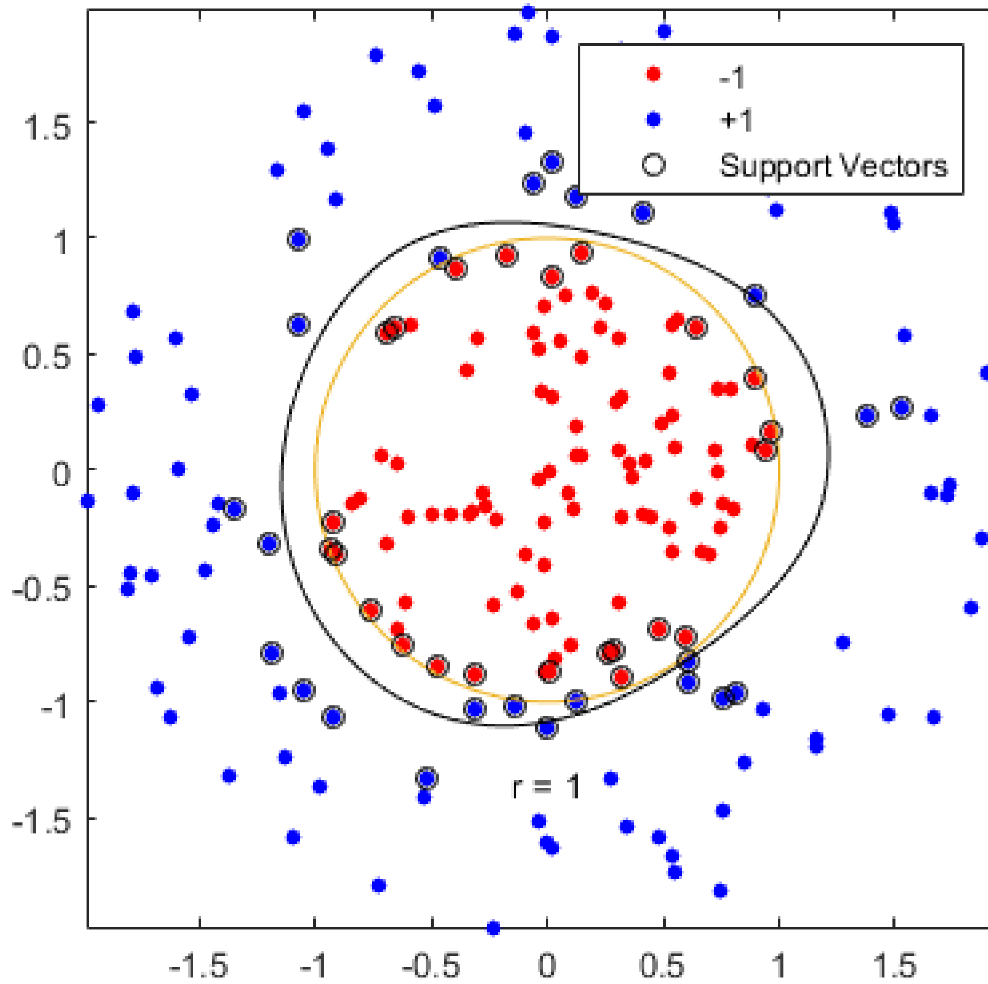
```
cl = fitcsvm(data3,theclass,'KernelFunction','rbf',...
   'BoxConstraint',Inf,'ClassNames',[-1,1]);
```

```
data3 = [data1;data2];
theclass = ones(200,1);
theclass(1:100) = -1;
```



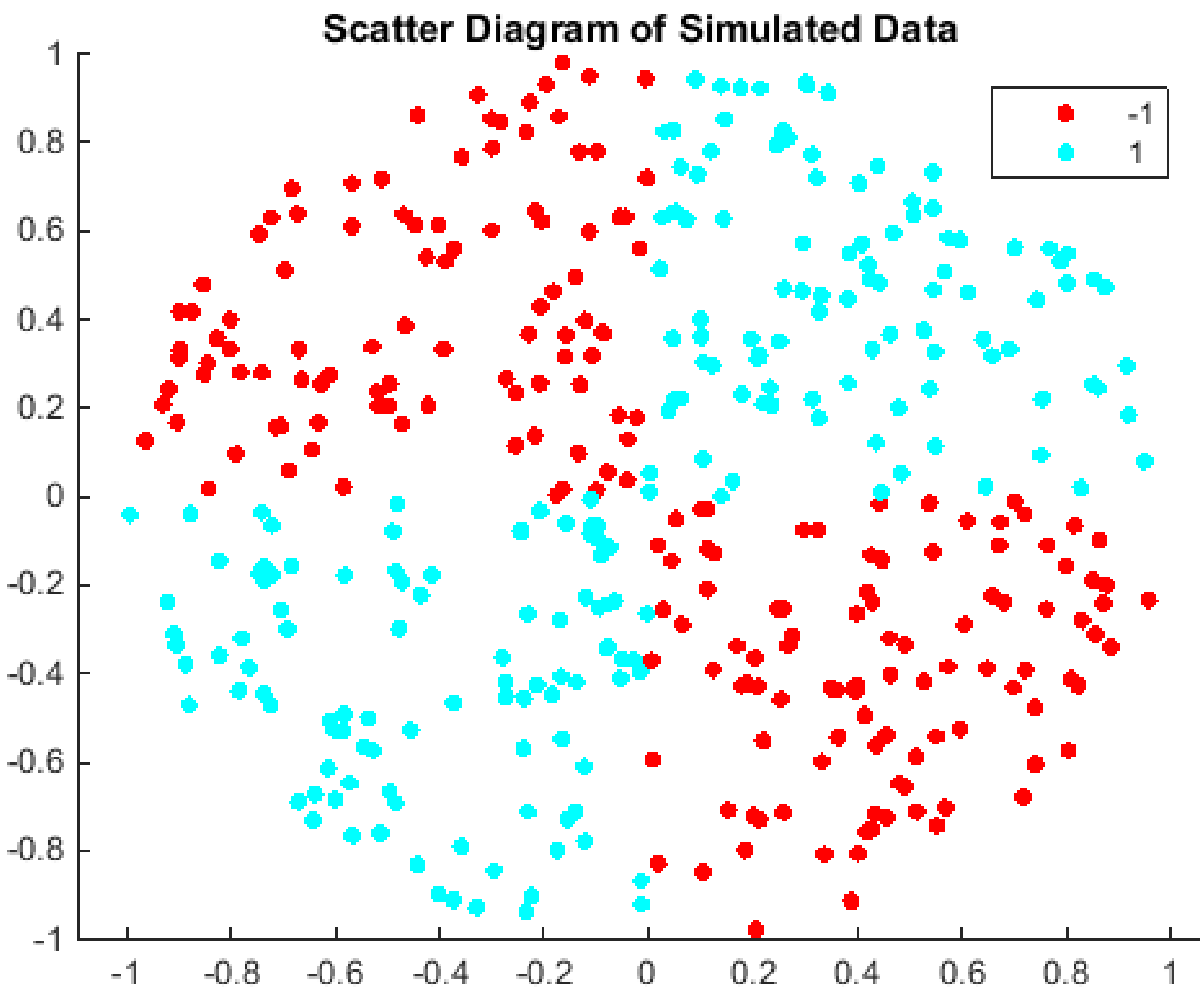
SVM

Training with the default parameters makes a more nearly circular classification boundary, but one that misclassifies some training data. Also, the default value of BoxConstraint is 1, and, therefore, there are more support vectors.

