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Description Computationally efficient tools for high dimensional predictive modeling (regression and classification). SAM is short for sparse additive modeling, and adopts the computationally efficient basis spline technique. We solve the optimization problems by various computational algorithms including the block coordinate descent algorithm, fast iterative soft-thresholding algorithm, and newton method. The computation is further accelerated by warm-start and active-set tricks.

License GPL-2

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`SAM-package` *Sparse Additive Modelling*

Description

SAM provides sparse additive models for high-dimensional prediction tasks (regression and classification). It uses spline basis expansion and efficient optimization routines to compute full regularization paths.

Details

The package exposes four model families:

- `samQL`: quadratic-loss sparse additive regression.
- `samLL`: logistic-loss sparse additive classification.
- `samHL`: hinge-loss sparse additive classification.
- `samEL`: Poisson-loss sparse additive regression.

All models share a common spline representation and return regularization paths, allowing model selection after one fit.

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References

P. Ravikumar, J. Lafferty, H.Liu and L. Wasserman. "Sparse Additive Models", *Journal of Royal Statistical Society: Series B*, 2009.
T. Zhao and H.Liu. "Sparse Additive Machine", *International Conference on Artificial Intelligence and Statistics*, 2012.

See Also

samQL,samHL,samLL,samEL

`plot.samEL` *Plot function for S3 class* `"samEL"`

Description

Plot the regularization path (regularization parameter versus functional norm).

Usage

```
## S3 method for class 'samEL'
plot(x, ...)
```

Arguments

`x`	An object with S3 class `"samEL"`
`...`	Additional arguments passed to methods; currently unused.

Details

The x-axis shows regularization parameters on a log scale. The y-axis shows the functional norm of each component function.

See Also

samEL

plot.samHL *Plot function for S3 class "samHL"*

Description

Plot the regularization path (regularization parameter versus functional norm).

Usage

```
## S3 method for class 'samHL'
plot(x, ...)
```

Arguments

x	An object with S3 class "samHL"
...	Additional arguments passed to methods; currently unused.

Details

The x-axis shows regularization parameters on a log scale. The y-axis shows the functional norm of each component function.

See Also

samHL

plot.samLL *Plot function for S3 class "samLL"*

Description

Plot the regularization path (regularization parameter versus functional norm).

Usage

```
## S3 method for class 'samLL'
plot(x, ...)
```

Arguments

x	An object with S3 class "samLL"
...	Additional arguments passed to methods; currently unused.

Details

The x-axis shows regularization parameters on a log scale. The y-axis shows the functional norm of each component function.

See Also

samLL

`plot.samQL` *Plot function for S3 class "samQL"*

Description

Plot the regularization path (regularization parameter versus functional norm).

Usage

```
## S3 method for class 'samQL'
plot(x, ...)
```

Arguments

`x`	An object with S3 class "samQL"
`...`	Additional arguments passed to methods; currently unused.

Details

The x-axis shows regularization parameters on a log scale. The y-axis shows the functional norm of each component function.

See Also

samQL

predict.samEL *Prediction function for S3 class "samEL"*

Description

Predict expected counts for test data.

Usage

```
## S3 method for class 'samEL'
predict(object, newdata, ...)
```

Arguments

object	An object with S3 class "samEL".
newdata	Numeric test matrix with n rows and d columns.
...	Additional arguments passed to methods; currently unused.

Details

The test matrix is rescaled using the training X.min/X.ran, truncated to [0, 1], and expanded with the same spline basis used during training.

Value

expectations	Estimated expected counts as an n by length(lambda) matrix.
expectation	Alias of expectations kept for backward compatibility.

See Also

samEL

predict.samHL *Prediction function for S3 class "samHL"*

Description

Predict decision values and class labels for test data.

Usage

```
## S3 method for class 'samHL'
predict(object, newdata, thol = 0, ...)
```

Arguments

object	An object with S3 class "samHL".
newdata	Numeric test matrix with n rows and d columns.
thol	Decision-value threshold used to convert scores to labels. The default value is 0.
...	Additional arguments passed to methods; currently unused.

