

Package ‘sdwd’

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Type Package

Title Sparse Distance Weighted Discrimination

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Description

Formulates a sparse distance weighted discrimination (SDWD) for high-dimensional classification and implements a very fast algorithm for computing its solution path with the L1, the elastic-net, and the adaptive elastic-net penalties. More details about the methodology SDWD is seen on Wang and Zou (2016) (<[doi:10.1080/10618600.2015.1049700](https://doi.org/10.1080/10618600.2015.1049700)>).

Depends Matrix

Imports grDevices, graphics, stats, methods

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sdwd-package

Sparse Distance Weighted Discrimination

Description

This package implements the generalized coordinate descent (GCD) algorithm to efficiently compute the solution path of the sparse distance weighted discrimination (DWD) at a given fine grid of regularization parameters. Sparse distance weighted discrimination is a high-dimensional margin-based classifier.

Details

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Suppose x is the predictors and y is the binary response. With a fixed value λ_2 , the package produces the solution path of the sparse DWD over a grid of λ values. The value of λ_2 can be further tuned by cross-validation.

The package `sdwd` contains five main functions:

`sdwd`
`cv.sdwd`
`coef.sdwd`
`plot.sdwd`
`plot.cv.sdwd`

Author(s)

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References

Wang, B. and Zou, H. (2016) "Sparse Distance Weighted Discrimination", *Journal of Computational and Graphical Statistics*, **25**(3), 826–838.

<https://www.tandfonline.com/doi/full/10.1080/10618600.2015.1049700>

Friedman, J., Hastie, T., and Tibshirani, R. (2010), "Regularization paths for generalized linear models via coordinate descent," *Journal of Statistical Software*, **33**(1), 1–22.

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<https://rss.onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-9868.2011.01004.x>

Yang, Y. and Zou, H. (2013) “An Efficient Algorithm for Computing the HHSVM and Its Generalizations”, *Journal of Computational and Graphical Statistics*, **22**(2), 396–415.

<https://www.tandfonline.com/doi/full/10.1080/10618600.2012.680324>

coef.cv.sdwd	<i>compute coefficients from a "cv.sdwd" object</i>
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Description

Computes coefficients at chosen values of lambda from the `cv.sdwd` object.

Usage

```
## S3 method for class 'cv.sdwd'
coef(object, s=c("lambda.1se", "lambda.min"),...)
```

Arguments

object	A fitted <code>cv.sdwd</code> object, obtained by conducting the cross-validation to the sparse DWD model.
s	Value(s) of the L1 tuning parameter lambda for computing coefficients. Default value is "lambda.1se", which represents the largest lambda value achieving the cross-validation error within one standard error of the minimum. An alternative value is "lambda.min", which is the lambda incurring the least cross-validation error. s can also be numeric, being taken as the value(s) to be used.
...	Other arguments that can be passed to <code>sdwd</code> .

Details

This function computes the coefficients at the values of lambda suggested by the cross-validation. This function is modified based on the `coef.cv` function from the `glmnet` and the `gcdnet` packages.

Value

The returned object depends on the choice of s and the ... argument passed on to the `sdwd` method.

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<https://www.jstatsoft.org/v33/i01/paper>

See Also

[cv.sdwd](#) and [predict.cv.sdwd](#) methods.

Examples

```
data(colon)
colon$x = colon$x[ , 1:100] # this example only uses the first 100 columns
set.seed(1)
cv = cv.sdwd(colon$x, colon$y, lambda2=1, nfolds=5)
c1 = coef(cv, s="lambda.1se")
```

coef.sdwd

compute coefficients for the sparse DWD

Description

Computes the coefficients or returns the indices of nonzero coefficients at chosen values of lambda from a fitted [sdwd](#) object.

Usage

```
## S3 method for class 'sdwd'
coef(object, s=NULL, type=c("coefficients", "nonzero"), ...)
```

Arguments

object	A fitted <code>sdwd</code> object.
s	Value(s) of the L1 tuning parameter lambda for computing coefficients. Default is the entire lambda sequence obtained by <code>sdwd</code> .
type	"coefficients" or "nonzero"? "coefficients" computes the coefficients at given values for s; "nonzero" returns a list of the indices of the nonzero coefficients for each value of s. Default is "coefficients".
...	Not used. Other arguments to predict.