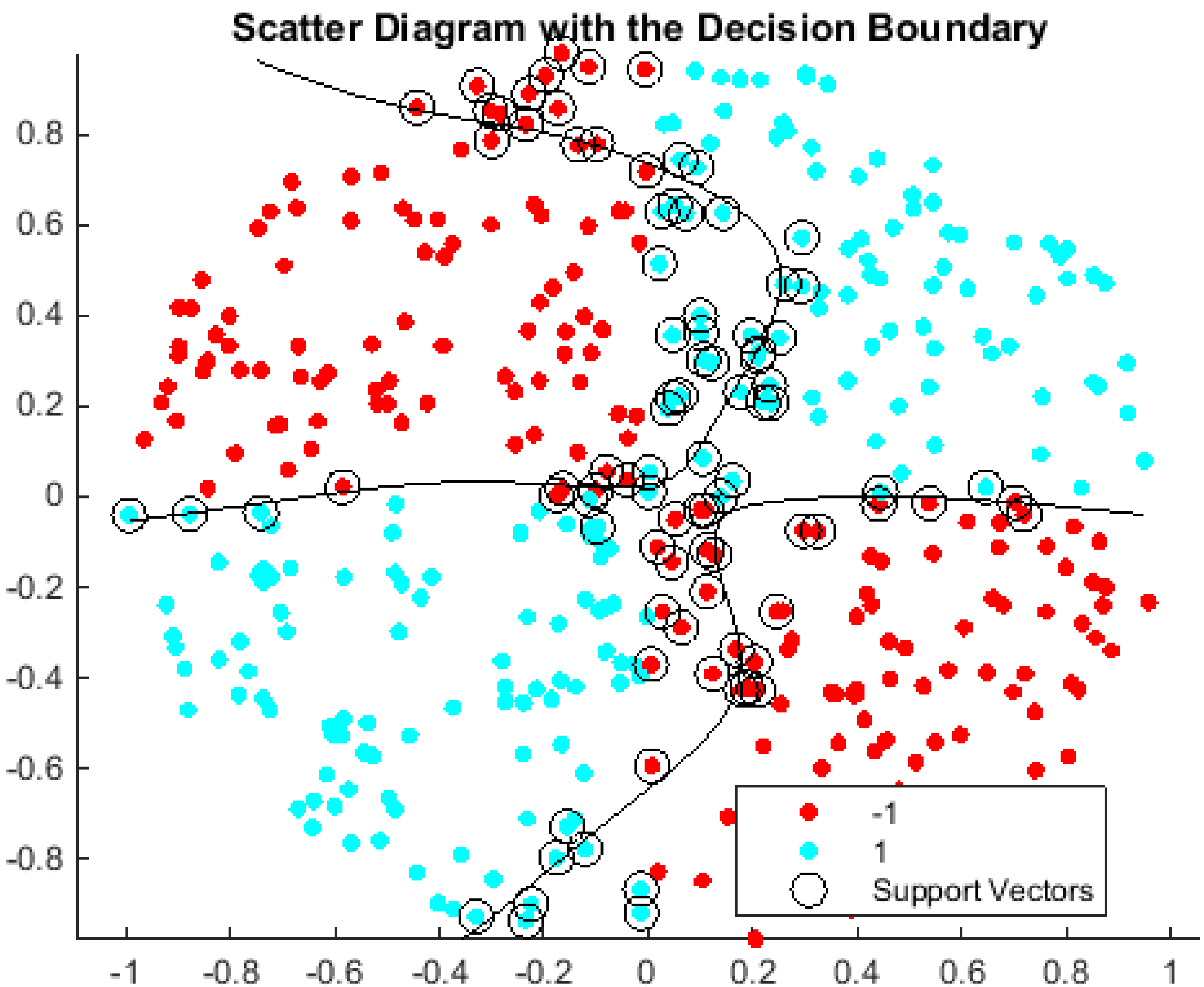


SVM

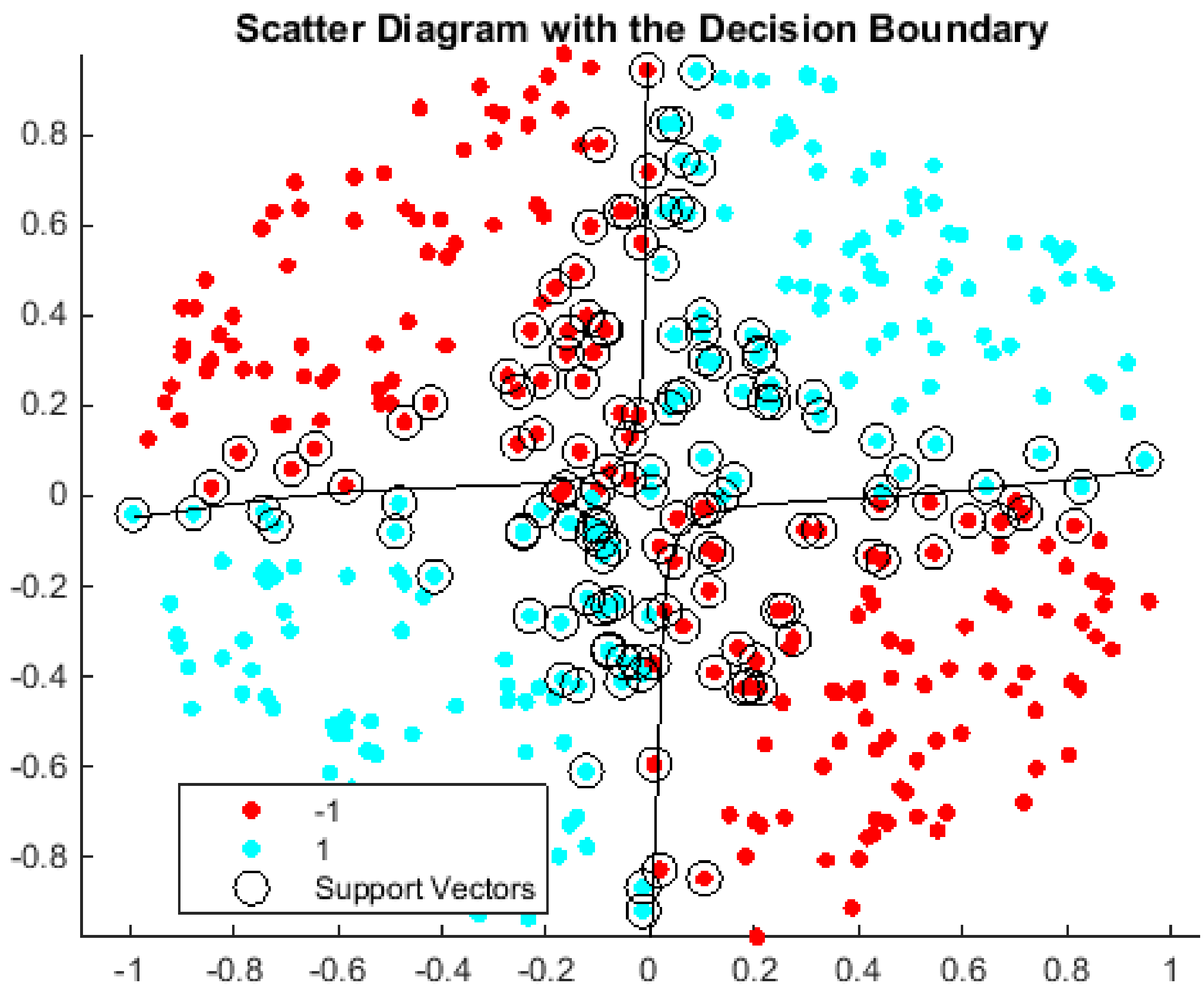
This example shows how to use a custom kernel function, such as the sigmoid kernel, to train SVM classifiers, and adjust custom kernel function parameters.



SVM

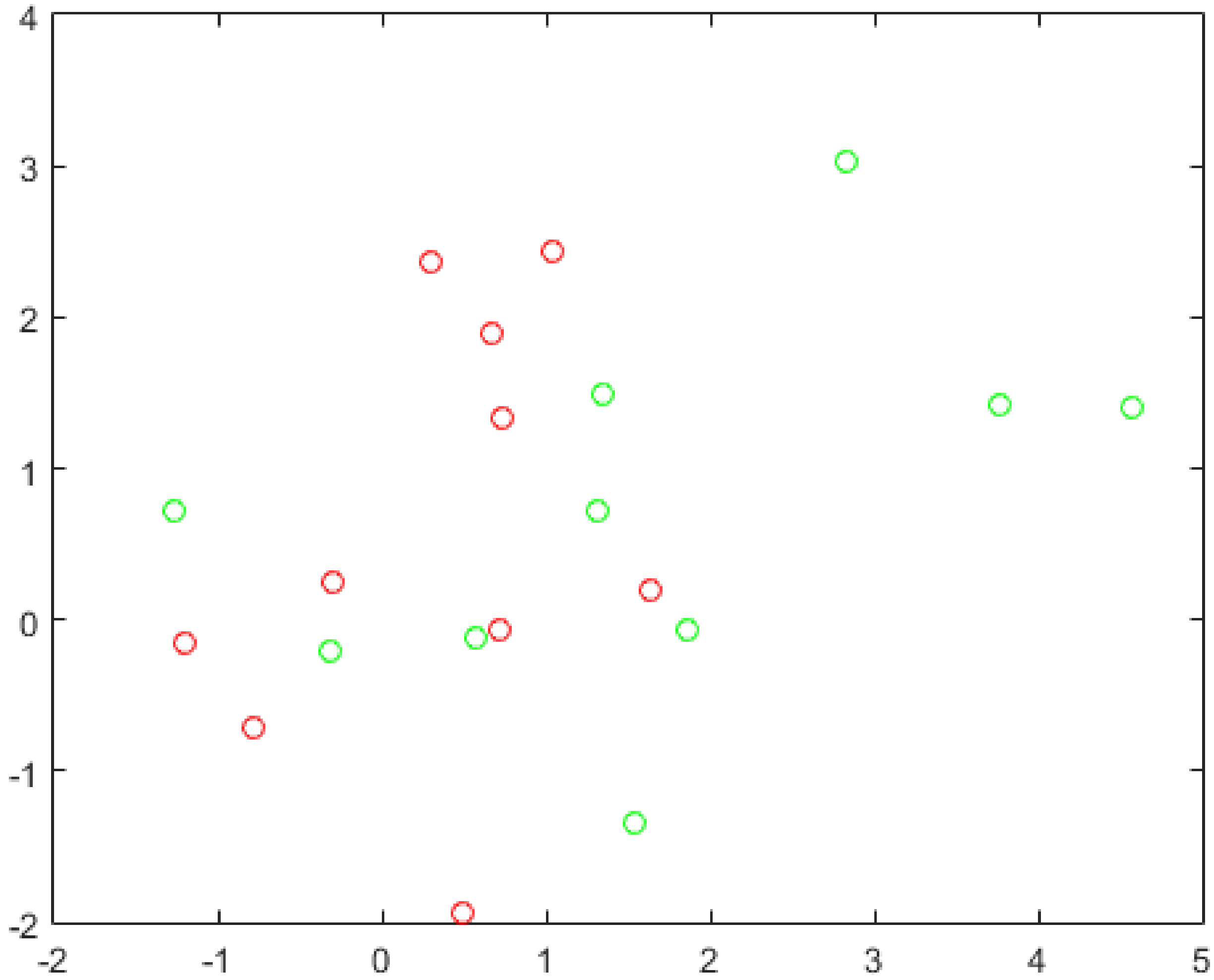

Scatter Diagram with the Decision Boundary
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
-1
1
Support Vectors

SVM

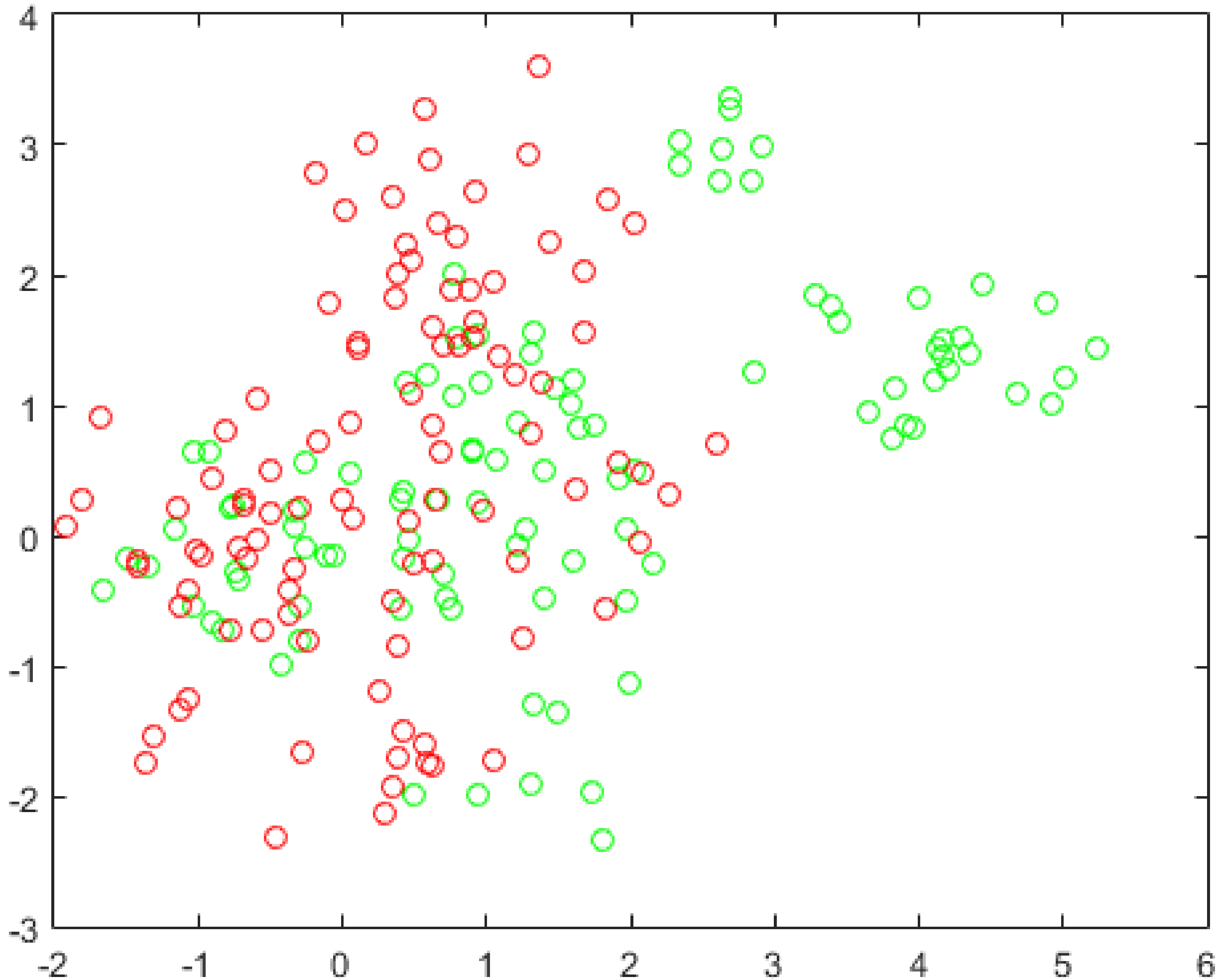


Scatter Diagram with the Decision Boundary
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
-1
1
Support Vectors

