Package ‘profoc’

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Description Combine probabilistic forecasts using CRPS learning algorithms proposed in Berrisch, Ziel (2021) <arXiv:2102.00968>. The package implements multiple online learning algorithms like Bernstein online aggregation; see Wintenberger (2014) <arXiv:1404.1356>. Quantile regression is also implemented for comparison purposes. Model parameters can be tuned automatically with respect to the loss of the forecast combination. Methods like predict(), update(), plot() and print() are available for convenience. This package utilizes the optim C++ library for numeric optimization <https://github.com/kthohr/optim>.

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profoc-package

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Description
Use multiple online-aggregation algorithms to combine probabilistic forecasts using CRPS Learning as described in Berrisch, Ziel: "CRPS Learning", 2021. The primary function of this package is called profoc.

Details

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Author(s)

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References

Berrisch, Ziel: "CRPS Learning", 2021

See Also

Source Code: https://github.com/BerriJ/profoc
BugReports: https://github.com/BerriJ/profoc/issues

autplot Create a complete ggplot appropriate to a particular data type

Description

‘autplot()’ uses ggplot2 to draw a particular plot for an object of a particular class in a single command. This defines the S3 generic that other classes and packages can extend.

Usage

autplot(object, ...)

Arguments

object an object, whose class will determine the behaviour of autplot
... other arguments passed to specific methods

Value

a ggplot object

See Also

[autolayer()], [ggplot()] and [fortify()]
Description

Plots the most recent weights in each quantile using ggplot2.

Usage

```r
## S3 method for class 'batch'
autoplot(object, ...)
```

Arguments

- `object` Object of class inheriting from 'batch'
- `...` further arguments are ignored

Description

Plots the most recent weights in each quantile using ggplot2.

Usage

```r
## S3 method for class 'online'
autoplot(object, ...)
```

Arguments

- `object` Object of class inheriting from 'online'
- `...` further arguments are ignored
**batch**  

*Probabilistic Forecast Combination - Batch*

**Description**

Returns predictions and weights calculated by sequential numeric optimization. The optimization is done stepwise, always calculating a one-step-ahead forecast.

**Usage**

```r
batch(
  y,
  experts,
  tau = 1:dim(experts)[2]/(dim(experts)[2] + 1),
  affine = FALSE,
  positive = FALSE,
  intercept = FALSE,
  debias = TRUE,
  lead_time = 0,
  initial_window = 30,
  rolling_window = initial_window,
  loss_function = "quantile",
  loss_parameter = 1,
  qw_crps = FALSE,
  basis_knot_distance = 1/(dim(experts)[2] + 1),
  basis_knot_distance_power = 1,
  basis_deg = 1,
  forget = 0,
  soft_threshold = -Inf,
  hard_threshold = -Inf,
  fixed_share = 0,
  p_smooth_lambda = -Inf,
  p_smooth_knot_distance = basis_knot_distance,
  p_smooth_knot_distance_power = basis_knot_distance_power,
  p_smooth_deg = basis_deg,
  p_smooth_ndiff = 1.5,
  parametergrid_max_combinations = 100,
  parametergrid = NULL,
  forget_past_performance = 0,
  allow_quantile_crossing = FALSE,
  trace = TRUE
)
```