Details

s is the new vector at which predictions are requested. If s is not in the lambda sequence used for fitting the model, the coef function will use linear interpolation to make predictions. The new values are interpolated using a fraction of coefficients from both left and right lambda indices. This function is modified based on the coef function from the `gcdnet` and the `glmnet` packages.

Value

Either the coefficients at the requested values of lambda, or a list of the indices of the nonzero coefficients for each lambda.

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See Also

[predict.sdwd](#)

Examples

```
# load sdwd library
library(sdwd)

# load data set
data(colon)

# how many samples and how many predictors?
dim(colon$x)

# how many samples of class -1 and 1 respectively?
sum(colon$y == -1)
sum(colon$y == 1)
```

cv.sdwd

cross-validation for the sparse DWD

Description

Conducts a k-fold cross-validation for [sdwd](#) and returns the suggested values of the L1 parameter `lambda`.

Usage

```
cv.sdwd(x, y, lambda = NULL, pred.loss = c("misclass", "loss"), nfold = 5, foldid, ...)
```

Arguments

<code>x</code>	A matrix of predictors, i.e., the <code>x</code> matrix used in sdwd .
<code>y</code>	A vector of binary class labels, i.e., the <code>y</code> used in sdwd .
<code>lambda</code>	Default is <code>NULL</code> , and the sequence generated by sdwd is used. User can also provide a new <code>lambda</code> sequence to use in cross-validation.
<code>pred.loss</code>	<code>misclass</code> for classification error, <code>loss</code> for DWD loss.
<code>nfold</code>	The number of folds. Default value is 5. The allowable range is from 3 to the sample size. Larger <code>nfold</code> needs more timing.
<code>foldid</code>	An optional vector with values between 1 and <code>nfold</code> , representing the folder indices for each observation. If supplied, <code>nfold</code> can be missing.
<code>...</code>	Other arguments that can be passed to sdwd .

Details

This function runs [sdwd](#) to the sparse DWD by excluding every fold alternatively, and then computes the mean cross-validation error and the standard deviation. This function is modified based on the `cv` function from the `gcdnet` and the `glmnet` packages.

Value

A `cv.sdwd` object is returned, which includes the cross-validation fit.

<code>lambda</code>	The lambda sequence used in <code>sdwd</code> .
<code>cvm</code>	A vector of length <code>length(lambda)</code> for the mean cross-validated error.
<code>cvstd</code>	A vector of length <code>length(lambda)</code> for estimates of standard error of <code>cvm</code> .
<code>cvupper</code>	The upper curve: <code>cvm + cvstd</code> .
<code>cvlower</code>	The lower curve: <code>cvm - cvstd</code> .
<code>nzero</code>	Numbers of non-zero coefficients at each lambda.
<code>name</code>	"Mis-classification error", for plotting purposes.
<code>sdwd.fit</code>	A fitted <code>sdwd</code> object using the full data.
<code>lambda.min</code>	The lambda incurring the minimum cross validation error <code>cvm</code> .
<code>lambda.1se</code>	The largest value of lambda such that error is within one standard error of the minimum.
<code>cv.min</code>	The minimum cross-validation error.
<code>cv.1se</code>	The cross-validation error associated with <code>lambda.1se</code> .

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See Also

`sdwd`, `plot.cv.sdwd`, `predict.cv.sdwd`, and `coef.cv.sdwd` methods.

Examples

```

data(colon)
colon$x = colon$x[ , 1:100] # this example only uses the first 100 columns
n = nrow(colon$x)
set.seed(1)
id = sample(n, trunc(n/3))
cvfit = cv.sdwd(colon$x[-id, ], colon$y[-id], lambda2=1, nfolds=5)
plot(cvfit)
predict(cvfit, newx=colon$x[id, ], s="lambda.min")

```

plot.cv.sdwd

plot the cross-validation curve of the sparse DWD

Description

Plots the cross-validation curve against a function of lambda values. The function also provides the upper and lower standard deviation curves.

