

An Introduction to Support Vector Machines

By
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Source: Documentation for package of R `kernlab' and 'e1071'

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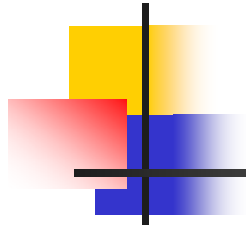
Outline

1. Support Vector Machines
2. Binary classification
3. R demo
4. References



1. Support Vector Machines

- History :
Statistical Learning Theory (Vapnik 1998)
- Development:
 - Binary classification SVM
 - Multi-class SVM



- Application:
 - Text categorization
 - Image recognition
 - Hand-written Digit Recognition
 - Bioinformatics



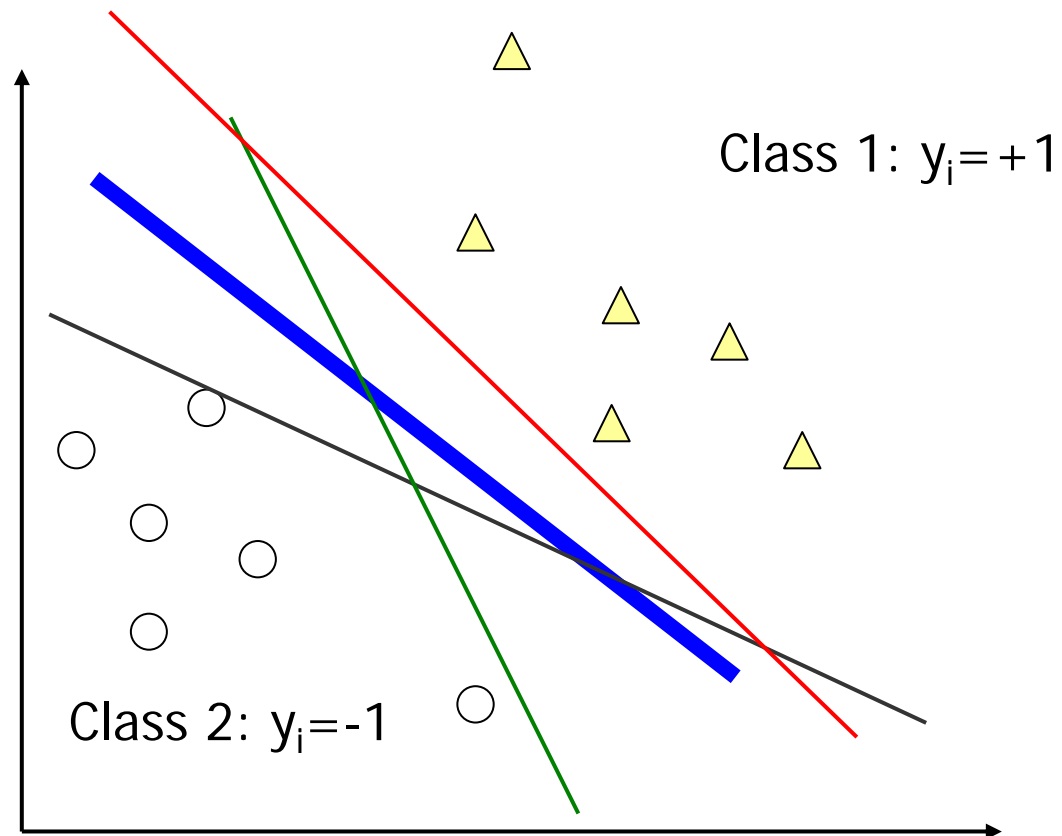
2. Binary classification

- Consider a two-class, linearly separable classification problem :

