Package ‘modeltime.ensemble’

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Type Package

Title Ensemble Algorithms for Time Series Forecasting with Modeltime

Version 1.0.2

Description A 'modeltime' extension that implements time series ensemble forecasting methods including model averaging,
weighted averaging, and stacking. These techniques are popular methods
to improve forecast accuracy and stability. Refer to papers such as
``Machine-
Learning Models for Sales Time Series Forecasting'' Pavlyshenko, B.M. (2019) <doi:10.3390>.

URL https://github.com/business-science/modeltime.ensemble

BugReports https://github.com/business-science/modeltime.ensemble/issues

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R topics documented:

`ensemble_average` *Creates an Ensemble Model using Mean/Median Averaging*

Description

Creates an Ensemble Model using Mean/Median Averaging

Usage

```
ensemble_average(object, type = c("mean", "median"))
```

Arguments

`object`	A Modeltime Table
`type`	Specify the type of average ("mean" or "median")

Details

The input to an `ensemble_average()` model is always a Modeltime Table, which contains the models that you will ensemble.

Averaging Methods

The average method uses an un-weighted average using `type` of either:

- `"mean"`: Performs averaging using `mean(x, na.rm = TRUE)` to aggregate each underlying models forecast at each timestamp
- `"median"`: Performs averaging using `stats::median(x, na.rm = TRUE)` to aggregate each underlying models forecast at each timestamp

Value

A `mdl_time_ensemble` object.

Examples

```
library(tidymodels)
library(modeltime)
library(modeltime.ensemble)
library(tidyverse)
library(timetk)

# Make an ensemble from a Modeltime Table
ensemble_fit <- m750_models %>%
    ensemble_average(type = "mean")

ensemble_fit

# Forecast with the Ensemble
modeltime_table(
    ensemble_fit
) %>%
    modeltime_forecast(
        new_data    = testing(m750_splits),
        actual_data = m750
    ) %>%
    plot_modeltime_forecast(
        .interactive = FALSE,
        .conf_interval_show = FALSE
    )
```

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ensemble_model_spec *Creates a Stacked Ensemble Model from a Model Spec*

Description

A 2-stage stacking regressor that follows:

1. Stage 1: Sub-Model's are Trained & Predicted using `modeltime.resample::modeltime_fit_resamples()`.
2. Stage 2: A Meta-learner (`model_spec`) is trained on Out-of-Sample Sub-Model Predictions using `ensemble_model_spec()`.

Usage

```
ensemble_model_spec(
  object,
  model_spec,
  kfolds = 5,
  param_info = NULL,
  grid = 6,
  control = control_grid()
)
```

Arguments

`object`	A Modeltime Table. Used for ensemble sub-models.
`model_spec`	A `model_spec` object defining the meta-learner stacking model specification to be used. Can be either: 1. **A non-tunable `model_spec`:** Parameters are specified and are not optimized via tuning. 2. **A tunable `model_spec`:** Contains parameters identified for tuning with `tune::tune()`
`kfolds`	K-Fold Cross Validation for tuning the Meta-Learner. Controls the number of folds used in the meta-learner's cross-validation. Gets passed to `rsample::vfold_cv()`.
`param_info`	A `dials::parameters()` object or `NULL`. If none is given, a parameters set is derived from other arguments. Passing this argument can be useful when parameter ranges need to be customized.
`grid`	Grid specification or grid size for tuning the Meta Learner. Gets passed to `tune::tune_grid()`.
`control`	An object used to modify the tuning process. Uses `tune::control_grid()` by default. Use `control_grid(verbose = TRUE)` to follow the training process.

Details

Stacked Ensemble Process

- Start with a *Modeltime Table* to define your sub-models.
- Step 1: Use `modeltime_fit_resamples()` to perform the submodel resampling procedure.
- Step 2: Use `ensemble_model_spec()` to define and train the meta-learner.

What goes on inside the Meta Learner?

The Meta-Learner Ensembling Process uses the following basic steps:

1. **Make Cross-Validation Predictions.** Cross validation predictions are made for each sub-model with `modeltime_fit_resamples()`. The out-of-sample sub-model predictions contained in `.resample_results` are used as the input to the meta-learner.
2. **Train a Stacked Regressor (Meta-Learner).** The sub-model out-of-sample cross validation predictions are then modeled using a `model_spec` with options:
   - **Tuning:** If the `model_spec` does include tuning parameters via `tune::tune()` then the meta-learner will be hypeparameter tuned using K-Fold Cross Validation. The parameters and grid can adjusted using `kfolds`, `grid`, and `param_info`.
   - **No-Tuning:** If the `model_spec` does *not* include tuning parameters via `tune::tune()` then the meta-learner will not be hypeparameter tuned and will have the model fitted to the sub-model predictions.
3. **Final Model Selection.**
   - **If tuned**, the final model is selected based on RMSE, then retrained on the full set of out of sample predictions.
   - **If not-tuned**, the fitted model from Stage 2 is used.