Details

The test matrix is rescaled using the training X.min/X.ran, truncated to [0, 1], and expanded with the same spline basis used during training.

Value

values	Predicted decision values as an n by length(lambda) matrix.
labels	Predicted class labels (-1/1) as an n by length(lambda) matrix.

See Also

samHL

---

predict.samLL *Prediction function for S3 class "samLL"*

Description

Predict class probabilities and labels for test data.

Usage

```
## S3 method for class 'samLL'
predict(object, newdata, thol = 0.5, ...)
```

Arguments

object	An object with S3 class "samLL".
newdata	Numeric test matrix with n rows and d columns.
thol	Decision-value threshold used to convert probabilities to labels. The default value is 0.5.
...	Additional arguments passed to methods; currently unused.

Details

The test matrix is rescaled using the training X.min/X.ran, truncated to [0, 1], and expanded with the same spline basis used during training.

Value

probs	Estimated posterior probabilities as an n by length(lambda) matrix.
labels	Predicted class labels (0/1) as an n by length(lambda) matrix.

See Also

samLL

---

predict.samQL *Prediction function for S3 class "samQL"*

Description

Predict responses for test data.

Usage

```
## S3 method for class 'samQL'
predict(object, newdata, ...)
```

Arguments

object	An object with S3 class "samQL".
newdata	Numeric test matrix with n rows and d columns.
...	Additional arguments passed to methods; currently unused.

Details

The test matrix is rescaled using the training X.min/X.ran, truncated to [0, 1], and expanded with the same spline basis used during training.

Value

values	Predicted responses as an n by length(lambda) matrix.

See Also

samQL

print.samEL *Printing function for S3 class "samEL"*

Description

Print a summary of an object of class "samEL".

Usage

```
## S3 method for class 'samEL'
print(x, ...)
```

Arguments

x	An object with S3 class "samEL"
...	Additional arguments passed to methods; currently unused.

Details

The output includes the regularization path length and its degrees of freedom.

See Also

samEL

print.samHL *Printing function for S3 class "samHL"*

Description

Print a summary of an object of class "samHL".

Usage

```
## S3 method for class 'samHL'
print(x, ...)
```

Arguments

x	An object with S3 class "samHL"
...	Additional arguments passed to methods; currently unused.

Details

The output includes the regularization path length and its degrees of freedom.

See Also

samHL

`print.samLL` *Printing function for S3 class* `"samLL"`

Description

Print a summary of an object of class `"samLL"`.

Usage

```
## S3 method for class 'samLL'
print(x, ...)
```

Arguments

`x`	An object with S3 class `"samLL"`
`...`	Additional arguments passed to methods; currently unused.

Details

The output includes the regularization path length and its degrees of freedom.

See Also

samLL

`print.samQL` *Printing function for S3 class* `"samQL"`

Description

Print a summary of an object of class `"samQL"`.

Usage

```
## S3 method for class 'samQL'
print(x, ...)
```

Arguments

`x`	An object with S3 class `"samQL"`
`...`	Additional arguments passed to methods; currently unused.

Details

The output includes the regularization path length and its degrees of freedom.

See Also

samQL

---

sam *Unified Entry Point for Sparse Additive Modelling*

Description

Fit a sparse additive model by dispatching to the appropriate family-specific function (samQL, samLL, samEL, or samHL).

Usage

```
sam(X, y, p = 3, family = c("gaussian", "binomial", "poisson", "hinge"), ...)
```

Arguments

X	Numeric training matrix with n rows (samples) and d columns (features).
y	Response vector of length n.
p	The number of basis spline functions. The default value is 3.
family	A string specifying the loss family. One of "gaussian" (default), "binomial", "poisson", or "hinge".
...	Additional arguments passed to the family-specific function.