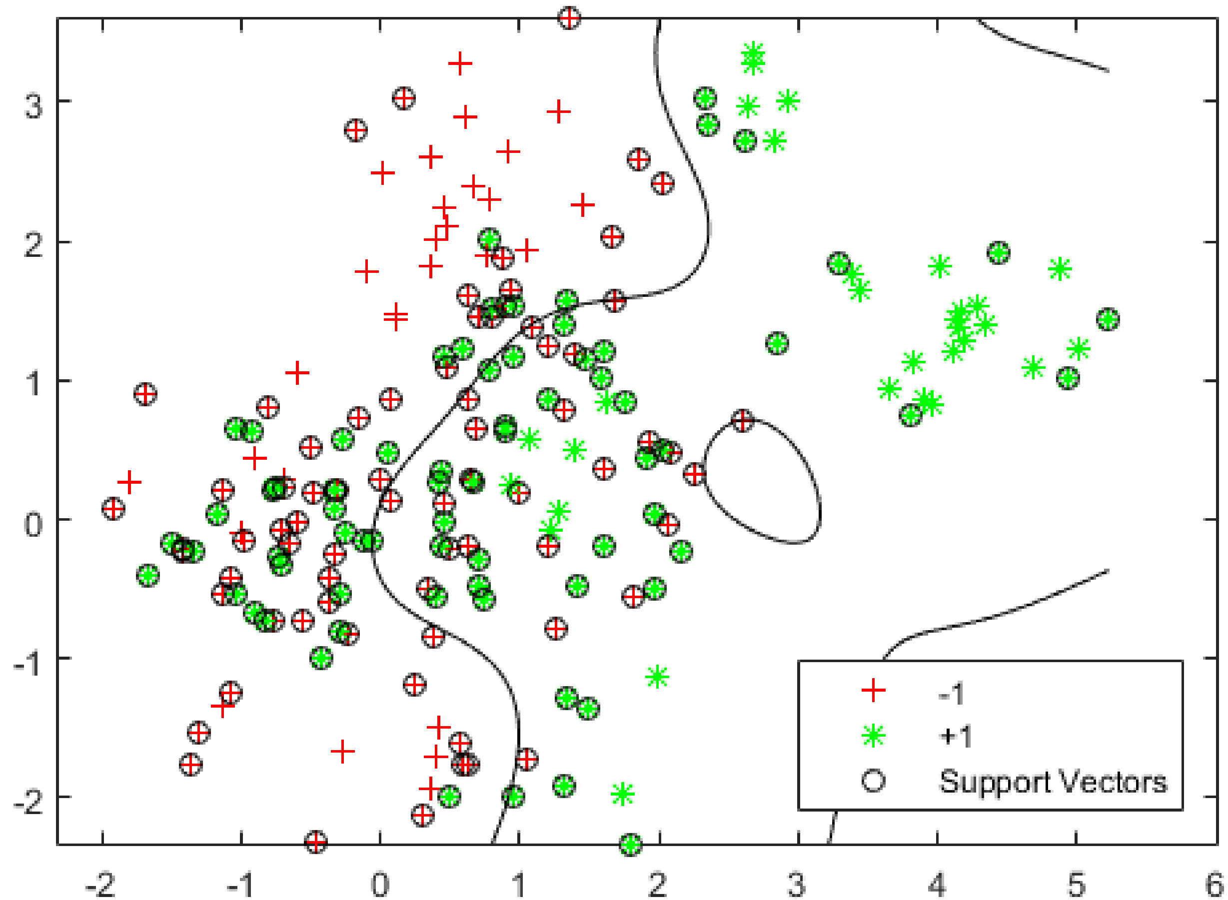
Train and Cross Validate SVM Classifiers



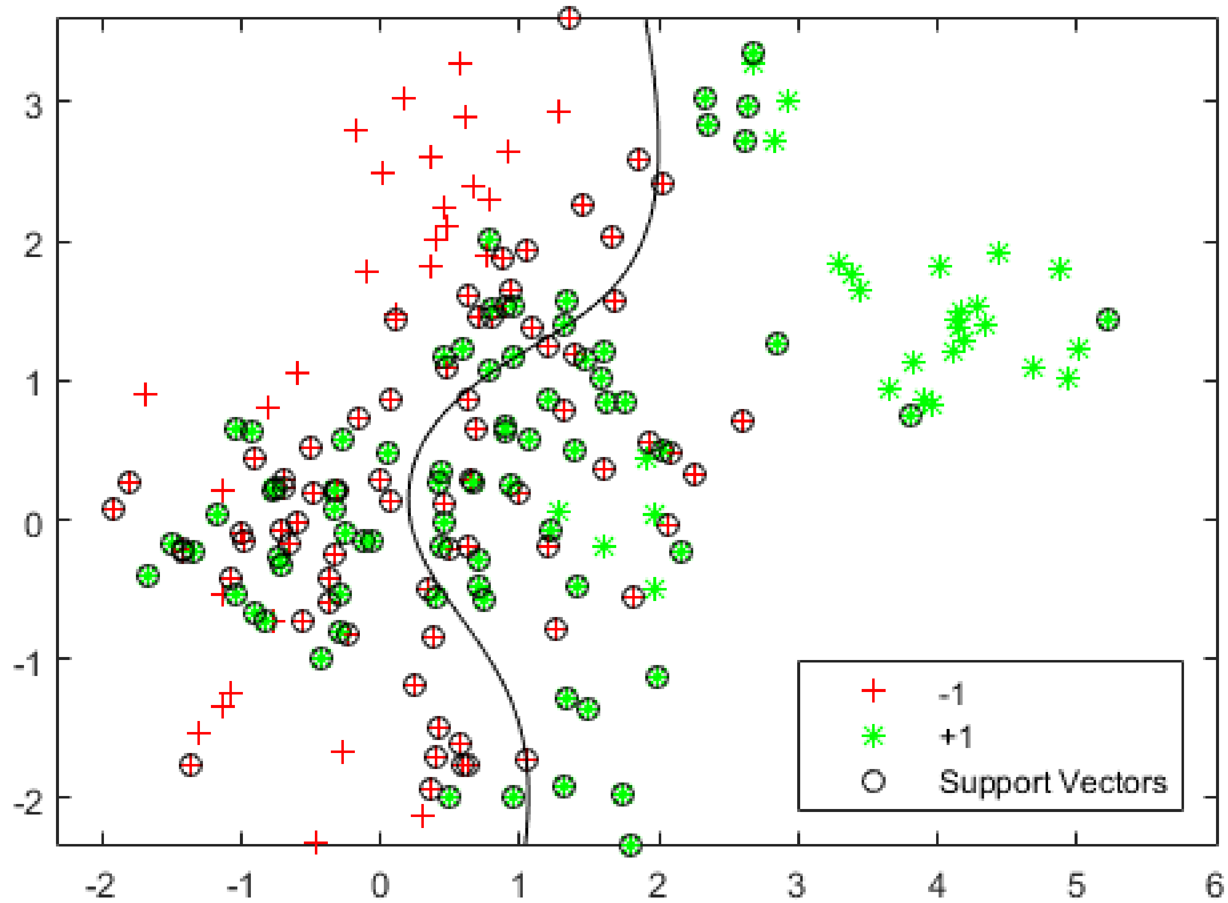
Train and Cross Validate SVM Classifiers



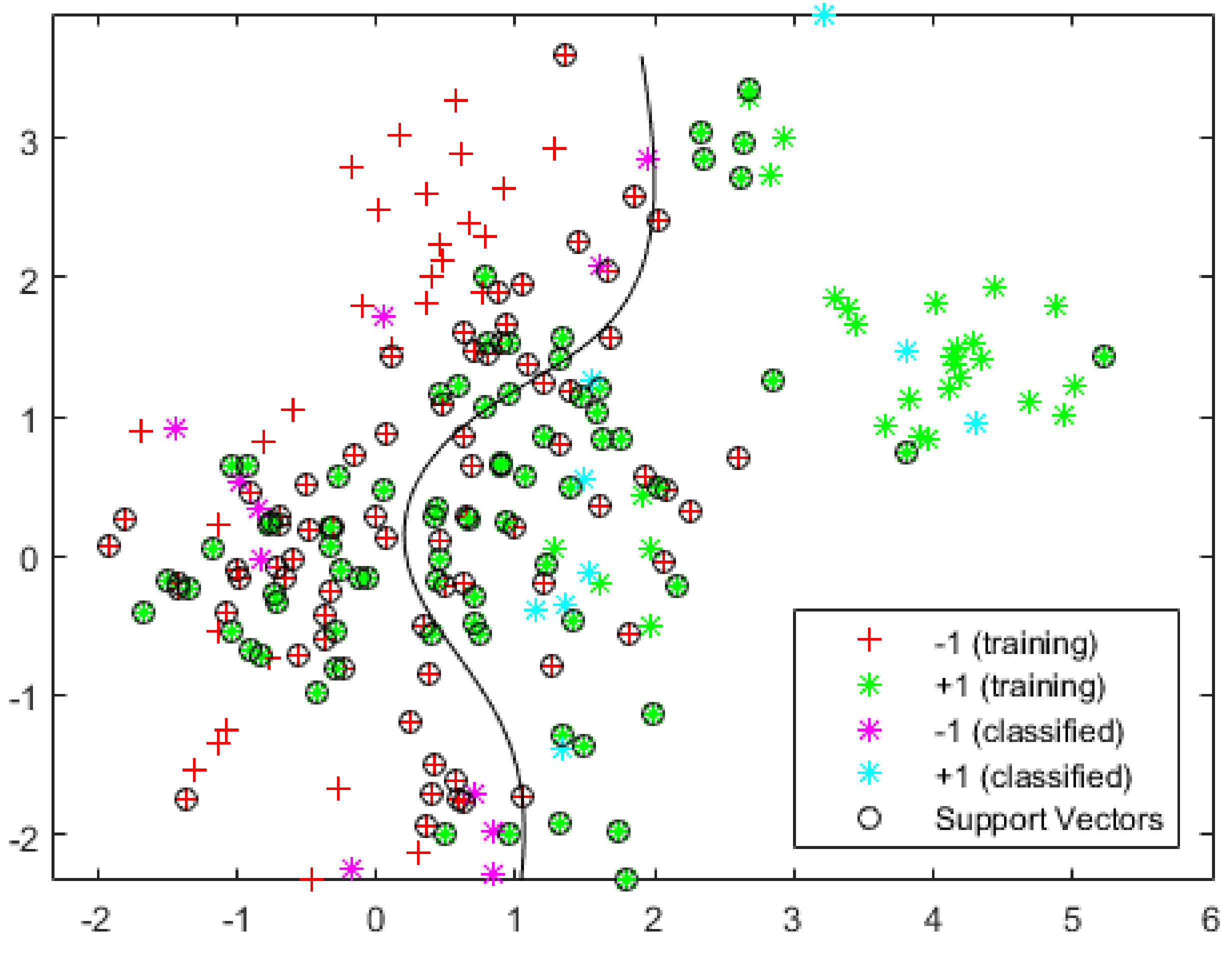
Train and Cross Validate SVM Classifiers