- training data $(x_i, y_i), i = 1, \dots, l. \{x_i, y_i\}, x_i \in R^n$

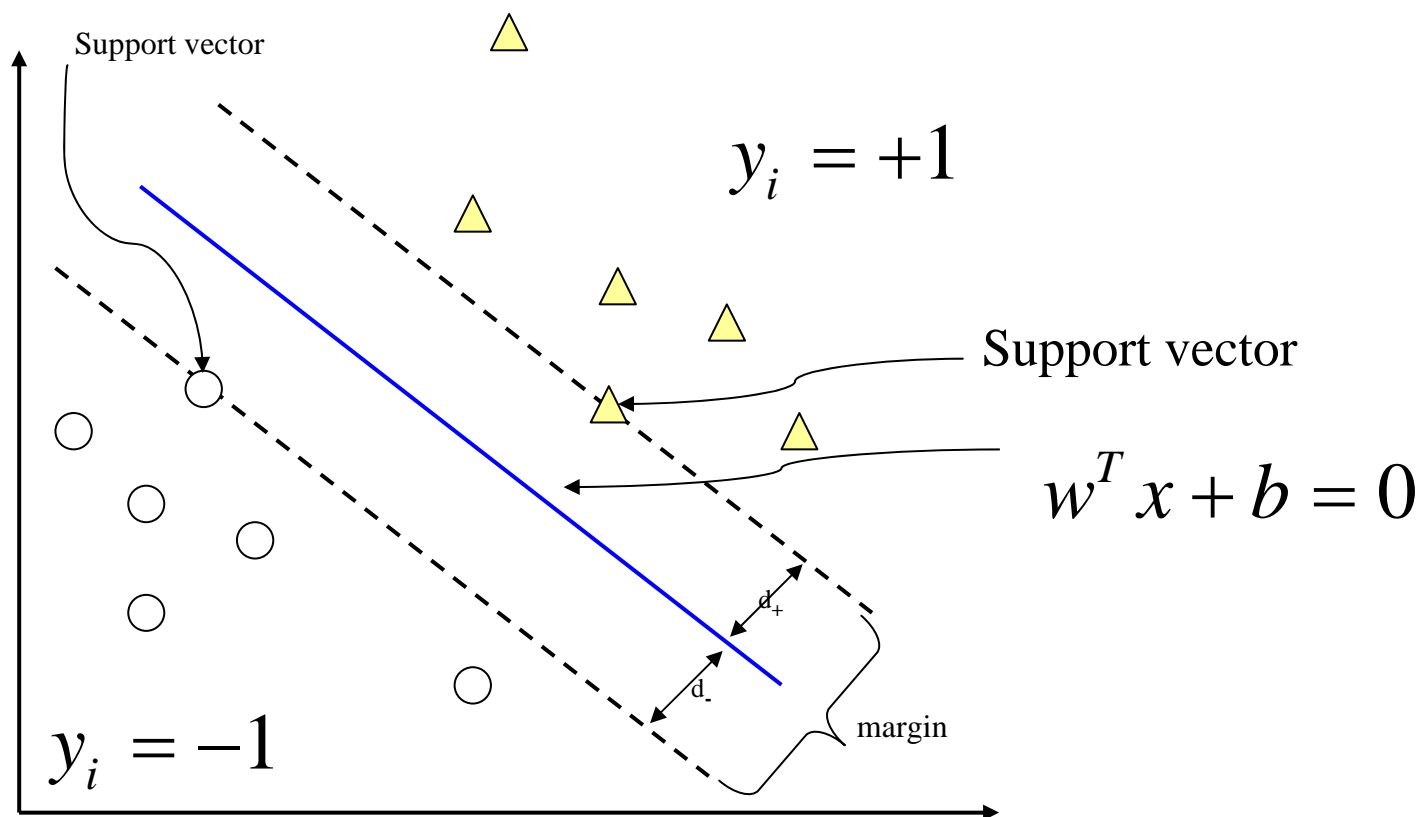
$$y_i = \begin{cases} +1, & x_i \in \text{class 1} \\ -1, & x_i \in \text{class 2} \end{cases}$$

Making decision boundary



Large-margin Decision Boundary

margin = (d_+) 與 (d_-) \rightarrow Goal: Max {margin}





Find maximum margin

$$\begin{aligned} w^T x_i + b &\geq 1 \quad \text{if } y_i = +1 \\ w^T x_i + b &\leq -1 \quad \text{if } y_i = -1 \end{aligned} \rightarrow y_i (w^T x_i + b) \geq 1 \quad \forall i = 1, \dots, l$$

$$\text{margin} = (d_+) + (d_-) = \frac{1}{\|w\|} + \frac{1}{\|w\|} = \frac{2}{\|w\|} = \frac{2}{\sqrt{w^T w}}$$

Minimize cost function, $\Phi(w) = \frac{1}{2} w^T w$

Subject to $y_i (w^T x_i + b) \geq 1 \quad \forall i = 1, \dots, l.$



Lagrange multipliers function

$$\text{Minimize} \quad J(w, b, \alpha) = \frac{1}{2} w^T w - \sum_{i=1}^l \alpha_i \left[y_i (w^T x_i + b) - 1 \right]$$

$$\text{Subject to} \quad \alpha_i \geq 0 \quad \forall i = 1, \dots, l.$$

$$\frac{dJ(w, b, \alpha)}{dw} = 0, \quad w = \sum_{i=1}^l \alpha_i y_i x_i$$

$$\frac{dJ(w, b, \alpha)}{db} = 0, \quad \sum_{i=1}^l \alpha_i y_i = 0$$



Dual problem

$$J(w, b, \alpha) = \frac{1}{2} w^T w - \sum_{i=1}^l \alpha_i y_i w^T x_i - b \sum_{i=1}^l \alpha_i y_i + \sum_{i=1}^l \alpha_i$$

$$w^T w = \sum_{i=1}^l \alpha_i y_i w^T x_i = \sum_{i=1}^l \sum_{j=1}^l \alpha_i \alpha_j y_i y_j x_i^T x_j$$