Usage

```

## S3 method for class 'cv.sdwd'
plot(x, sign.lambda, ...)

```

Arguments

x	A fitted <code>cv.sdwd</code> object.
sign.lambda	Whether to plot against $\log(\lambda)$ (default) or its negative if <code>sign.lambda=-1</code> .
...	Other graphical parameters to plot.

Details

This function depicts the cross-validation curves. This function is modified based on the `plot.cv` function from the `glmnet` and the `gcdnet` packages.

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<https://www.jstatsoft.org/v33/i01/paper>

See Also

[cv.sdwd](#).

Examples

```
data(colon)
colon$x = colon$x[ , 1:100] # this example only uses the first 100 columns
set.seed(1)
cv = cv.sdwd(colon$x, colon$y, lambda2=1, nfolds=5)
plot(cv)
```

plot.sdwd

plot coefficients for the sparse DWD

Description

Plots the solution paths for a fitted [sdwd](#) object.

Usage

```
## S3 method for class 'sdwd'
plot(x, xvar=c("norm", "lambda"), color=FALSE, label=FALSE, ...)
```

Arguments

x	A fitted sdwd model.
xvar	Specifies the X-axis. If xvar == "norm", plots against the L1-norm of the coefficients; if xvar == "lambda" against the log-lambda sequence.
color	If TRUE, plots the curves with rainbow colors; otherwise, with gray colors (default).
label	If TRUE, labels the curves with variable sequence numbers. Default is FALSE.
...	Other graphical parameters to plot.

Details

Plots the solution paths as a coefficient profile plot. This function is modified based on the plot function from the `gcdnet` and the `glmnet` packages.

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<https://www.jstatsoft.org/v33/i01/paper>

See Also

print.sdwd, predict.sdwd, coef.sdwd, plot.sdwd, and cv.sdwd.

Examples

```
data(colon)
fit = sdwd(colon$x, colon$y)
par(mfrow=c(1,3))
# plots against the L1-norm of the coefficients
plot(fit)
# plots against the log-lambda sequence
plot(fit, xvar="lambda", label=TRUE)
# plots with colors
plot(fit, color=TRUE)
```

predict.cv.sdwd

make predictions from a "cv.sdwd" object

Description

This function predicts the class labels of new observations by the sparse DWD at the lambda values suggested by [cv.sdwd](#).

Usage

```
## S3 method for class 'cv.sdwd'
predict(object, newx, s=c("lambda.1se", "lambda.min"), ...)
```

Arguments

object	A fitted <code>cv.sdwd</code> object.
newx	A matrix of new values for x at which predictions are to be made. Must be a matrix. See documentation for <code>predict.sdwd</code> .
s	Value(s) of the L1 tuning parameter λ for making predictions. Default is the <code>s="lambda.1se"</code> saved on the <code>cv.sdwd</code> object. An alternative choice is <code>s="lambda.min"</code> . s can also be numeric, being taken as the value(s) to be used.
...	Not used. Other arguments to <code>predict</code> .

Details

This function uses the cross-validation results to making predictions. This function is modified based on the `predict.cv` function from the `glmnet` and the `gcdnet` packages.

Value

Predicted class labels or fitted values, depending on the choice of s and the ... argument passed on to the `sdwd` method.

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References

- Wang, B. and Zou, H. (2016) "Sparse Distance Weighted Discrimination", *Journal of Computational and Graphical Statistics*, **25**(3), 826–838.
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<https://www.jstatsoft.org/v33/i01/paper>

See Also

`cv.sdwd`, and `coef.cv.sdwd` methods.

Examples

```
data(colon)
colon$x = colon$x[ , 1:100] # this example only uses the first 100 columns
set.seed(1)
cv = cv.sdwd(colon$x, colon$y, lambda2=1, nfolds=5)
```

```
predict(cv$sdwd.fit, newx=colon$x[2:5, ],
       s=cv$lambda.1se, type="class")
```

predict.sdwd	<i>make predictions for the sparse DWD</i>
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Description

This function predicts the binary class labels or the fitted values of an [sdwd](#) object.