Value

An S3 object of class samQL, samLL, samEL, or samHL, depending on the chosen family.

See Also

samQL, samLL, samEL, samHL

Examples

```
n <- 100; d <- 50
X <- matrix(runif(n * d), n, d)
y <- rnorm(n)
fit <- sam(X, y, family = "gaussian")
fit
```

samEL *Training function of Sparse Additive Poisson Regression*

Description

Fit a sparse additive Poisson regression model on training data.

Usage

```
samEL(
  X,
  y,
  p = 3,
  lambda = NULL,
  nlambda = NULL,
  lambda.min.ratio = 0.25,
  thol = 1e-05,
  max.ite = 1e+05,
  regfunc = "L1",
  dfmax = NULL,
  verbose = FALSE,
  dev.ratio.thr = NULL,
  dev.change.thr = NULL
)
```

Arguments

X	Numeric training matrix with n rows (samples) and d columns (features).
y	Response vector of length n; values must be non-negative integers.
p	The number of basis spline functions. The default value is 3.
lambda	Optional user-supplied regularization sequence. If provided, use a decreasing sequence; warm starts are used along the path and are usually much faster than fitting a single value.
nlambda	The number of lambda values. The default value is 20.
lambda.min.ratio	Smallest lambda as a fraction of lambda.max (the smallest value that keeps all component functions at zero). The default is 0.25.
thol	Stopping tolerance. The default value is 1e-5.
max.ite	Maximum number of iterations. The default value is 1e5.
regfunc	A string indicating the regularizer. The default value is "L1". You can also assign "MCP" or "SCAD" to it.
dfmax	Maximum number of non-zero groups allowed. When the number of non-zero groups reaches dfmax, the regularization path is terminated early. NULL (default) means no limit.

verbose	Logical; if TRUE, print iteration info for each lambda.
dev.ratio.thr	Deviance ratio threshold for early stopping. When the deviance ratio $1-D(\lambda)/D_0$ exceeds this value the regularization path is terminated early. NULL (default) disables this criterion.
dev.change.thr	Relative deviance change threshold for early stopping. When the relative change in deviance over the last few lambda steps falls below this value, the path is terminated. NULL (default) disables this criterion.

Details

The solver combines block coordinate descent, fast iterative soft-thresholding, and Newton updates. Computation is accelerated by warm starts and active-set screening.

Value

p	The number of basis spline functions used in training.
X.min	Per-feature minimums from training data (used to rescale test data).
X.ran	Per-feature ranges from training data (used to rescale test data).
lambda	Sequence of regularization parameters used in training.
w	Solution path matrix with size d*p+1 by length(lambda); each column corresponds to one regularization parameter.
df	Degrees of freedom along the solution path (number of non-zero component functions).
knots	The p-1 by d matrix. Each column contains the knots applied to the corresponding variable.
Boundary.knots	The 2 by d matrix. Each column contains the boundary points applied to the corresponding variable.
func_norm	Functional norm matrix (d by length(lambda)); each column corresponds to one regularization parameter.

See Also

SAM,plot.samEL,print.samEL,predict.samEL

Examples

```
## generating training data
n = 200
d = 100
X = 0.5*matrix(runif(n*d),n,d) + matrix(rep(0.5*runif(n),d),n,d)
u = exp(-2*sin(X[,1]) + X[,2]^2-1/3 + X[,3]-1/2 + exp(-X[,4])+exp(-1)-1+1)
y = rep(0,n)
for(i in 1:n) y[i] = rpois(1,u[i])

## Training
out.trn = samEL(X,y)
out.trn
```

```
## plotting solution path
plot(out.trn)

## generating testing data
nt = 1000
Xt = 0.5*matrix(runif(nt*d),nt,d) + matrix(rep(0.5*runif(nt),d),nt,d)
ut = exp(-2*sin(Xt[,1]) + Xt[,2]^2-1/3 + Xt[,3]-1/2 + exp(-Xt[,4])+exp(-1)-1+1)
yt = rep(0,nt)
for(i in 1:nt) yt[i] = rpois(1,ut[i])

## predicting response
out.tst = predict(out.trn,Xt)
```

---

samHL *Training function of Sparse Additive Hinge-Loss Classifier*

Description

Fit a sparse additive classifier with hinge loss.

