EasyML Library

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Chapter 1

Documentation

Welcome to the EasyML library documentation! EasyML is a set of classic machine learning algorithms written in C++. It extensively uses the `Armadillo` library which in turn uses the LAPACK library to work with vectors and matrices. `Boost` is also used, for example, to obtain object's human-readable type during runtime and to work with probability distributions.

Supported models and solvers:

- Linear Regression
  - Ordinary Least Squares
  - QR-decomposition
  - Derivative-based: Gradient Descent, Newton (single feature only)
- Logistic Regression
  - Derivative-based: Gradient Descent, Newton (single feature only)
- Autoregressive AR(p)
  - Ordinary Least Squares
  - QR-decomposition
  - Derivative-based: Gradient Descent, Newton (single lag only)

Supported transformers and extractors:

- Standard scaler (z-score transformation)
- Time series (extract features and target from process)

More models and possibly transformers to be implemented in future versions.

Installation instructions and examples of usage can be found in the GitHub `repo` of the author.

A good way to start is to browse the Class Hierarchy section.

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Chapter 2

Hierarchical Index

2.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

Chapter 3

Class Index

3.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 4

File Index

4.1 File List

Here is a list of all documented files with brief descriptions:

Chapter 5

Class Documentation

5.1 AutoRegExtractor Class Reference

Features and target extractor class for Autoregressive AR(p) model.

`#include <autoreg_extractor.hpp>`

Public Member Functions

- AutoRegExtractor (const size_t p)
  Construct a new AutoRegExtractor object of order p.
- const Features extract_X (TimeSeries &process)
  Extract feature variables: $\{X_{t-i}\}, i = 1 \dots p$.
- const Target extract_y (TimeSeries &process)
  Extract target variable: y_t.
- const std::string get_name () const
  Get extractor's name.

Private Attributes

- size_t p_
- std::string name_
  Extractor's name (string).

5.1.1 Detailed Description

Features and target extractor class for Autoregressive AR(p) model.

5.1.2 Constructor & Destructor Documentation

5.1.2.1 AutoRegExtractor()

```
AutoRegExtractor::AutoRegExtractor (
            const size_t p )
```

Construct a new AutoRegExtractor object of order p.

5.1.3 Member Function Documentation

5.1.3.1 extract_X()

```
const Features AutoRegExtractor::extract_X (
            TimeSeries & process )
```

Extract feature variables: $\{X_{t-i}\}, i = 1 \dots p$.

Parameters

process	Time series vector

Returns

const Types::Features

5.1.3.2 extract_y()

```
const Target AutoRegExtractor::extract_y (
            TimeSeries & process )
```

Extract target variable: y_t.

Parameters

process	Time series vector

Returns

const Types::Target

5.1.3.3 get_name()

```
const std::string AutoRegExtractor::get_name ( ) const
```

Get extractor's name.

Returns

std::string

5.1.4 Member Data Documentation

5.1.4.1 p_

```
size_t AutoRegExtractor::p_  [private]
```

Order of lag.

5.1.4.2 name_

```
std::string AutoRegExtractor::name_  [private]
```

Extractor's name (string).

The documentation for this class was generated from the following file:

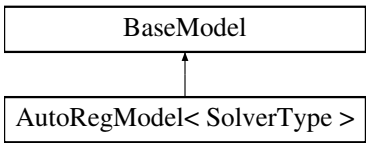
- autoreg_extractor.hpp

5.2 AutoRegModel< SolverType > Class Template Reference

Autoregressive AR(p) model class template. Inherits from BaseModel class.

```
#include <autoreg_model.hpp>
```

Inheritance diagram for AutoRegModel< SolverType >:



Public Member Functions

- AutoRegModel (const SolverType &solver)
  Construct a new AutoRegModel object.
- const Weights get_weights () const
  Get model's weights.
- const double get_sigma () const
  Get model's sigma (standard deviation).
- const size_t get_order () const
  Get model's order (lag).
- const AutoRegModel fit (Features &X, const Target &y)
  Fit AR(p) model.
- const TimeSeries predict (const Features &X, const size_t num_periods) const
  Predict future values of time series with fitted model.

Public Member Functions inherited from BaseModel

- BaseModel ()
  Construct a new BaseModel object.
- virtual ~BaseModel ()
  Destroy the BaseModel object.
- const BaseModel fit (const Features &X, const Target &y)
  Fit model.
- const Target predict (const Features &X) const
  Predict target variable with fitted model.
- const bool is_fitted () const
  Check if model is fitted.
- const std::string get_name () const
  Get model's name.

Private Attributes

- Weights weights_

  Row vector of model's weights.
- double sigma_

  Model's sigma (standard deviation).
- size_t p_

  Model's order (lag).
- SolverType solver_

  Solver to fit model with.