Usage

```
## S3 method for class 'sdwd'
predict(object, newx, s=NULL, type=c("class", "link"), ...)
```

Arguments

object	A fitted sdwd object.
newx	A matrix of new values for x at which predictions are to be made. We note that newx must be a matrix, predict function does not accept a vector or other formats of newx.
s	Value(s) of the L1 tuning parameter lambda for computing coefficients. Default is the entire lambda sequence obtained by sdwd .
type	"class" or "link"? "class" produces the predicted binary class labels. "link" returns the fitted values. Default is "class".
...	Not used. Other arguments to predict.

Details

s stands for the new lambda values for making predictions. If s is not in the original lambda sequence generated by [sdwd](#), the predict.sdwd function will use linear interpolation by using a fraction of predicted values from the lambda values in the original sequence adjacent to the s to make predictions. The [predict.sdwd](#) function is modified based on the predict function from the glmnet and the gcdnet packages.

Value

Returns either the predicted class labels or the fitted values, depending on the choice of type.

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References

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<https://www.jstatsoft.org/v33/i01/paper>

See Also

[coef.sdwd](#)

Examples

```
data(colon)
fit = sdwd(colon$x, colon$y, lambda2=1)
print(predict(fit ,type="class",newx=colon$x[2:5,]))
```

```
print.sdwd
```

```
print an sdwd object
```

Description

Print a summary of the [sdwd](#) solution paths.

Usage

```
## S3 method for class 'sdwd'
print(x, digits=max(3, getOption("digits") - 3), ...)
```

Arguments

<code>x</code>	A fitted sdwd object.
<code>digits</code>	Specify the significant digits.
<code>...</code>	Additional print arguments.

Details

This function prints a two-column matrix with columns Df and Lambda, where the Df column exhibits the number of nonzero coefficients and the Lambda column displays the corresponding lambda value. This function is modified based on the `print` function from the `gcdnet` and the `glmnet` packages.

Value

A two-column matrix with one column of the number of nonzero coefficients and a second column of lambda values.

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References

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<https://www.jstatsoft.org/v33/i01/paper>

See Also

print.sdwd, predict.sdwd, coef.sdwd, plot.sdwd, and cv.sdwd.

Examples

```
data(colon)
fit = sdwd(colon$x, colon$y)
print(fit)
```

sdwd

fit the sparse DWD

Description

Fits the sparse distance weighted discrimination (SDWD) model with imposing L1, elastic-net, or adaptive elastic-net penalties. The solution path is computed at a grid of values of tuning parameter lambda. This function is modified based on the glmnet and the gcdnet packages.

Usage

```
sdwd(x, y, nlambda=100,
     lambda.factor=ifelse(nobs < nvars, 0.01, 1e-04),
     lambda=NULL, lambda2=0, pf=rep(1, nvars),
     pf2=rep(1, nvars), exclude, dfmax=nvars + 1,
     pmax=min(dfmax * 1.2, nvars), standardize=TRUE,
     eps=1e-8, maxit=1e6, strong=TRUE)
```