**Arguments**

- **y**  
  A numeric matrix of realizations. In probabilistic settings a matrix of dimension Tx1, in multivariate settings a TxP matrix. In the latter case, each slice of the expert’s array gets evaluated using the corresponding column of the y matrix.
experts An array of predictions with dimension (Observations, Quantiles, Experts).
tau A numeric vector of probabilities.
affine Defines whether weights are summing to 1 or not. Defaults to FALSE.
positive Defines if a positivity constraint is applied to the weights. Defaults to FALSE.
intercept Determines if an intercept is added, defaults to FALSE. If true, a new first expert is added, always predicting 1.
debias Defines whether the intercepts weight is constrained or not. If TRUE (the default), the intercept weight is unconstrained. Only affects the results if affine and or positive is set to TRUE. If FALSE, the intercept is treated as an expert.
lead_time offset for expert forecasts. Defaults to 0, which means that experts forecast t+1 at t. Setting this to h means experts predictions refer to t+1+h at time t. The weight updates delay accordingly.
initial_window Defines the size of the initial estimation window.
rolling_window Defines the size of the rolling window. Defaults to the value of initial_window. Set it to the number of observations to receive an expanding window.
loss_function Either "quantile", "expectile" or "percentage".
loss_parameter Optional parameter scaling the power of the loss function.
qw_crps Decides whether the sum of quantile scores (FALSE) or the quantile weighted CRPS (TRUE) should be minimized. Defaults to FALSE. Which corresponds to Berrisch & Ziel (2021)
basis_knot_distance determines the distance of the knots in the probability basis. Defaults to 1 / (dim(exerts)[2] + 1).
basis_knot_distance_power Parameter which defines the symmetry of the basis reducing the probability space. Defaults to 1, which corresponds to equidistant knots. Values less than 1 create more knots in the center, while values above 1 concentrate more knots in the tails.
basis_deg Degree of the basis reducing the probability space. Defaults to 1.
forget Adds an exponential forgetting to the optimization. Past observations will get less influence on the optimization. Defaults to 0, which corresponds to no forgetting.
soft_threshold If specified, the following soft threshold will be applied to the weights: w = sgn(w)*max(abs(w)-t,0) where t is the soft_threshold parameter. Defaults to -inf, which means that no threshold will be applied. If all expert weights are thresholded to 0, a weight of 1 will be assigned to the expert with the highest weights prior to thresholding. Thus soft_threshold = 1 leads to the 'follow the leader' strategy if method is set to "ewa".
hard_threshold If specified, the following hard thresholding will be applied to the weights: w = w*(abs(w)>t) where t is the threshold_hard parameter. Defaults to -inf, which means that no threshold will be applied. If all expert weights are thresholded to 0, a weight of 1 will be assigned to the expert with the highest weight prior to thresholding. Thus hard_threshold = 1 leads to the 'follow the leader' strategy if method is set to "ewa".
fixed_share  Amount of fixed share to be added to the weights. Defaults to 0. 1 leads to uniform weights.

p_smooth_lambda  
Penalization parameter used in the smoothing step. -Inf causes the smoothing step to be skipped (default).

p_smooth_knot_distance  
determines the distance of the knots. Defaults to the value of basis_knot_distance. Corresponds to the grid steps when knot_distance_power = 1 (the default).

p_smooth_knot_distance_power  
Parameter which defines the symmetry of the P-Spline basis. Takes the value of basis_knot_distance_power if unspecified.

p_smooth_deg  
Degree of the B-Spine basis functions. Defaults to the value of basis_deg.

p_smooth_ndiff  
Degree of the differencing operator in the smoothing equation. 1.5 (default) leads to shrinkage towards a constant. Can take values from 1 to 2. If a value in between is used, a weighted sum of the first and second differentiation matrix is calculated.

parametergrid_max_combinations  
Integer specifying the maximum number of parameter combinations that should be considered. If the number of possible combinations exceeds this threshold, the maximum allowed number is randomly sampled. Defaults to 100.

parametergrid  
User supplied grid of parameters. Can be used if not all combinations of the input vectors should be considered. Must be a matrix with 13 columns (online) or 12 columns batch with the following order: basis_knot_distance, basis_knot_distance_power, basis_deg, forget_regret, soft_threshold, hard_threshold, fixed_share, p_smooth_lambda, p_smooth_knot_distance, p_smooth_knot_distance_power, p_smooth_deg, p_smooth_ndiff, gamma.

forget_past_performance  
Share of past performance not to be considered, resp. to be forgotten in every iteration of the algorithm when selecting the best parameter combination. Defaults to 0.

allow_quantile_crossing  
Shall quantile crossing be allowed? Defaults to false, which means that predictions are sorted in ascending order.

trace  
Print a progress bar to the console? Defaults to TRUE.

Value

Returns weights and corresponding predictions. It is possible to impose a convexity constraint to the weights by setting affine and positive to TRUE.

Examples

```r
## Not run:
T <- 50 # Observations
N <- 2 # Experts
P <- 9 # Quantiles
prob_grid <- 1:P / (P + 1)
```
y <- rnorm(n = T) # Realized
experts <- array(dim = c(T, P, N)) # Predictions
for (t in 1:T) {
  experts[t, , 1] <- qnorm(prob_grid, mean = -1, sd = 1)
  experts[t, , 2] <- qnorm(prob_grid, mean = 3, sd = sqrt(4))
}
model <- batch(
  y = matrix(y),
  experts = experts,
  p_smooth_lambda = 10
)
print(model)
plot(model)
autoplot(model)

## End(Not run)

---

**conline**

---

Create a Student Object from the Student C++ Class

**Description**

Allows for the creation of a Student Object in _C++_ from _R_ using the _C++_ Student class.