Progress

The best way to follow the training process and watch progress is to use `control = control_grid(verbose = TRUE)` to see progress.

Parallelize

Portions of the process can be parallelized. To parallelize, set up parallelization using `tune` via one of the backends such as `doFuture`. Then set `control = control_grid(allow_par = TRUE)`

Value

A `mdl_time_ensemble` object.

Examples

```
library(tidymodels)
library(modeltime)
library(modeltime.ensemble)
library(tidyverse)
library(timetk)

# Step 1: Make resample predictions for submodels
resamples_tscv <- training(m750_splits) %>%
    time_series_cv(
        assess  = "2 years",
        initial = "5 years",
        skip    = "2 years",
        slice_limit = 1
    )

submodel_predictions <- m750_models %>%
    modeltime_fit_resamples(
        resamples = resamples_tscv,
        control   = control_resamples(verbose = TRUE)
    )

# Step 2: Metalearner ----

# * No Metalearner Tuning
ensemble_fit_lm <- submodel_predictions %>%
    ensemble_model_spec(
        model_spec = linear_reg() %>% set_engine("lm"),
        control    = control_grid(verbose = TRUE)
    )

ensemble_fit_lm

# * With Metalearner Tuning ----
ensemble_fit_glmnet <- submodel_predictions %>%
    ensemble_model_spec(
        model_spec = linear_reg(
            penalty = tune(),
```

```
            mixture = tune()
        ) %>%
            set_engine("glmnet"),
        grid       = 2,
        control    = control_grid(verbose = TRUE)
    )

ensemble_fit_glmnet
```

---

ensemble_nested_average

Nested Ensemble Average

Description

Creates an Ensemble Model using Mean/Median Averaging in the Modeltime Nested Forecasting Workflow.

Usage

```
ensemble_nested_average(
  object,
  type = c("mean", "median"),
  keep_submodels = TRUE,
  model_ids = NULL,
  control = control_nested_fit()
)
```

Arguments

object	A nested modeltime object (inherits class `nested_mdl_time`)
type	One of "mean" for mean averaging or "median" for median averaging
keep_submodels	Whether or not to keep the submodels in the nested modeltime table results
model_ids	A vector of id's (`.model_id`) identifying which submodels to use in the ensemble.
control	Controls various aspects of the ensembling process. See `control_nested_fit()`.

Details

If we start with a nested modeltime table, we can add ensembles.

```
nested_modeltime_tbl

# Nested Modeltime Table
```

```
Trained on: .splits | Model Errors: [0]
# A tibble: 2 x 5
  id    .actual_data       .future_data      .splits         .modeltime_tables
  <fct> <list>             <list>            <list>          <list>
1 1_1   <tibble [104 x 2]> <tibble [52 x 2]> <split [52|52]> <mdl_time_tbl [2 x 5]>
2 1_3   <tibble [104 x 2]> <tibble [52 x 2]> <split [52|52]> <mdl_time_tbl [2 x 5]>
```

An ensemble can be added to a Nested modeltime table.

```
ensem <- nested_modeltime_tbl %>%
    ensemble_nested_average(
        type           = "mean",
        keep_submodels = TRUE,
        control        = control_nested_fit(allow_par = FALSE, verbose = TRUE)
    )
```

We can then verify the model has been added.

```
ensem %>% extract_nested_modeltime_table()
```

This produces an ensemble .model_id 3, which is an ensemble of the first two models.

```
# A tibble: 4 x 6
  id    .model_id .model        .model_desc               .type .calibration_data
  <fct>     <dbl> <list>          <chr>                       <chr> <list>
1 1_1           1 <workflow>    PROPHET                   Test  <tibble [52 x 4]>
2 1_1           2 <workflow>    XGBOOST                   Test  <tibble [52 x 4]>
3 1_1          3 <ensemble [2]> ENSEMBLE (MEAN): 2 MODELS  Test  <tibble [52 x 4]>
```

Additional ensembles can be added by simply adding onto the nested modeltime table. Notice that we make use of `model_ids` to make sure it only uses model id's 1 and 2.

```
ensem_2 <- ensem %>%
    ensemble_nested_average(
        type           = "median",
        keep_submodels = TRUE,
        model_ids      = c(1,2),
        control        = control_nested_fit(allow_par = FALSE, verbose = TRUE)
    )
```

This returns a 4th model that is a median ensemble of the first two models.

```
ensem_2 %>% extract_nested_modeltime_table()
# A tibble: 4 x 6
  id    .model_id .model        .model_desc               .type .calibration_data
  <fct>     <dbl> <list>          <chr>                       <chr> <list>
1 1_1           1 <workflow>    PROPHET                   Test  <tibble [52 x 4]>
2 1_1           2 <workflow>    XGBOOST                   Test  <tibble [52 x 4]>
3 1_1          3 <ensemble [2]> ENSEMBLE (MEAN): 2 MODELS  Test  <tibble [52 x 4]>
4 1_1          4 <ensemble [2]> ENSEMBLE (MEDIAN): 2 MODELS Test  <tibble [52 x 4]>
```

ensemble_nested_weighted

Nested Ensemble Weighted

Description

Creates an Ensemble Model using Weighted Averaging in the Modeltime Nested Forecasting Workflow.