Arguments

x	A matrix with N rows and p columns for predictors.
y	A vector of length p for binary responses. The element of y is either -1 or 1.
nlambda	The number of lambda values, i.e., length of the lambda sequence. Default is 100.
lambda.factor	The ratio of the smallest to the largest lambda in the sequence: $\text{lambda.factor} = \min(\text{lambda}) / \max(\text{lambda})$. $\max(\text{lambda})$ is the least lambda to make all coefficients to be zero. The default value of lambda.factor is 0.0001 if $N \geq p$ or 0.01 if $N < p$. Takes no effect when user specifies a lambda sequence.
lambda	An optional user-supplied lambda sequence. If $\text{lambda} = \text{NULL}$ (default), the program computes its own lambda sequence based on $n\text{lambda}$ and lambda.factor ; otherwise, the program uses the user-specified one. Since the program will automatically sort user-defined lambda sequence in decreasing order, it is better to supply a decreasing sequence.
lambda2	The L2 tuning parameter λ_2 .
pf	A vector of length p representing the L1 penalty weights to each coefficient of β for adaptive L1 or adaptive elastic net. pf can be 0 for some predictor(s), leading to including the predictor(s) all the time. One suggested choice of pf is $(\beta + 1/n)^{-1}$, where n is the sample size and β is the coefficients obtained by L1 DWD or enet DWD. Default is 1 for all predictors (and infinity if some predictors are listed in <code>exclude</code>).
pf2	A vector of length p for L2 penalty factor for adaptive L1 or adaptive elastic net. To allow different L2 shrinkage, user can set pf2 to be different L2 penalty weights for each coefficient of β . pf2 can be 0 for some variables, indicating no L2 shrinkage. Default is 1 for all predictors.
exclude	Whether to exclude some predictors from the model. This is equivalent to adopting an infinite penalty factor when excluding some predictor. Default is none.
dfmax	Restricts at most how many predictors can be incorporated in the model. Default is $p + 1$. This restriction is helpful when p is large, provided that a partial path is acceptable.
pmax	Restricts the maximum number of variables ever to be nonzero; e.g, once some β enters the model, it counts once. The count will not change when the β exits or re-enters the model. Default is $\min(\text{dfmax} * 1.2, p)$.
standardize	Whether to standardize the data. If TRUE, <code>sdwd</code> normalizes the predictors such that each column has sum squares $\sum_{i=1}^N x_{ij}^2 / N = 1$ of one. Note that x is always centered (i.e. $\sum_{i=1}^N x_{ij} = 0$) no matter <code>standardize</code> is TRUE or FALSE. <code>sdwd</code> always returns coefficient beta on the original scale. Default value is TRUE.

eps	The algorithm stops when (i.e. $4 \max_j (\beta_j^{new} - \beta_j^{old})^2$ is less than eps, where $j = 0, \dots, p$. Defaults value is 1e-8.
maxit	Restricts how many outer-loop iterations are allowed. Default is 1e6. Consider increasing maxit when the algorithm does not converge.
strong	If TRUE, adopts the strong rule to accelerate the algorithm.

Details

The `sdwd` minimizes the sparse penalized DWD loss function,

$$L(y, X, \beta)/N + \lambda_1 \|\beta\|_1 + 0.5\lambda_2 \|\beta\|_2^2,$$

where $L(u) = 1 - u$ if $u \leq 1/2$, $1/(4u)$ if $u > 1/2$ is the DWD loss. The value of lambda2 is user-specified.

To use the L1 penalty (lasso), set lambda2=0. To use the elastic net, set lambda2 as nonzero. To use the adaptive L1, set lambda2=0 and specify pf and pf2. To use the adaptive elastic net, set lambda2 as nonzero and specify pf and pf2 as well.

When the algorithm do not converge or run slow, consider increasing eps, decreasing nlambda, or increasing lambda.factor before increasing maxit.

Value

An object with S3 class `sdwd`.

b0	A vector of length <code>length(lambda)</code> representing the intercept at each lambda value.
beta	A matrix of dimension $p \times \text{length}(\text{lambda})$ representing the coefficients at each lambda value. The matrix is stored as a sparse matrix (Matrix package). To convert it into normal type matrix use <code>as.matrix()</code> .
df	The number of nonzero coefficients at each lambda.
dim	The dimension of coefficient matrix, i.e., $p \times \text{length}(\text{lambda})$.
lambda	The lambda sequence that was actually used.
npasses	Total number of iterations for all lambda values.
jerr	Warnings and errors; 0 if no error.
call	The call that produced this object.

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See Also

`print.sdwd`, `predict.sdwd`, `coef.sdwd`, `plot.sdwd`, and `cv.sdwd`.

Examples

```
# load the data
data(colon)
# fit the elastic-net penalized DWD with lambda2=1
fit = sdwd(colon$x, colon$y, lambda2=1)
print(fit)
# coefficients at some lambda value
c1 = coef(fit, s=0.005)
# make predictions
predict(fit, newx=colon$x[1:10, ], s=c(0.01, 0.005))
```

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