**Arguments**

- **name**: Name of Student
- **age**: Age of Student
- **male**: Is Student a Male?

**Value**

A 'Student' object from the _C++_ Student Class.

**Examples**

# TODO
online

Probabilistic Forecast Combination - Online

Description

Returns predictions and weights calculated by online-learning algorithms using CRPS Learning.

Usage

```r
online(
  y,
  experts,
  tau,
  lead_time = 0,
  loss_function = "quantile",
  loss_parameter = 1,
  loss_gradient = TRUE,
  method = "bewa",
  b_smooth_pr = list(knots = P, mu = 0.5, sigma = 1, nonc = 0, tailweight = 1, deg = 1),
  p_smooth_pr = list(knots = P, mu = 0.5, sigma = 1, nonc = 0, tailweight = 1, deg = 1,
                    ndiff = 1.5, lambda = -Inf),
  b_smooth_mv = list(knots = D, mu = 0.5, sigma = 1, nonc = 0, tailweight = 1, deg = 1),
  p_smooth_mv = list(knots = D, mu = 0.5, sigma = 1, nonc = 0, tailweight = 1, deg = 1,
                    ndiff = 1.5, lambda = -Inf),
  forget_regret = 0,
  soft_threshold = -Inf,
  hard_threshold = -Inf,
  fixed_share = 0,
  gamma = 1,
  parametergrid_max_combinations = 100,
  parametergrid = NULL,
  forget_past_performance = 0,
  allow_quantile_crossing = FALSE,
  init = NULL,
  loss = NULL,
  regret = NULL,
  trace = TRUE
)
```

Arguments

- **y**: A numeric matrix of realizations. In probabilistic settings a matrix of dimension Tx1, in multivariate settings a TxP matrix. In the latter case, each slice of the expert’s array gets evaluated using the corresponding column of the y matrix.
- **experts**: An array of predictions with dimension (Observations, Quantiles, Experts).
- **tau**: A numeric vector of probabilities.
lead_time offset for expert forecasts. Defaults to 0, which means that experts forecast \(t+1\) at \(t\). Setting this to \(h\) means experts predictions refer to \(t+1+h\) at time \(t\). The weight updates delay accordingly.

loss_function Either "quantile", "expectile" or "percentage".

loss_parameter Optional parameter scaling the power of the loss function.

loss_gradient Determines if a linearized version of the loss is used.

method One of "boa", "bewa", "ml_poly" or "ewa". Where "bewa" refers to a mixture of boa and ewa, including the second order refinement of boa, but updating weights with the simple exponential weighting.

b_smooth_pr A named list determining how the B-Spline matrices for probabilistic smoothing are created. Default corresponds to no probabilistic smoothing. See details.

p_smooth_pr A named list determining how the hat matrices for probabilistic P-Spline smoothing are created. Default corresponds to no smoothing. See details.

b_smooth_mv A named list determining how the B-Spline matrices for multivariate smoothing are created. Default corresponds to no probabilistic smoothing. See details.

p_smooth_mv A named list determining how the hat matrices for probabilistic P-Spline smoothing are created. Default corresponds to no smoothing. See details.

forget_regret Share of past regret not to be considered, resp. to be forgotten in every iteration of the algorithm. Defaults to 0.

soft_threshold If specified, the following soft threshold will be applied to the weights: \(w = sgn(w) \times \max(abs(w) - t, 0)\) where \(t\) is the soft_threshold parameter. Defaults to -inf, which means that no threshold will be applied. If all expert weights are thresholded to 0, a weight of 1 will be assigned to the expert with the highest weights prior to thresholding. Thus soft_threshold = 1 leads to the 'follow the leader' strategy if method is set to "ewa".

hard_threshold If specified, the following hard thresholding will be applied to the weights: \(w = w \times (abs(w) > t)\) where \(t\) is the threshold_hard parameter. Defaults to -inf, which means that no threshold will be applied. If all expert weights are thresholded to 0, a weight of 1 will be assigned to the expert with the highest weight prior to thresholding. Thus hard_threshold = 1 leads to the 'follow the leader' strategy if method is set to "ewa".