Usage

```
samHL(
  X,
  y,
  p = 3,
  lambda = NULL,
  nlambda = NULL,
  lambda.min.ratio = 0.4,
  thol = 1e-05,
  mu = 0.05,
  max.ite = 1e+05,
  w = NULL,
  dfmax = NULL,
  verbose = FALSE
)
```

Arguments

X	Numeric training matrix with n rows (samples) and d columns (features).
y	Training labels of length n. Labels must be coded as -1 and 1.
p	The number of basis spline functions. The default value is 3.
lambda	Optional user-supplied regularization sequence. If provided, use a decreasing sequence; warm starts are used along the path and are usually much faster than fitting a single value.
nlambda	The number of lambda values. The default value is 20.

`lambda.min.ratio`
: Smallest lambda as a fraction of `lambda.max` (the smallest value that keeps all component functions at zero). The default is `0.4`.

`thol`
: Stopping tolerance. The default value is `1e-5`.

`mu`
: Smoothing parameter used to approximate hinge loss. The default value is `0.05`.

`max.ite`
: Maximum number of iterations. The default value is `1e5`.

`w`
: Optional positive observation weights of length `n`. The default is `1` for all observations.

`dfmax`
: Maximum number of non-zero groups allowed. When the number of non-zero groups reaches `dfmax`, the regularization path is terminated early. `NULL` (default) means no limit.

`verbose`
: Logical; if `TRUE`, print iteration info for each lambda.

Details

The solver combines block coordinate descent, fast iterative soft-thresholding, and Newton updates. Computation is accelerated by warm starts and active-set screening.

Value

`p`
: The number of basis spline functions used in training.

`X.min`
: Per-feature minimums from training data (used to rescale test data).

`X.ran`
: Per-feature ranges from training data (used to rescale test data).

`lambda`
: Sequence of regularization parameters used in training.

`w`
: Solution path matrix with size `d*p+1` by `length(lambda)`; each column corresponds to one regularization parameter.

`df`
: Degrees of freedom along the solution path (number of non-zero component functions).

`knots`
: The `p-1` by `d` matrix. Each column contains the knots applied to the corresponding variable.

`Boundary.knots`
: The `2` by `d` matrix. Each column contains the boundary points applied to the corresponding variable.

`func_norm`
: Functional norm matrix (`d` by `length(lambda)`); each column corresponds to one regularization parameter.

See Also

`SAM`,`plot.samHL`,`print.samHL`,`predict.samHL`

Examples

```
## generating training data
n = 200
d = 100
X = 0.5*matrix(runif(n*d),n,d) + matrix(rep(0.5*runif(n),d),n,d)
y = sign(((X[,1]-0.5)^2 + (X[,2]-0.5)^2)-0.06)
```

```
## flipping about 5 percent of y
y = y*sign(runif(n)-0.05)

## Training
out.trn = samHL(X,y)
out.trn

## plotting solution path
plot(out.trn)

## generating testing data
nt = 1000
Xt = 0.5*matrix(runif(nt*d),nt,d) + matrix(rep(0.5*runif(nt),d),nt,d)

yt = sign(((Xt[,1]-0.5)^2 + (Xt[,2]-0.5)^2)-0.06)

## flipping about 5 percent of y
yt = yt*sign(runif(nt)-0.05)

## predicting response
out.tst = predict(out.trn,Xt)
```

---

samLL *Training function of Sparse Additive Logistic Regression*

Description

Fit a sparse additive logistic regression model on training data.