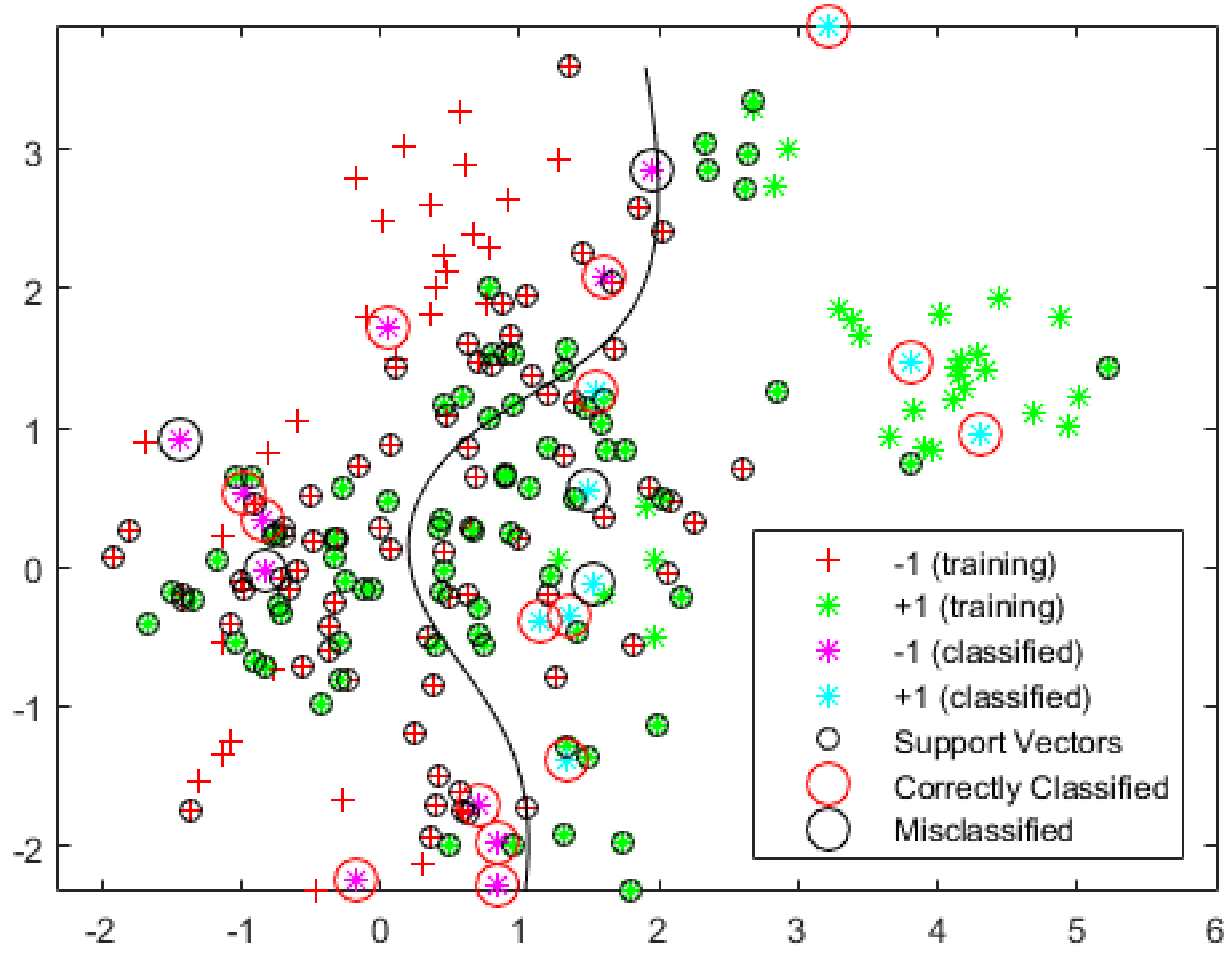
Train and Cross Validate SVM Classifiers



Train and Cross Validate SVM Classifiers



Train and Cross Validate SVM Classifiers



Indoor Localization

- **Indoor Localization**
- **Ambient Intelligence (Occupancy dependent services)**
- **Thermal Load Estimation**

Energy Efficiency

(mainly Air conditioning)

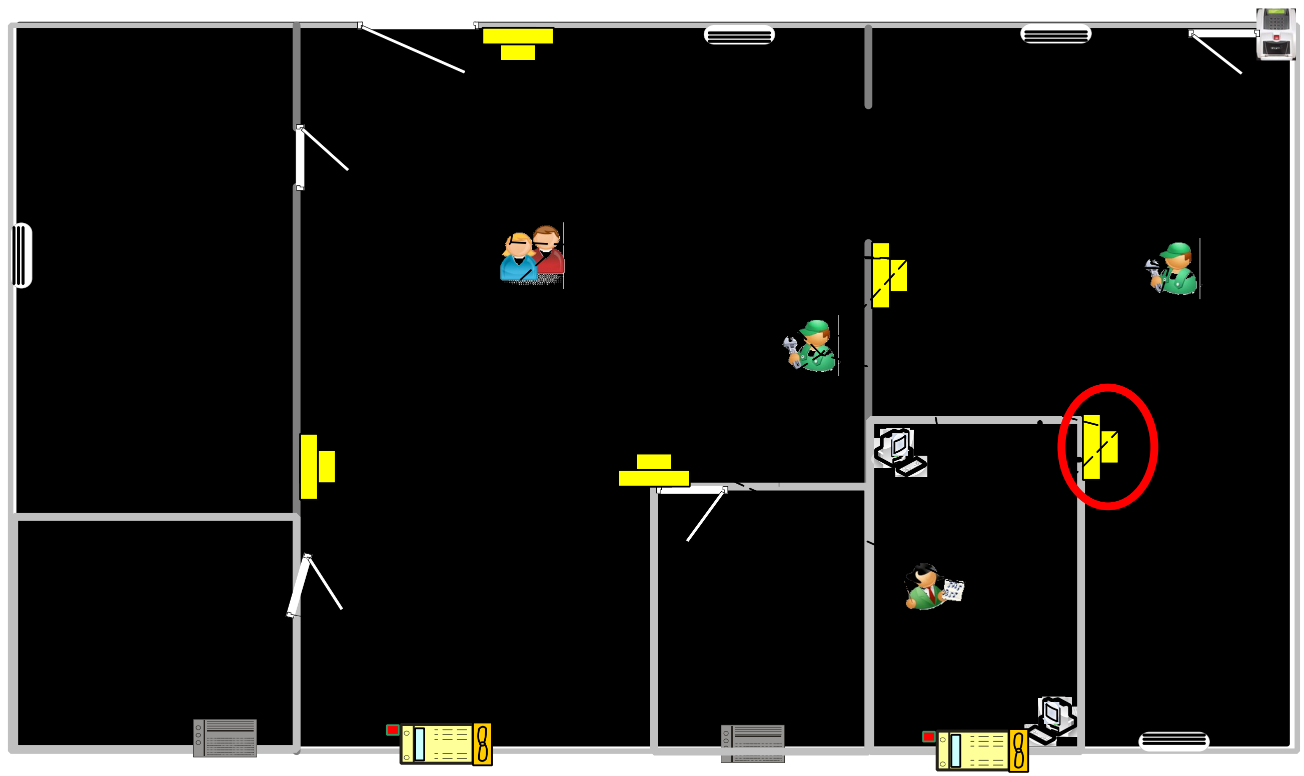
Credits:

Next slides are mainly based on:

- Lucas O. Fonseca, 2011, Sistema de Identificação de Usuários utilizando RFID para Racionalização de Energia em Ambientes Inteligentes.
- Gabriel Figueiró Oliveir e André Luiz Gama de Souza, 2011, Sistema de Localização para Robótica Móvel com RFID.
- Cristovam A. Silva Jr., 2012, Classificação de Ambientes Prediais para usuários utilizanod tags RFID ativas e Filtro de Kalman.