fixed_share Amount of fixed share to be added to the weights. Defaults to 0. 1 leads to uniform weights.

gamma Scaling parameter for the learning rate.

parametergrid_max_combinations Integer specifying the maximum number of parameter combinations that should be considered. If the number of possible combinations exceeds this threshold, the maximum allowed number is randomly sampled. Defaults to 100.

parametergrid User supplied grid of parameters. Can be used if not all combinations of the input vectors should be considered. Must be a matrix with 13 columns (online) or 12 columns batch with the following order: basis_knot_distance, basis_knot_distance_power, basis_deg, forget_regret, soft_threshold, hard_threshold, fixed_share, p_smooth_lambda, p_smooth_knot_distance, p_smooth_knot_distance_power, p_smooth_deg, p_smooth_ndiff, gamma.
online

forget_past_performance
Share of past performance not to be considered, resp. to be forgotten in every iteration of the algorithm when selecting the best parameter combination. Defaults to 0.

allow_quantile_crossing
Shall quantile crossing be allowed? Defaults to false, which means that predictions are sorted in ascending order.

init
A named list containing "init_weights": Array of dimension DxPxK used as starting weights. "R0" a matrix of dimension PxK or 1xK used as starting regret.

loss
User specified loss array. Can also be a list with elements "loss_array" and "share", share mixes the provided loss with the loss calculated by profoc. 1 means, only the provided loss will be used. share can also be vector of shares to consider.

regret
User specified regret array. If specific, the regret will not be calculated by profoc. Can also be a list with elements "regret_array" and "share", share mixes the provided regret with the regret calculated by profoc. 1 means, only the provided regret will be used. share can also be vector of shares to consider.

trace
Print a progress bar to the console? Defaults to TRUE.

Details

online selects various parameters automatically based on the past loss. For this, lambda, forget, fixed_share, gamma, and the smoothing parameters (see below) can be specified as numeric vectors containing values to consider.

This package offers two options for smoothing (Basis Smoothing and P-Splines). Both options can be used to smooth the weights over dimension D (covariates) or P (quantiles) or both. Parameters b_smooth_pr and b_smooth_mv take named lists to create the corresponding basis matrices. The arguments include are: knots which determines the number of knots to be created, mu, sigma, sigma, nonc, tailweight correspond to to parameters of the beta distribution, which defines how the knots are distributed (see ?make_knots2 for details) the defaults will create an equidistant knot sequence, deg sets the degree of the spline function and also influences how many outer knots will be used. It’s possible to provide vectors of values for each of these parameters. In that case, all parameter combinations will be used to create the respective matrices and all candidates will be considered during online-learning. Parameters p_smooth_pr and p_smooth_mv determine the hat-matrix creation for P-Spline smoothing. In addition to the inputs mentioned before, they require to provide ndiff which determines the degree of differentiation applied to the basis-matrix (can take any value between and including 1 and 2), lambda which determines the degree of penalization applied to the smoothing, higher values will give smoother weight functions. As for the other parameters, it is possible to provide multiple values.

Value

Returns weights and corresponding predictions.

Examples

```r
## Not run:
T <- 50 # Observations
```
N <- 2 # Experts
P <- 9 # Quantiles
prob_grid <- 1:P / (P + 1)

y <- rnorm(n = T) # Realized
experts <- array(dim = c(T, P, N)) # Predictions
for (t in 1:T) {
  experts[t, , 1] <- qnorm(prob_grid, mean = -1, sd = 1)
  experts[t, , 2] <- qnorm(prob_grid, mean = 3, sd = sqrt(4))
}

model <- online(
  y = matrix(y),
  experts = experts,
  tau = prob_grid,
  p_smooth_pr = list(lambda = 10)
)

print(model)
plot(model)

new_y <- matrix(rnorm(T)) # Realized
new_experts <- experts[T, , drop = FALSE]

# Update will update the models weights etc if you provide new realizations
model <- update(model, new_y = new_y, new_experts = new_experts)

# Predict will expand $\text{model}predictions$ by default
model <- predict(model, new_experts = new_experts, update_model = TRUE)

## End(Not run)

---

**oracle**

*Probabilistic Forecast Combination - Oracle*

**Description**

Returns predictions and weights calculated by numeric optimization. The optimization is done in hindsight. This means all observations are used.