Usage

```
samLL(
  X,
  y,
  p = 3,
  lambda = NULL,
  nlambda = NULL,
  lambda.min.ratio = 0.1,
  thol = 1e-05,
  max.ite = 1e+05,
  regfunc = "L1",
  dfmax = NULL,
  verbose = FALSE,
  dev.ratio.thr = NULL,
  dev.change.thr = NULL
)
```

Arguments

X	Numeric training matrix with n rows (samples) and d columns (features).
y	Binary training labels of length n. Labels must be coded as 0 and 1.
p	The number of basis spline functions. The default value is 3.
lambda	Optional user-supplied regularization sequence. If provided, use a decreasing sequence; warm starts are used along the path and are usually much faster than fitting a single value.
nlambda	The number of lambda values. The default value is 20.
lambda.min.ratio	Smallest lambda as a fraction of lambda.max (the smallest value that keeps all component functions at zero). The default is 0.1.
thol	Stopping tolerance. The default value is 1e-5.
max.ite	Maximum number of iterations. The default value is 1e5.
regfunc	A string indicating the regularizer. The default value is "L1". You can also assign "MCP" or "SCAD" to it.
dfmax	Maximum number of non-zero groups allowed. When the number of non-zero groups reaches dfmax, the regularization path is terminated early. NULL (default) means no limit.
verbose	Logical; if TRUE, print iteration info for each lambda.
dev.ratio.thr	Deviance ratio threshold for early stopping. When the deviance ratio $1-D(\lambda)/D_0$ exceeds this value the regularization path is terminated early. NULL (default) disables this criterion.
dev.change.thr	Relative deviance change threshold for early stopping. When the relative change in deviance over the last few lambda steps falls below this value, the path is terminated. NULL (default) disables this criterion.

Details

The solver combines block coordinate descent, fast iterative soft-thresholding, and Newton updates. Computation is accelerated by warm starts and active-set screening.

Value

p	The number of basis spline functions used in training.
X.min	Per-feature minimums from training data (used to rescale test data).
X.ran	Per-feature ranges from training data (used to rescale test data).
lambda	Sequence of regularization parameters used in training.
w	Solution path matrix with size d*p+1 by length(lambda); each column corresponds to one regularization parameter.
df	Degrees of freedom along the solution path (number of non-zero component functions).
knots	The p-1 by d matrix. Each column contains the knots applied to the corresponding variable.

Boundary.knots	The 2 by d matrix. Each column contains the boundary points applied to the corresponding variable.
func_norm	Functional norm matrix (d by length(lambda)); each column corresponds to one regularization parameter.

See Also

SAM,plot.samLL,print.samLL,predict.samLL

Examples

```
## generating training data
n = 200
d = 100
X = 0.5*matrix(runif(n*d),n,d) + matrix(rep(0.5*runif(n),d),n,d)
y = sign(((X[,1]-0.5)^2 + (X[,2]-0.5)^2)-0.06)

## flipping about 5 percent of y
y = y*sign(runif(n)-0.05)
y = sign(y==1)

## Training
out.trn = samLL(X,y)
out.trn

## plotting solution path
plot(out.trn)

## generating testing data
nt = 1000
Xt = 0.5*matrix(runif(nt*d),nt,d) + matrix(rep(0.5*runif(nt),d),nt,d)

yt = sign(((Xt[,1]-0.5)^2 + (Xt[,2]-0.5)^2)-0.06)

## flipping about 5 percent of y
yt = yt*sign(runif(nt)-0.05)
yt = sign(yt==1)

## predicting response
out.tst = predict(out.trn,Xt)
```

---

samQL *Training function of Sparse Additive Regression with Quadratic Loss*

Description

Fit a sparse additive regression model with quadratic loss.