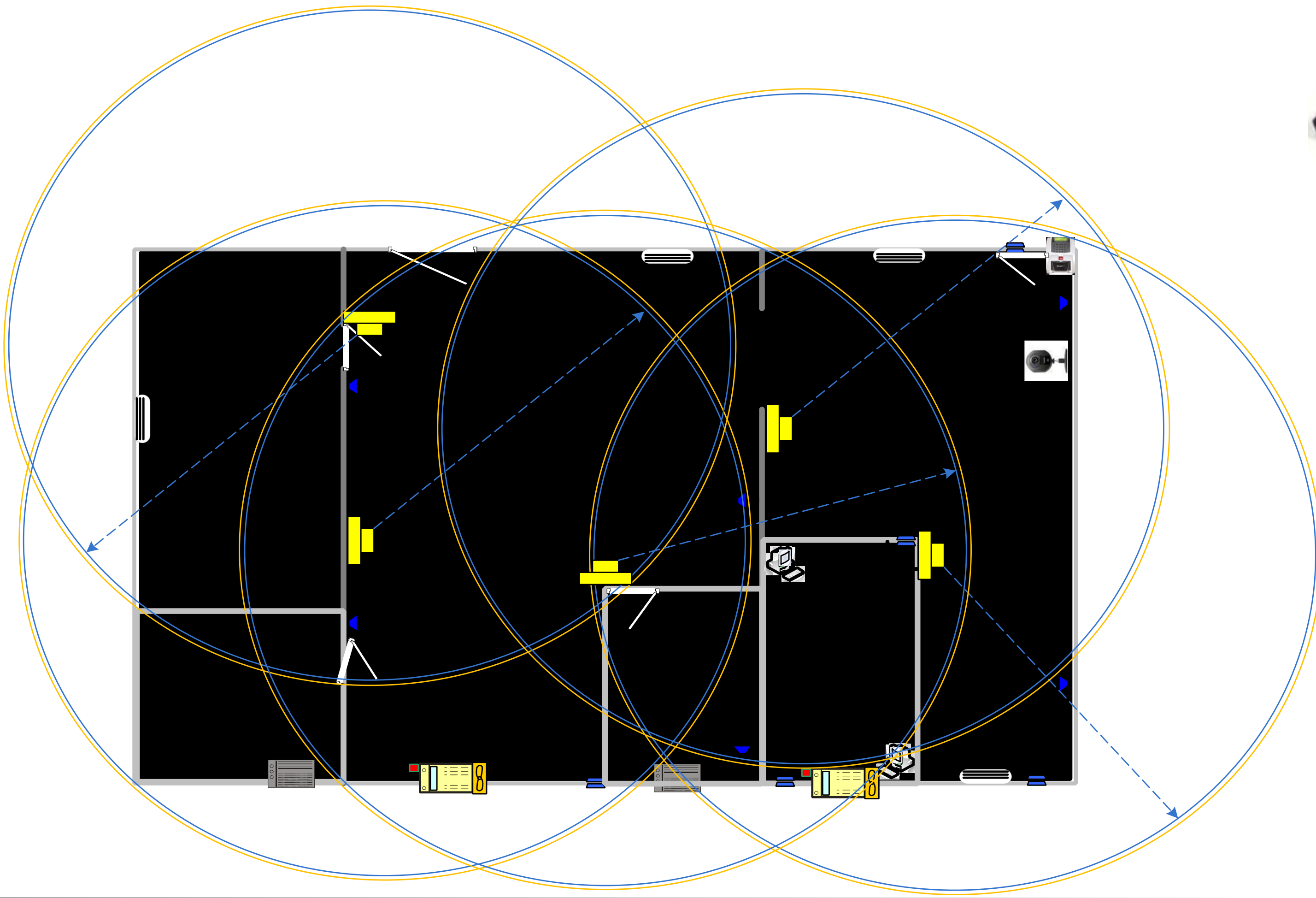
RFID occupancy identification

(GPS indoor) for thermal load estimation



RFID occupancy identification

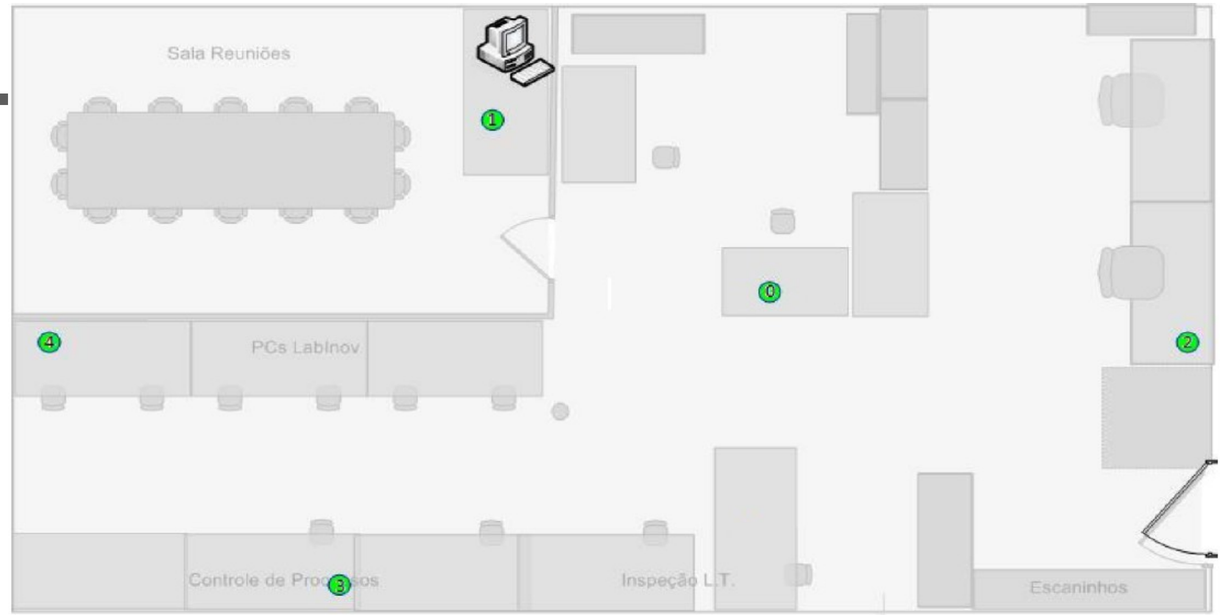
for thermal load estimation



RFID

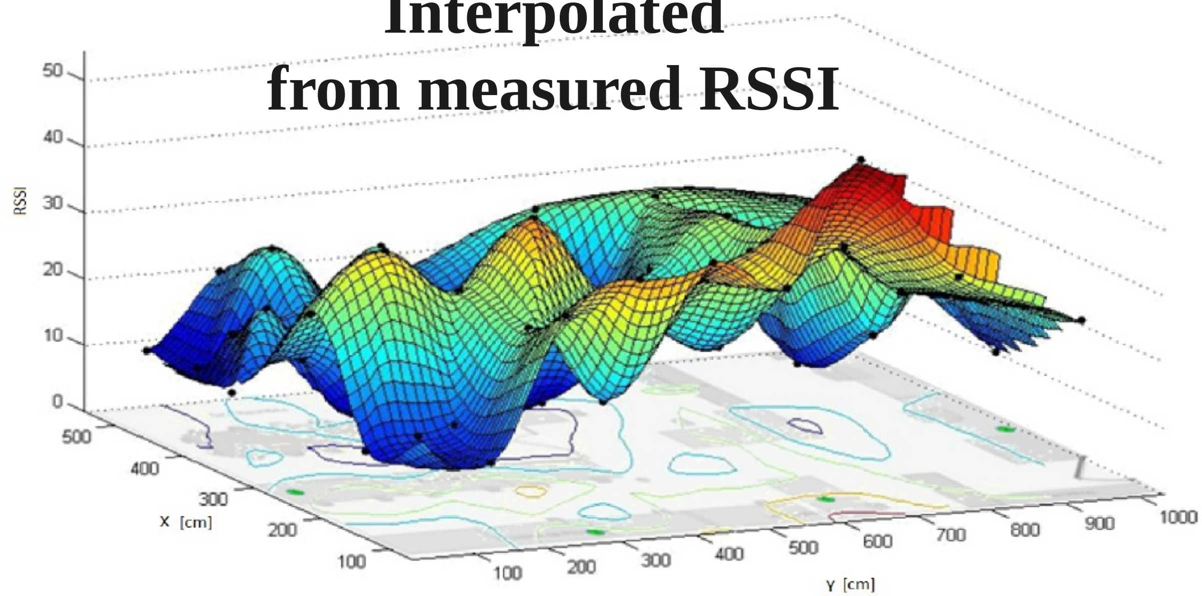
occupancy identification

for thermal load estimation



(Lucas Fonseca, 2011)

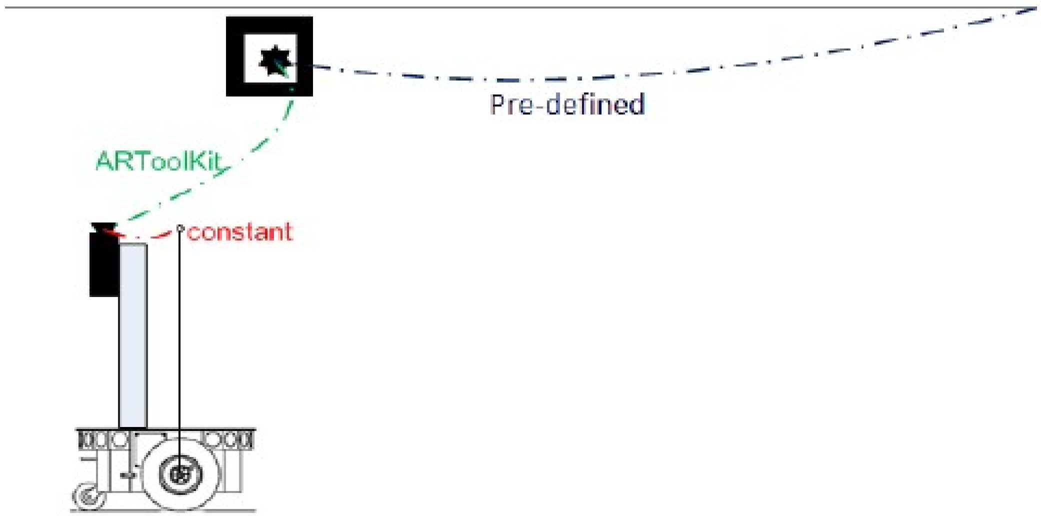
Interpolated from measured RSSI



Indoor RFID Localization

in the Context of Mobile Robotics with Application in Ambient Intelligence

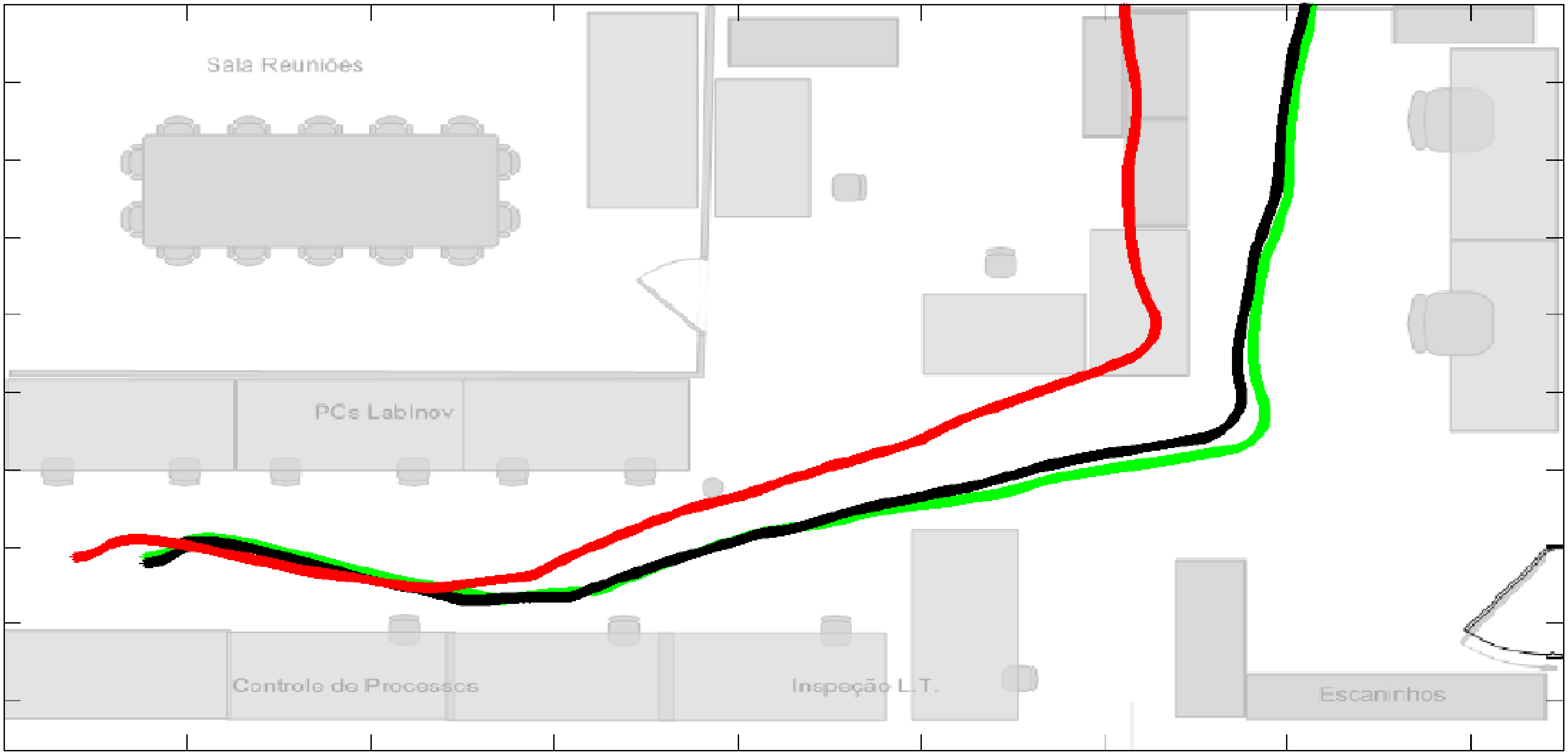
Augmented Reality Localization



(Gabriel Figueiró e André Luiz Gama, 2011)

Indoor Localization

(Gabriel Figueiró e André Luiz Gama, 2011)

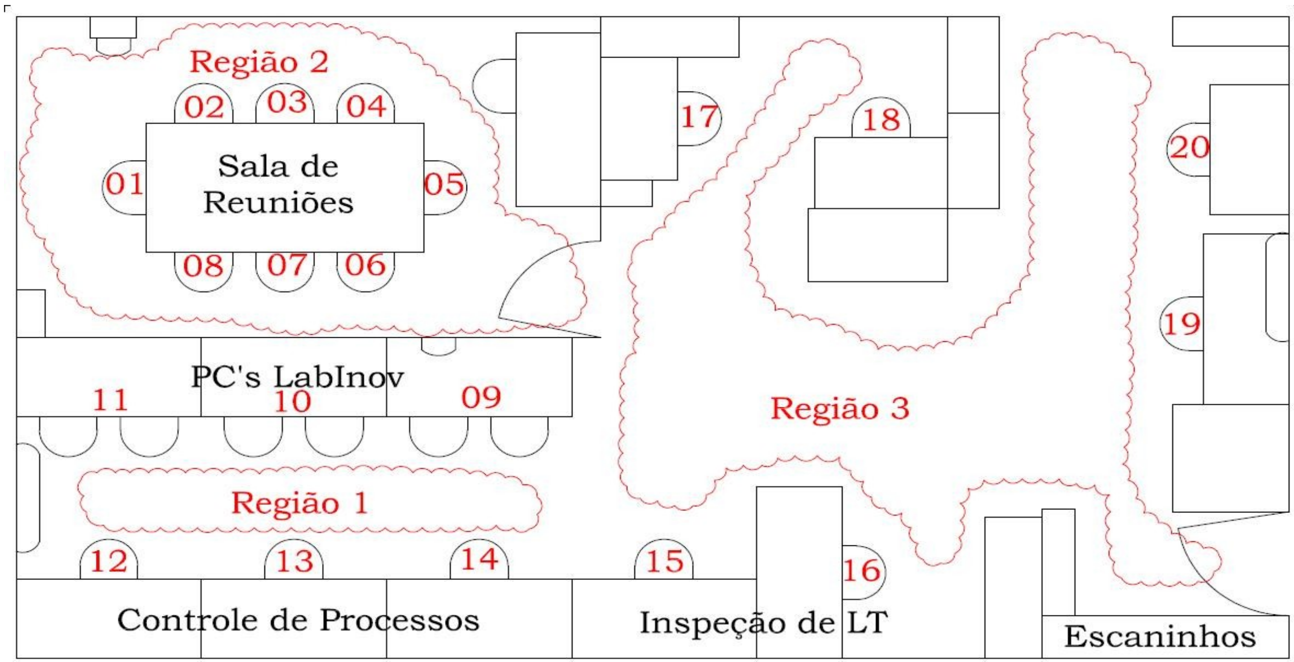


Red – odometry

Black – odometry + vision (augmented reality)