Maximize

$$Q(\alpha) = \sum_{i=1}^l \alpha_i - \frac{1}{2} \sum_{i=1}^l \sum_{j=1}^l \alpha_i \alpha_j y_i y_j x_i^T x_j$$

Subject to

$$(1) \sum_{i=1}^l \alpha_i y_i = 0$$

$$(2) \alpha_i \geq 0 \quad \forall i = 1, 2, \dots, l$$



Solution - Support vectors

- Many of the α_i are zero
- Support vectors (SV) x_i :
 - Non-zero α_i
 - The decision boundary is determined only by the SV
 - $$w = \sum_{i=1}^l \alpha_i y_i x_i$$
- Testing with a new data x_{new} :
 - Compute $w^T x_{new} + b$
 - If the result is positive , then classify x_{new} as class 1 , class 2 otherwise



3. R demo

- Data set: Glass
- Numbers 214, input variables: 9.
- Training data: 143(2/3)
- Testing data: 71(1/3)
- Use SVM to classify

How to get the R?



The screenshot shows the CRAN website in a web browser. The address bar shows <http://cran.r-project.org/>. The page features the R logo on the left and a large pink watermark of the URL <http://cran.r-project.org/> in the center. The main content is organized into sections: 'Precompiled Binary Distributions' and 'Source Code for all Platforms'. The left sidebar contains links for navigation, including 'CRAN', 'Mirrors', 'What's new?', 'Task Views', 'Search', 'About R', 'R Homepage', 'Software', 'R Sources', 'R Binaries', 'Packages', 'Other', 'Documentation', 'Manuals', 'FAQs', 'Contributed', and 'Newsletter'. The 'R Binaries' link is circled in red. The 'Precompiled Binary Distributions' section lists links for Linux, MacOS X (10.2.x and above), MacOS (System 8.6 to 9.1 and MacOS X up to 10.1.x), and Windows (95 and later). The 'Source Code for all Platforms' section provides information on the latest release, daily snapshots, and source code of older versions.

網址 <http://cran.r-project.org/>

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Precompiled Binary Distributions

Base system and contributed packages. **Windows and Mac** users most likely want these versions of R.

- [Linux](#)
- [MacOS X \(10.2.x and above\)](#) This version of R for the Mac is actively maintained.
- [MacOS \(System 8.6 to 9.1 and MacOS X up to 10.1.x\)](#) Last supported version of R is 1.7.1, there will be no more updates.
- [Windows \(95 and later\)](#)

Source Code for all Platforms

Windows and Mac users most likely want the precompiled binaries listed in the upper box, not the source code. The sources have to be compiled before you can use them. If you do not know what this means, you probably do not want to do it!

- **The latest release** (2005-10-06): [R-2.2.0.tar.gz](#) (read [what's new](#) in the latest version).
- Daily snapshots of current patched and development versions are [available here](#). Please read about [new features and bug fixes](#) before filing corresponding feature requests or bug reports.
- Source code of older versions of R is [available here](#).
- Contributed extension [packages](#)


What are R and CRAN?

R is 'GNU S', a freely available language and environment for statistical computing and graphics which provides a wide variety of statistical and graphical techniques: linear and nonlinear modelling, statistical tests, time series analysis, classification, clustering, etc. Please consult the [R project homepage](#) for further information.






CRAN is a network of ftp and web servers around the world that store identical, up-to-date, versions of code and documentation for R. Please use the CRAN [mirror](#) nearest to you to minimize network load.

→ R Binaries

網址: <http://cran.r-project.org/>



Index of /bin

Name	Last modified	Size	Description
 Parent Directory	14-Oct-2005 19:19	-	
 linux/	21-Feb-2005 11:27	-	
 macos/	19-Apr-2005 09:45	-	
 macosx/	19-Oct-2005 15:31	-	
 windows/	17-Dec-2004 16:38	-	

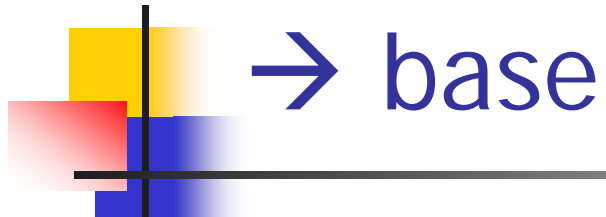
Apache/1.3.33 Server at cran.r-project.org Port 80

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網址 http://cran.r-project.org/



R for Windows

This directory contains binaries for a base distribution and packages to run on Windows (NT, 95 and later) on Intel and clones (but not NT on Alpha and other platforms).