**Usage**

```
oracle(y, experts, tau, affine = FALSE,
       positive = FALSE, intercept = FALSE, debias = TRUE,
       loss_function = "quantile", loss_parameter = 1, forget = 0)
```

**Arguments**

- `y` A numeric matrix of realizations. In probabilistic settings a matrix of dimension Tx1, in multivariate settings a TxP matrix. In the latter case, each slice of the expert’s array gets evaluated using the corresponding column of the y matrix.
experts  An array of predictions with dimension (Observations, Quantiles, Experts).
tau  A numeric vector of probabilities.
affine  Defines whether weights are summing to 1 or now. Defaults to FALSE.
positive  Defines if a positivity constraint is applied to the weights. Defaults to FALSE.
intercept  Determines if an intercept is added, defaults to FALSE. If true, a new first expert is added, always predicting 1.
debias  Defines whether the intercepts weight is constrained or not. If TRUE (the default), the intercept weight is unconstrained. Only affects the results if affine and or positive is set to TRUE. If FALSE, the intercept is treated as an expert.
loss_function  Either "quantile", "expectile" or "percentage".
loss_parameter  Optional parameter scaling the power of the loss function.
forget  Adds an exponential forgetting to the optimization. Past observations will get less influence on the optimization. Defaults to 0, which corresponds to no forgetting.

Value

Returns weights and corresponding predictions. It is possible to calculate the best convex combination of weights by setting affine and positive to TRUE.

Examples

```r
## Not run:
T <- 50 # Observations
N <- 2 # Experts
P <- 9 # Quantiles
prob_grid <- 1:P / (P + 1)
y <- rnorm(n = T) # Realized
experts <- array(dim = c(T, P, N)) # Predictions
for (t in 1:T) {
  experts[t, , 1] <- qnorm(prob_grid, mean = -1, sd = 1)
  experts[t, , 2] <- qnorm(prob_grid, mean = 3, sd = sqrt(4))
}
model <- oracle(
  y = matrix(y),
  experts = experts
)
## End(Not run)
```
### plot.batch

*Plot method for batch models*

**Description**

Plots the most recent weights in each quantile.

**Usage**

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

**Arguments**

- `x` Object of class inheriting from `batch`
- `...` further arguments are ignored

### plot.online

*Plot method for online models*

**Description**

Plots the most recent weights in each quantile.

**Usage**

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

**Arguments**

- `x` Object of class inheriting from `online`
- `...` further arguments are ignored
predict.online

Predict method for online models

Description
Calculates predictions based on new expert advice. This does not update weights. If new observations are available use update instead. The latter updates and weights and computes predictions.

Usage
## S3 method for class 'online'
predict(object, new_experts, update_model = TRUE, ...)

Arguments
- object: Object of class inheriting from 'online'
- new_experts: new expert predictions
- update_model: Defines whether the model object should be updated or not. If TRUE, new forecaster and expert predictions are appended onto the respective object items. Defaults to TRUE.
- ...: further arguments are ignored

Value
predict.online produces an updated model object.

print.batch
Print method for batch models

Description
Prints the average loss of all and the forecast combination.

Usage
## S3 method for class 'batch'
print(x, ...)

Arguments
- x: Object of class inheriting from 'batch'
- ...: further arguments are ignored
print.online  

*Print method for online models*

**Description**

Prints the average loss of all experts and the forecast combination.

**Usage**

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

**Arguments**

- `x`: Object of class inheriting from 'online'
- `...`: Further arguments are ignored

summary.online  

*Summary method for online models*

**Description**

Calculates parameters chosen during optimization and aggregates losses.

**Usage**

```r
## S3 method for class 'online'
summary(object, ...)
```

**Arguments**

- `object`: Object of class inheriting from 'online'
- `...`: Further arguments are ignored
update.online  

Update method for online models

Description

Continues learning using new observations and new expert advice.

Usage

```r
## S3 method for class 'online'
update(object, new_y, new_experts = NULL, trace = FALSE, ...)
```

Arguments

- `object` Object of class inheriting from 'online'
- `new_y` new observations
- `new_experts` new expert predictions. This must be left unspecified
- `trace` If a progressbar shall be shown. Defaults to FALSE if the model already contains
  the expert predictions corresponding to `new_y`.
- `...` further arguments are ignored

Value

`update.online` produces an updated model object.
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