Usage

```
ensemble_nested_weighted(
  object,
  loadings,
  scale_loadings = TRUE,
  metric = "rmse",
  keep_submodels = TRUE,
  model_ids = NULL,
  control = control_nested_fit()
)
```

Arguments

object	A nested modeltime object (inherits class nested_mdl_time)
loadings	A vector of weights corresponding to the loadings
scale_loadings	If TRUE, divides by the sum of the loadings to proportionally weight the submodels.
metric	The accuracy metric to rank models by the test accuracy table. Loadings are then applied in the order from best to worst models. Default: "rmse".
keep_submodels	Whether or not to keep the submodels in the nested modeltime table results
model_ids	A vector of id's (.model_id) identifying which submodels to use in the ensemble.
control	Controls various aspects of the ensembling process. See control_nested_fit().

Details

If we start with a nested modeltime table, we can add ensembles.

```
nested_modeltime_tbl

# Nested Modeltime Table
Trained on: .splits | Model Errors: [0]
# A tibble: 2 x 5
  id    .actual_data       .future_data      .splits         .modeltime_tables
  <fct> <list>             <list>            <list>          <list>
1 1_1   <tibble [104 x 2]> <tibble [52 x 2]> <split [52|52]> <mdl_time_tbl [2 x 5]>
2 1_3   <tibble [104 x 2]> <tibble [52 x 2]> <split [52|52]> <mdl_time_tbl [2 x 5]>
```

An ensemble can be added to a Nested modeltime table.

```
ensem <- nested_modeltime_tbl %>%
    ensemble_nested_weighted(
        loadings       = c(2,1),
        control        = control_nested_fit(allow_par = FALSE, verbose = TRUE)
    )
```

We can then verify the model has been added.

```
ensem %>% extract_nested_modeltime_table()
```

This produces an ensemble .model_id 3, which is an ensemble of the first two models.

```
# A tibble: 4 x 6
  id    .model_id .model         .model_desc                .type .calibration_data
  <fct>     <dbl> <list>           <chr>                          <chr> <list>
1 1_3         1 <workflow>    PROPHET                     Test  <tibble [52 x 4]>
2 1_3         2 <workflow>    XGBOOST                     Test  <tibble [52 x 4]>
3 1_3        3 <ensemble [2]> ENSEMBLE (WEIGHTED): 2 MODELS Test  <tibble [52 x 4]>
```

We can verify the loadings have been applied correctly. Note that the loadings will be applied based on the model with the lowest RMSE.

```
ensem %>%
    extract_nested_modeltime_table(1) %>%
    slice(3) %>%
    pluck(".model", 1)
```

Note that the xgboost model gets the 66% loading and prophet gets 33% loading. This is because xgboost has the lower RMSE in this case.

```
-- Modeltime Ensemble -------------------------------------------
    Ensemble of 2 Models (WEIGHTED)

# Modeltime Table
# A tibble: 2 x 6
  .model_id .model     .model_desc .type .calibration_data .loadings
      <int> <list>     <chr>       <chr> <list>                <dbl>
1         1 <workflow> PROPHET     Test  <tibble [52 x 4]>     0.333
2         2 <workflow> XGBOOST     Test  <tibble [52 x 4]>     0.667
```

ensemble_weighted *Creates a Weighted Ensemble Model*

Description

Makes an ensemble by applying `loadings` to weight sub-model predictions

Usage

```
ensemble_weighted(object, loadings, scale_loadings = TRUE)
```

Arguments

`object`	A Modeltime Table
`loadings`	A vector of weights corresponding to the loadings
`scale_loadings`	If TRUE, divides by the sum of the loadings to proportionally weight the submodels.

Details

The input to an `ensemble_weighted()` model is always a Modeltime Table, which contains the models that you will ensemble.

Weighting Method

The weighted method uses uses `loadings` by applying a *loading x model prediction* for each submodel.

Value

A `mdl_time_ensemble` object.

Examples

```
library(tidymodels)
library(modeltime)
library(modeltime.ensemble)
library(tidyverse)
library(timetk)

# Make an ensemble from a Modeltime Table
ensemble_fit <- m750_models %>%
    ensemble_weighted(
        loadings = c(3, 3, 1),
        scale_loadings = TRUE
    )

ensemble_fit
```

```
# Forecast with the Ensemble
modeltime_table(
    ensemble_fit
) %>%
    modeltime_forecast(
        new_data    = testing(m750_splits),
        actual_data = m750
    ) %>%
    plot_modeltime_forecast(
        .interactive = FALSE,
        .conf_interval_show = FALSE
    )
```

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