Note: CRAN does not have Windows systems and cannot check these binaries for viruses. Use the normal precautions with downloaded executables.

Subdirectories:

[base](#)
[contrib](#)

Binaries for base distribution (managed by Duncan Murdoch)

Binaries of contributed packages (managed by Uwe Ligges)

Please do not submit binaries to CRAN. Package developers might want to contact Duncan Murdoch or Uwe Ligges directly in case of questions / suggestions related to Windows binaries.

You may also want to read the [R FAQ](#) and [R for Windows FAQ](#).

Last modified: April 4, 2004, by Friedrich Leisch

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→ R-2.2.0-win32.exe

網址 http://cran.r-project.org/



R-2.2.0 for Windows

This directory contains a binary distribution of R-2.2.0 to run on Windows 95, 98, ME, NT4.0, 2000 and XP on Intel/clone chips.

Patches to this release are incorporated in the [r-patched snapshot build](#).

A build of the development version (which will eventually become the next major release of R) is available in the [r-devel snapshot build](#).

In this directory:

README R-2.2.0	Installation and other instructions.
CHANGES	New features of this Windows version.
NEWS	New features of all versions.
R-2.2.0-win32.exe	Setup program (about 25 megabytes). Please download this from a mirror near you . This corresponds to the file named SetupR.exe or rwXXXX.exe in pre-2.2.0 releases.
old	The previous release.
md5sum.txt	md5sum output for the setup program. A Windows GUI version of md5sum is available at http://www.md5summer.org/ ; a Windows command line version is available at http://www.ettee.org/md5com.html .

Please see the [R FAQ](#) for general information about R and the [R Windows FAQ](#) for Windows-specific information, including upgrade advice.

Note to webmasters: A stable link which will redirect to the current Windows binary release is [<CRAN MIRROR>/bin/windows/base/release.htm](http://CRAN.MIRROR/bin/windows/base/release.htm).

Last change: 2005-10-06, by Duncan Murdoch

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→ Packages

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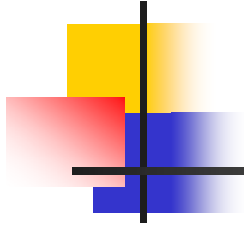
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dse	Bundle of tframe, dse1, dse2
dyn	Time Series Regression
dynamicGraph	dynamicGraph
dynlm	Dynamic Linear Regression
e1071	Misc Functions of the Department of Statistics (e1071), TU Wien
eba	Elimination-By-Aspects (EBA) Models
EbayesThresh	Empirical Bayes thresholding and related methods
Ecdat	Data sets for econometrics
eco	R Package for Fitting Bayesian Models of Ecological Inference in
edci	Edge Detection and Clustering in Images
effects	Effect Displays for Linear and Generalized Linear Models
eha	Event History Analysis.
elasticnet	Elastic Net Regularization and Variable Selection
ElemStatLearn	Data sets, functions and examples from the book: "The Elements o
ellipse	Functions for drawing ellipses and ellipse-like confidence region
elliptic	elliptic functions
emme2	Read and Write to an EMME/2 databank
emplik	Empirical likelihood ratio for censored/truncated data
EMV	Estimation of Missing Values for a Data Matrix
energy	E-statistics (energy statistics) tests of fit, independence, clus
ensembleBMA	Probabilistic forecasting using Bayesian Model Averaging
Epi	A package for statistical analysis in epidemiology.
epitools	Epidemiology Tools
epsi	Edge Preserving Smoothing for Images
equivalence	Provides tests and graphics for assessing tests of equivalence
evd	Functions for extreme value distributions
evdbayes	Bayesian Analysis in Extreme Value Theory
evir	Extreme Values in R
exactLoglinTest	Monte Carlo Exact Tests for Log-linear models
exactRankTests	Exact Distributions for Rank and Permutation Tests
extRemes	Extreme value toolkit.
Fahrmeir	Data from the book "Multivariate Statistical Modelling Based on
far	Modelization for Functional AutoRegressive processes
faraway	Functions and datasets for books by Julian Faraway.
FastICA	FastICA algorithms to perform ICA and Restricted Boltz



4. References

1. Burges, C. (1998) **A tutorial on support vector machines for pattern recognition**, *Data Mining and Knowledge Discovery*, 121-167.
2. Lin C. J., etc. **A Practical Guide to Support Vector Classification**, 2003.
source: <http://www.csie.ntu.edu.tw/~cjlin/>
3. Vapnik, V. N. (1998) **Statistical Learning Theory**. Wiley.



THANKS

Q & A