Green – odometry + vision + ANN RFID RSSI

Thermal Load Influence Areas



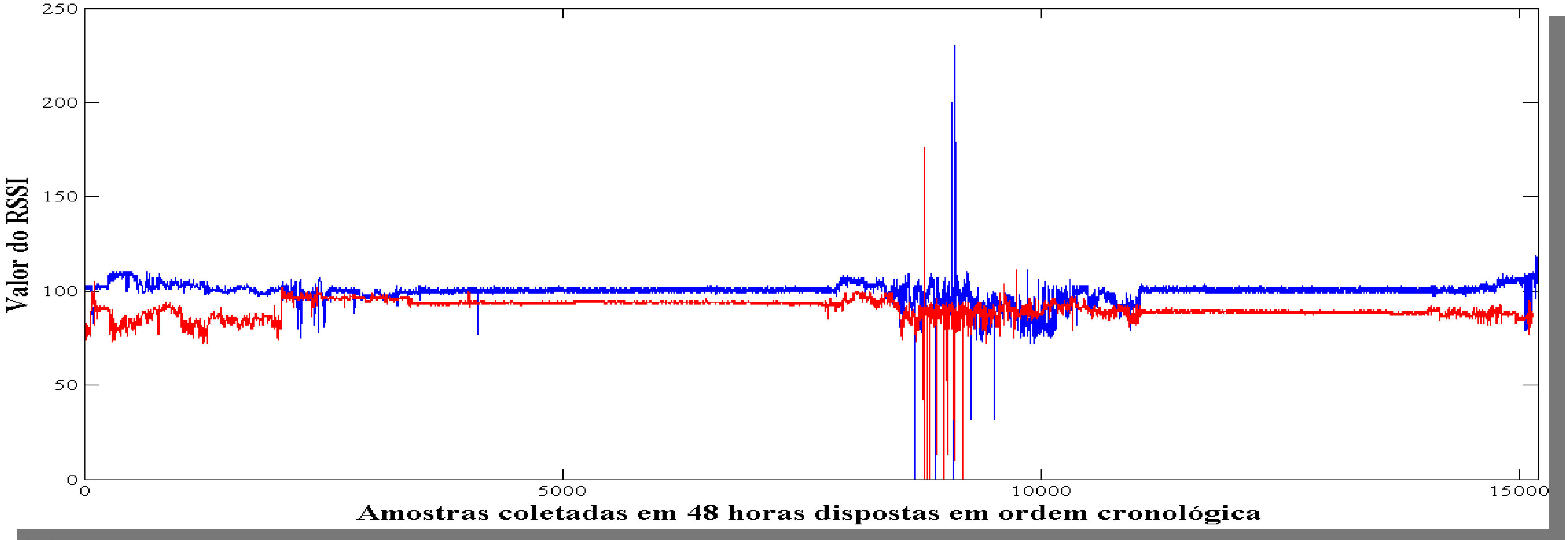
Identification of users in areas by RFID – RSSI classificators

(Cristovam Silva Jr., 2012)

Sistemas de Localização Indoor

RSSI – Received Signal Strength Indicator

- valor adimensional
- influenciado pelo efeito de Caminhos Múltiplos



Sistemas de Localização Indoor

OUTROS SISTEMAS DE LOCALIZAÇÃO

- GPS-Indoor
  - A-GPS
  - Repetidores
  - LOCATA
- UWB – Principio de funcionamento de um radar
- WIFI – Localização baseada em RSSI
- WSN – Localização baseada em RSSI
- Bluetooth – Localização baseada em RSSI

Classificação

MULTI LAYER PERCEPTRON - MLP

- Reconhecedor de padrões de ampla aplicação;
- Sua arquitetura permite atuar em problemas não lineares e complexos;

Classificação

LEARNING VECTOR QUANTIZATION - LVQ

- Rede do tipo Mapa Auto Organizável com aprendizagem supervisionada;

- Possui uma camada competitiva e outra linear;

- Quantidade de saídas igual a quantidade de classes do problema;

Classificação

SUPPORT VECTOR MACHINE - SVM

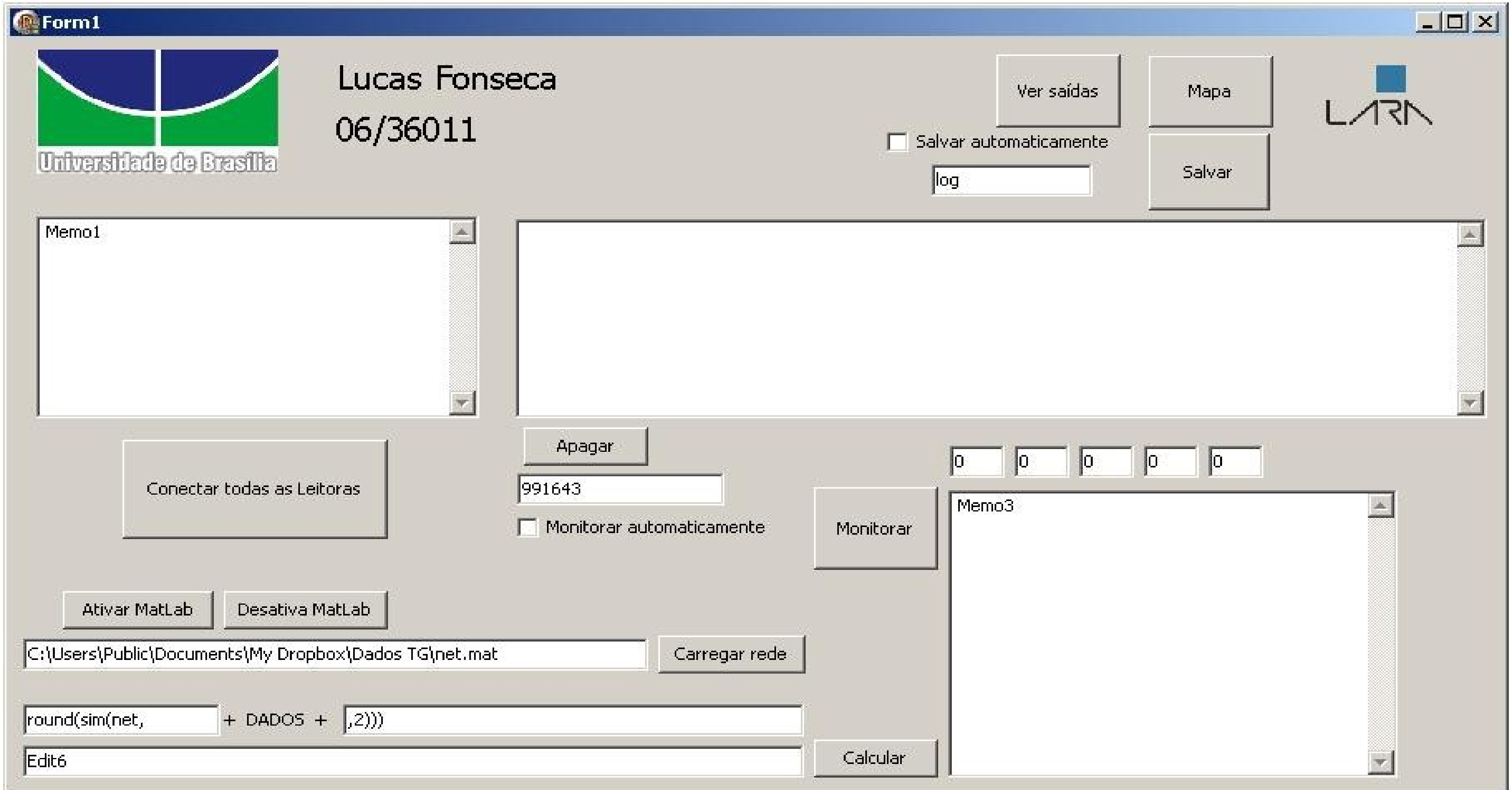
- Classificador de padrões binários;
- Vetores de Suporte definem hiperplano que separa as classes;
- Definição de classe vem da comparação com os vetores de suporte;
- Consegue fazer multiclassificação dividindo o problema em várias classificações.

Materiais e Métodos Aplicados

Hardware do Sistema RFID Ativo

Materiais e Métodos Aplicados

MIDDLEWARE DO SISTEMA RFID



Materiais e Métodos Aplicados

NEURAL NETWORK TOOLBOX DO MATLAB

- Ferramenta completa para Redes Neurais;
- Interfaces gráficas facilitam o acompanhamento dos processos de treinamento e teste das redes neurais;

Materiais e Métodos Aplicados

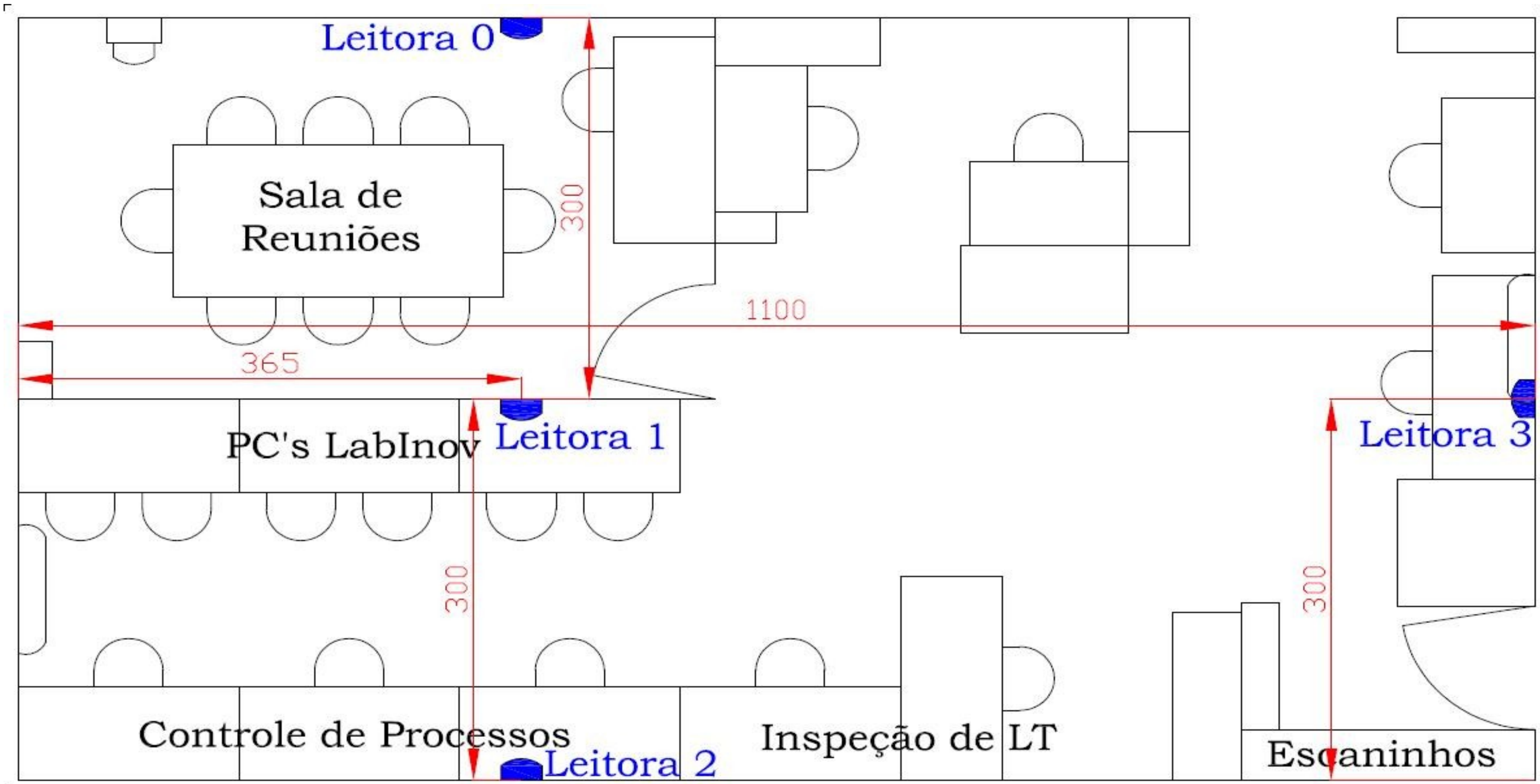
PACOTE DE APLICATIVOS LIBSVM

- Biblioteca de Software Livre;
- Aplicativos de treinamento gera conjunto de Vetores de Suporte;
- Permite várias configurações de função de núcleo da SVM (Linear, RBF, Polinomial, Sigmoides)