Usage

```
samQL(
  X,
  y,
  p = 3,
  lambda = NULL,
  nlambda = NULL,
  lambda.min.ratio = 0.005,
  thol = 1e-05,
  max.ite = 1e+05,
  regfunc = "L1",
  dfmax = NULL,
  verbose = FALSE,
  dev.ratio.thr = NULL,
  dev.change.thr = NULL,
  solver = c("actnewton", "actgd"),
  type.gaussian = c("naive", "covariance", "auto")
)
```

Arguments

X	Numeric training matrix with n rows (samples) and d columns (features).
y	Numeric response vector of length n.
p	The number of basis spline functions. The default value is 3.
lambda	Optional user-supplied regularization sequence. If provided, use a decreasing sequence; warm starts are used along the path and are usually much faster than fitting a single value.
nlambda	The number of lambda values. The default value is 30.
lambda.min.ratio	Smallest lambda as a fraction of lambda.max (the smallest value that keeps all component functions at zero). The default is 5e-3.
thol	Stopping tolerance. The default value is 1e-5.
max.ite	Maximum number of iterations. The default value is 1e5.
regfunc	A string indicating the regularizer. The default value is "L1". You can also assign "MCP" or "SCAD" to it.
dfmax	Maximum number of non-zero groups allowed. When the number of non-zero groups reaches dfmax, the regularization path is terminated early. NULL (default) means no limit.
verbose	Logical; if TRUE, print iteration info for each lambda.
dev.ratio.thr	Deviance ratio threshold for early stopping. When the deviance ratio $1-D(\lambda)/D_0$ exceeds this value the regularization path is terminated early. NULL (default) disables this criterion.
dev.change.thr	Relative deviance change threshold for early stopping. When the relative change in deviance over the last few lambda steps falls below this value, the path is terminated. NULL (default) disables this criterion.

solver	Which solver to use: "actnewton" (default, active-set Newton) or "actgd" (group active gradient descent with strong rule screening). "actgd" only supports L1 regularization and is automatically replaced by "actnewton" when regfunc is "MCP" or "SCAD".
type.gaussian	Which internal update strategy to use: "naive" (default) maintains an n-dimensional residual vector, "covariance" precomputes the Gram matrix and updates gradients incrementally. "covariance" is faster when d * p < n and is silently ignored (falls back to "naive") otherwise. "auto" selects automatically based on d * p < n.

Details

The solver combines block coordinate descent, fast iterative soft-thresholding, and Newton updates. Computation is accelerated by warm starts and active-set screening.

Value

p	The number of basis spline functions used in training.
X.min	Per-feature minimums from training data (used to rescale test data).
X.ran	Per-feature ranges from training data (used to rescale test data).
lambda	Sequence of regularization parameters used in training.
w	Solution path matrix with size d*p by length(lambda); each column corresponds to one regularization parameter.
intercept	The solution path of the intercept.
df	Degrees of freedom along the solution path (number of non-zero component functions).
knots	The p-1 by d matrix. Each column contains the knots applied to the corresponding variable.
Boundary.knots	The 2 by d matrix. Each column contains the boundary points applied to the corresponding variable.
func_norm	Functional norm matrix (d by length(lambda)); each column corresponds to one regularization parameter.
sse	Sums of square errors of the solution path.

See Also

SAM,plot.samQL,print.samQL,predict.samQL

Examples

```
## generating training data
n = 100
d = 500
X = 0.5*matrix(runif(n*d),n,d) + matrix(rep(0.5*runif(n),d),n,d)

## generating response
y = -2*sin(X[,1]) + X[,2]^2-1/3 + X[,3]-1/2 + exp(-X[,4])+exp(-1)-1
```

```
## Training
out.trn = samQL(X,y)
out.trn

## plotting solution path
plot(out.trn)

## generating testing data
nt = 1000
Xt = 0.5*matrix(runif(nt*d),nt,d) + matrix(rep(0.5*runif(nt),d),nt,d)

yt = -2*sin(Xt[,1]) + Xt[,2]^2-1/3 + Xt[,3]-1/2 + exp(-Xt[,4])+exp(-1)-1

## predicting response
out.tst = predict(out.trn,Xt)
```

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