Materiais e Métodos Aplicados

CONFIGURAÇÃO FÍSICA DOS EXPERIMENTOS

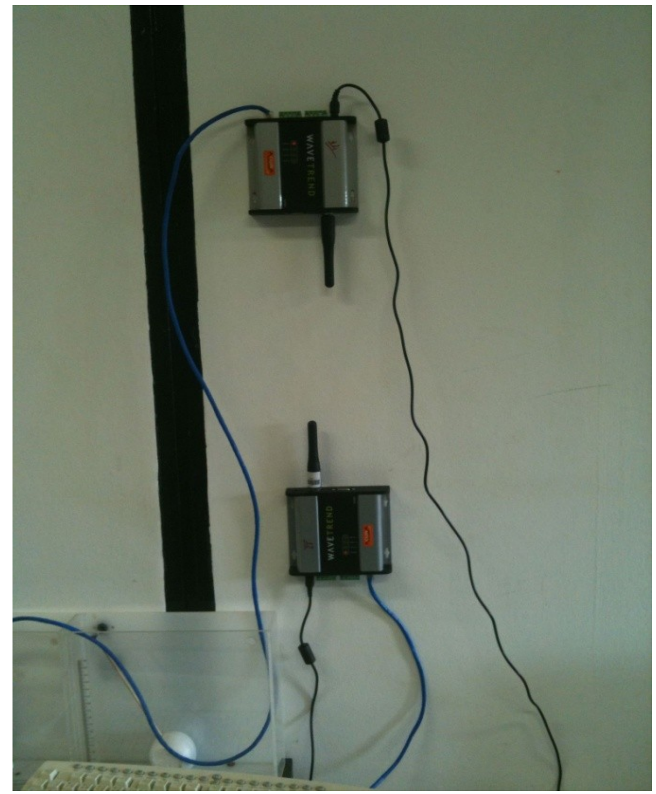
Localização das leitoras nos ambientes delimitados



Materiais e Métodos Aplicados

CONFIGURAÇÃO FÍSICA DOS EXPERIMENTOS

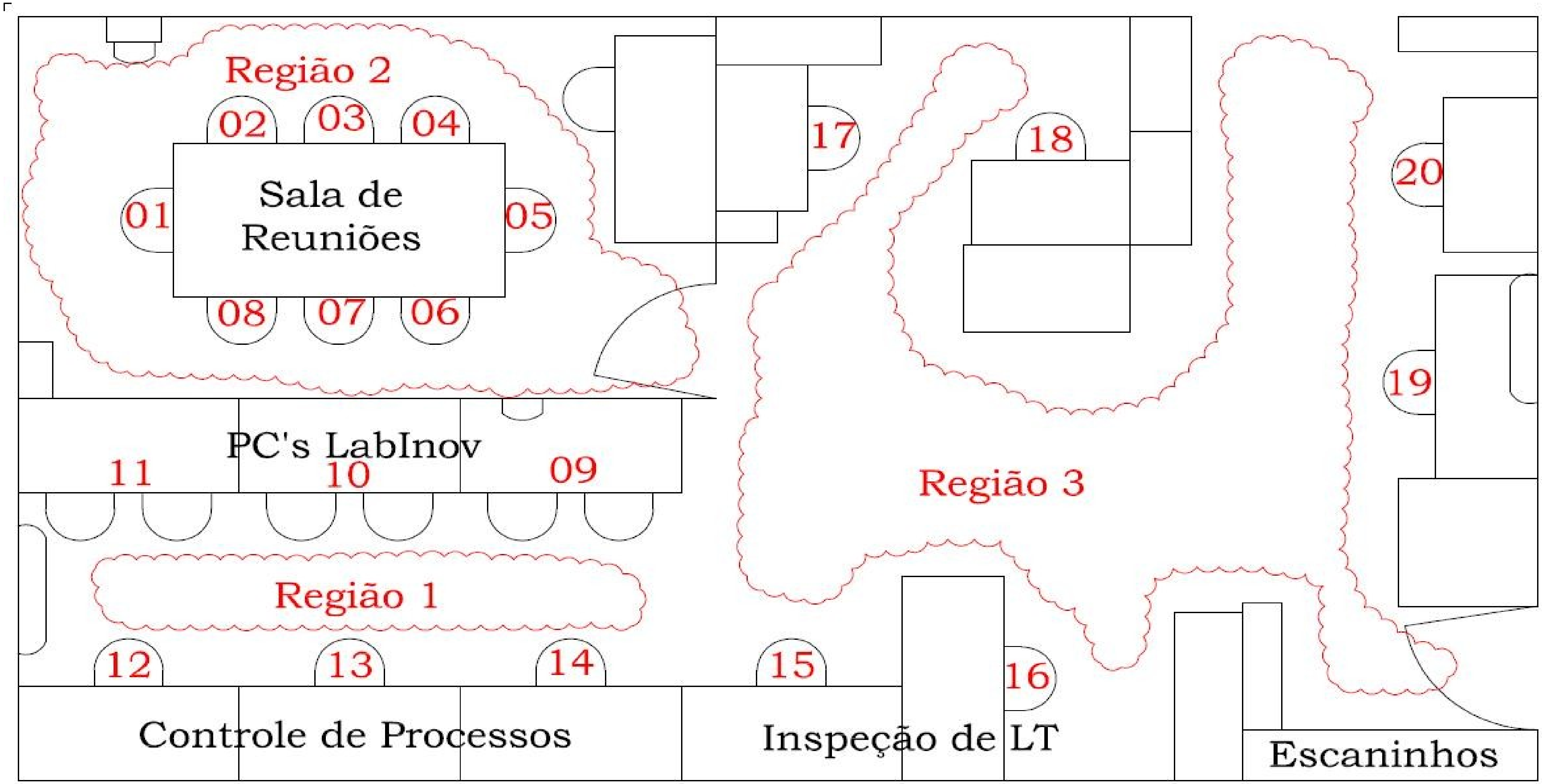
Leitoras instaladas nos ambientes delimitados



Materiais e Métodos Aplicados

CONFIGURAÇÃO FÍSICA DOS EXPERIMENTOS

Pontos de coleta de dados nos ambientes delimitados



Materiais e Métodos Aplicados

PROCEDIMENTOS DE LEITURA DOS DADOS

- Tempo de coleta de 30 minutos por ponto;
- Usuário portando a *Tag* como crachá;
- Liberdade de movimento em torno do eixo vertical;
- Dados armazenados em planilhas eletrônicas;
- Correção manual de erros de registro do middleware.

Pré-Tratamento e Filtragem dos Dados

(Como lidar com a ausência de alguma leitura das antenas)

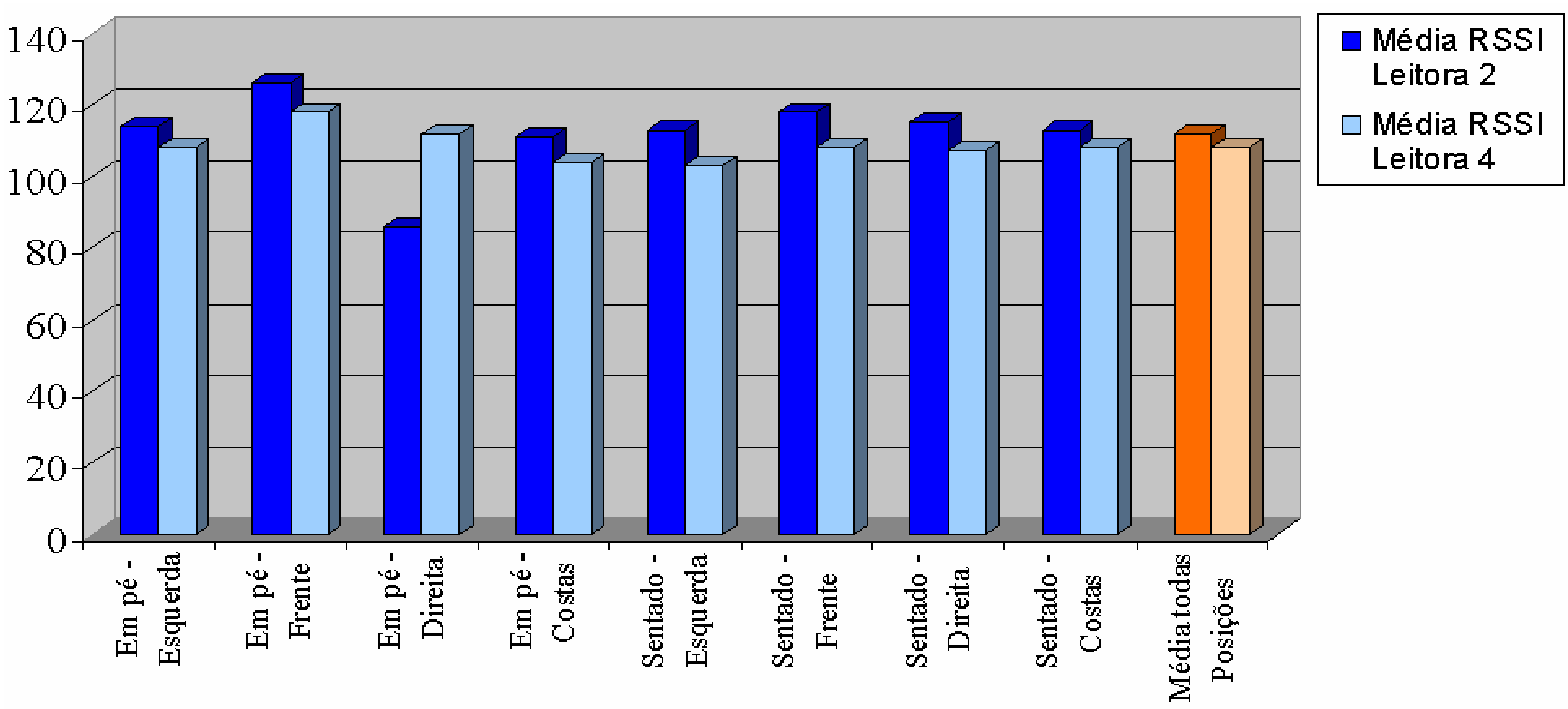
Metodologia	Formulação
Método_1	Sem alteração (Dados conforme coleta)
Método_1E	Método_1 + Filtragem EKF
Método_2	RSSI nulo = 71
Método_2E	Método_2 + Filtragem EKF
Método_3	RSSI nulo = RSSI anterior
Método_3E	Método_3 + Filtragem EKF

Arquivos de Treinamento dos Classificadores

- Rotulação das amostras quanto aos ambientes;
- Aglutinação das amostras em uma única planilha;
- Embaralhamento das amostras;
- Separação de amostras para teste e validação;

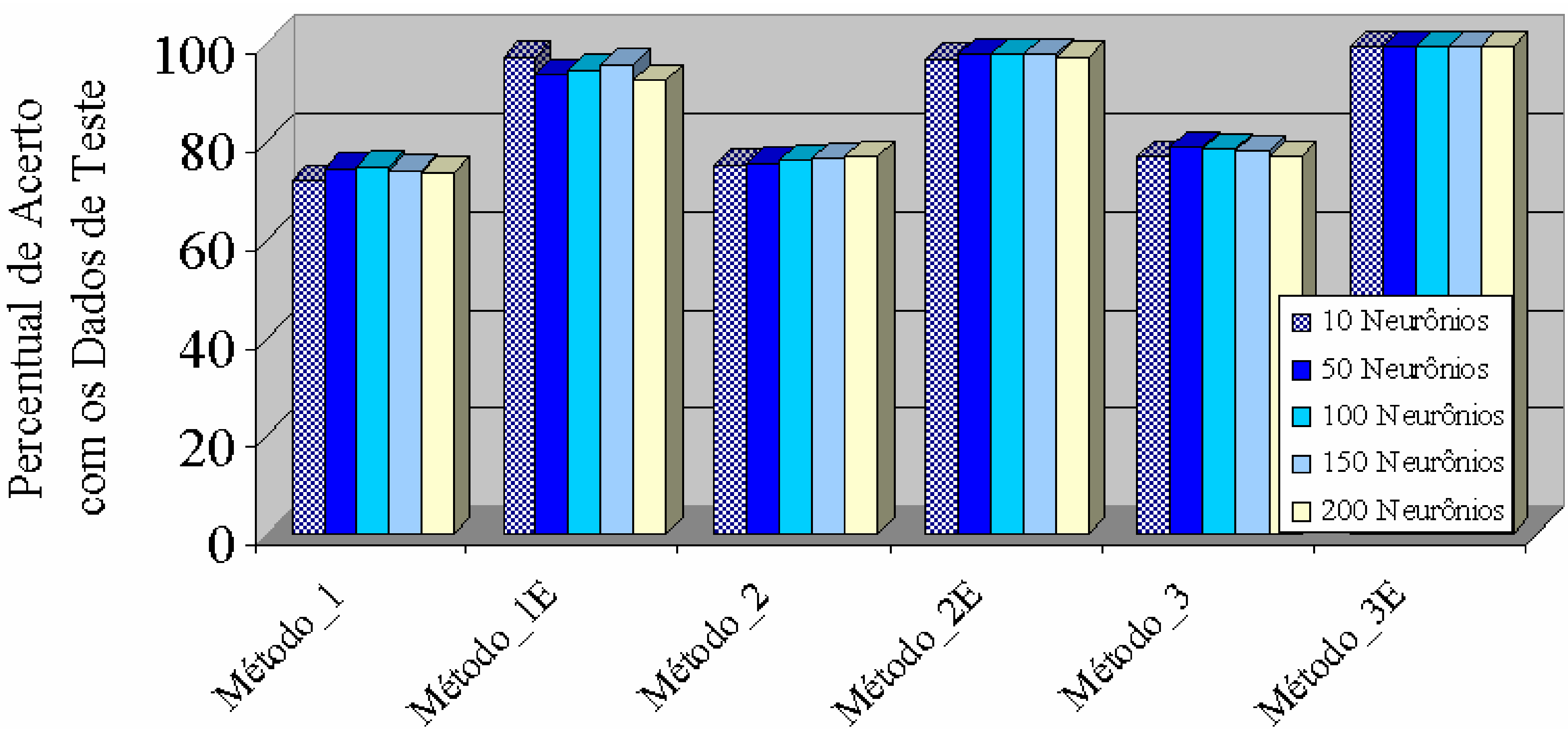
Resultados

Testes em relação à Orientação das Antenas



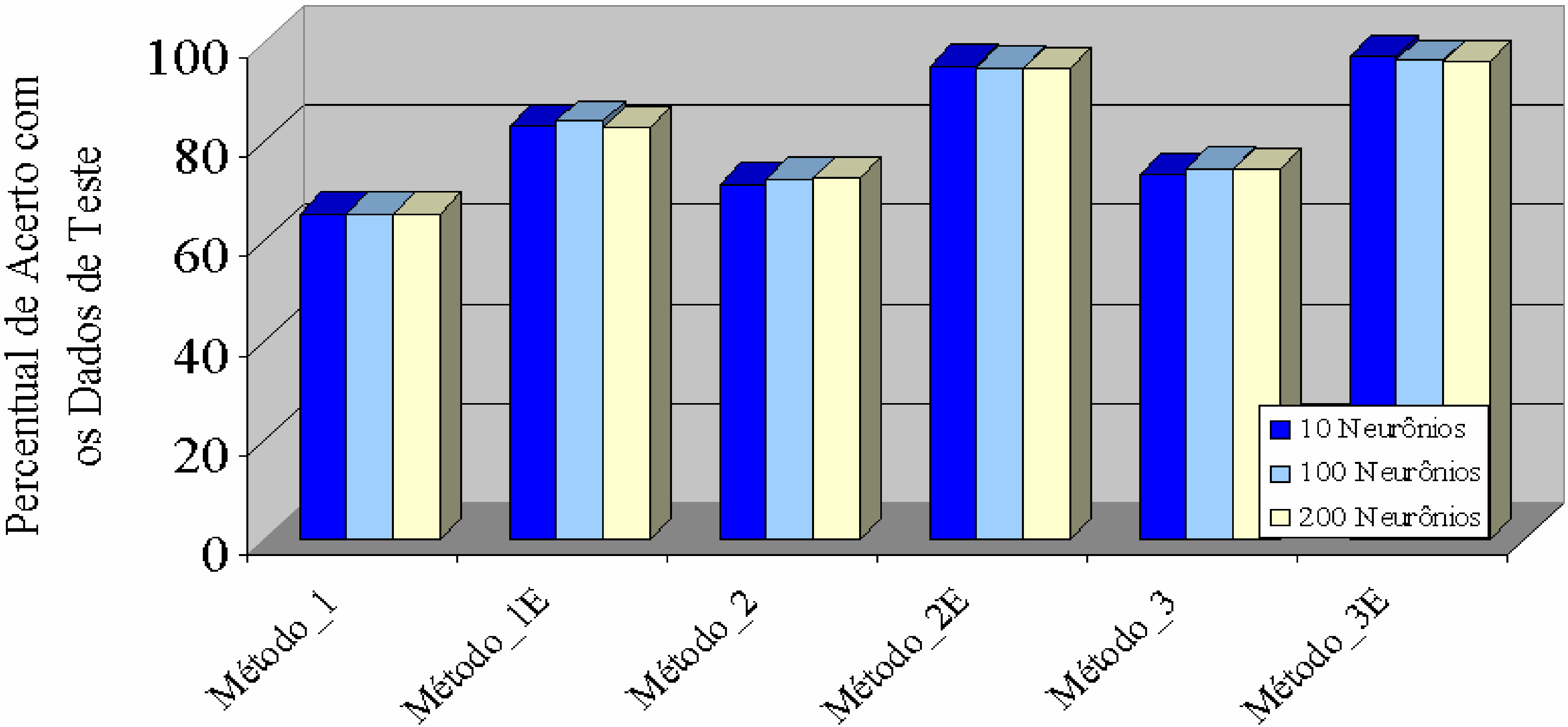
Resultados

DESEMPENHO DO TREINAMENTO DAS REDES MLP



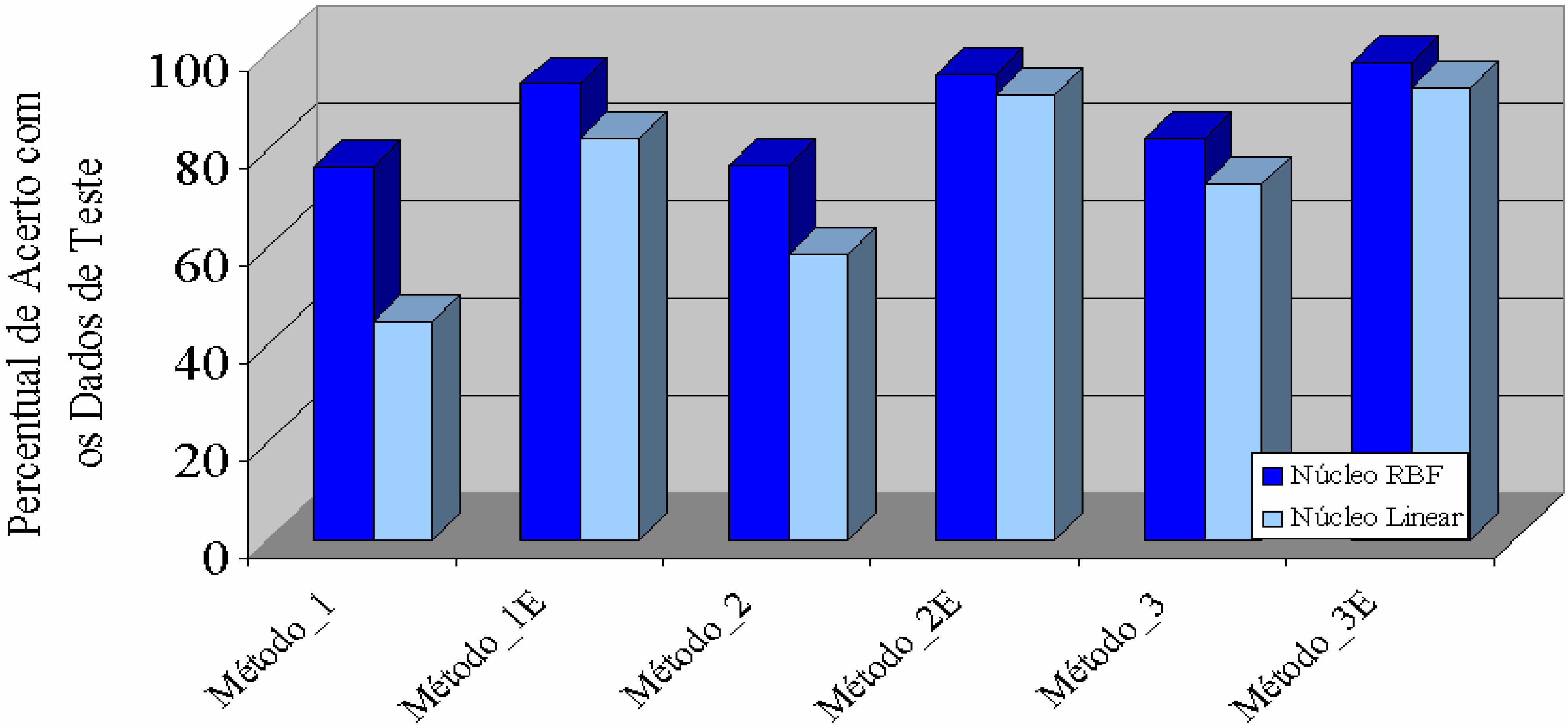
Resultados

DESEMPENHO DO TREINAMENTO DAS REDES LVQ



Resultados

DESEMPENHO DO TREINAMENTO DAS SVM



Resultados

MELHOR DESEMPENHO DENTRE OS CLASSIFICADORES PARA CADA BASE DE DADOS