Additional Inherited Members

Protected Member Functions inherited from BaseModel

- void mark_as_fitted_ ()

  Mark model as fitted.

Protected Attributes inherited from BaseModel

- std::string name_

  Model's name (string).

5.2.1 Detailed Description

template<typename SolverType>
class AutoRegModel< SolverType >

Autoregressive AR(p) model class template. Inherits from BaseModel class.

Template Parameters

SolverType	class of solver: BaseSolver, OLSSolver, QRSolver, DerivativeSolver

5.2.2 Constructor & Destructor Documentation

5.2.2.1 AutoRegModel()

```
template<typename SolverType >
AutoRegModel< SolverType >::AutoRegModel (
            const SolverType & solver )
```

Construct a new AutoRegModel object.

Parameters

solver	Solver type

5.2.3 Member Function Documentation

5.2.3.1 get_weights()

```
template<typename SolverType >
const Weights AutoRegModel< SolverType >::get_weights ( ) const
```

Get model's weights.

Returns

const Types::Weights

5.2.3.2 get_sigma()

```
template<typename SolverType >
const double AutoRegModel< SolverType >::get_sigma ( ) const
```

Get model's sigma (standard deviation).

Returns

const double

5.2.3.3 get_order()

```
template<typename SolverType >
const size_t AutoRegModel< SolverType >::get_order ( ) const
```

Get model's order (lag).

Returns

const size_t

5.2.3.4 fit()

```
template<typename SolverType >
const AutoRegModel AutoRegModel< SolverType >::fit (
            Features & X,
            const Target & y )
```

Fit AR(p) model.

Parameters

X	Matrix of feature variables extracted with AutoRegExtractor
y	Column vector of target variable extracted with AutoRegExtractor

Returns

AutoRegModel

5.2.3.5 predict()

```
template<typename SolverType >
const TimeSeries AutoRegModel< SolverType >::predict (
            const Features & X,
            const size_t num_periods ) const
```

Predict future values of time series with fitted model.

Parameters

X	Matrix of feature variables extracted with AutoRegExtractor
num_periods	Number of forecast periods

Returns

const TimeSeries

5.2.4 Member Data Documentation

5.2.4.1 weights_

```
template<typename SolverType >
Weights AutoRegModel< SolverType >::weights_  [private]
```

Row vector of model's weights.

5.2.4.2 sigma_

```
template<typename SolverType >
double AutoRegModel< SolverType >::sigma_  [private]
```

Model's sigma (standard deviation).

5.2.4.3 p_

```
template<typename SolverType >
size_t AutoRegModel< SolverType >::p_  [private]
```

Model's order (lag).

5.2.4.4 solver_

```
template<typename SolverType >
SolverType AutoRegModel< SolverType >::solver_  [private]
```

Solver to fit model with.

The documentation for this class was generated from the following file:

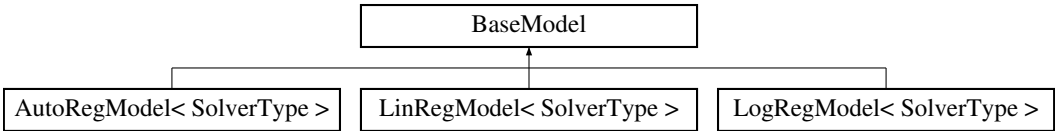
- autoreg_model.hpp

5.3 BaseModel Class Reference

Base Model class. All concrete model classes must inherit from this class.

```
#include <base_model.hpp>
```

Inheritance diagram for BaseModel:



Public Member Functions

- BaseModel ()
  Construct a new BaseModel object.
- virtual ~BaseModel ()
  Destroy the BaseModel object.
- const BaseModel fit (const Features &X, const Target &y)
  Fit model.
- const Target predict (const Features &X) const
  Predict target variable with fitted model.
- const bool is_fitted () const
  Check if model is fitted.
- const std::string get_name () const
  Get model's name.

Protected Member Functions

- void mark_as_fitted_ ()
  Mark model as fitted.

Protected Attributes

- std::string name_
  Model's name (string).

Private Attributes

- bool fitted_
- Target y_mean_

  Base predictions – simply the mean value of target variable.

5.3.1 Detailed Description

Base Model class. All concrete model classes must inherit from this class.

5.3.2 Constructor & Destructor Documentation

5.3.2.1 BaseModel()

```
BaseModel::BaseModel ( )
```

Construct a new BaseModel object.

5.3.2.2 ~BaseModel()

```
virtual BaseModel::~BaseModel ( )  [virtual]
```

Destroy the BaseModel object.

5.3.3 Member Function Documentation

5.3.3.1 fit()

```
const BaseModel BaseModel::fit (
            const Features & X,
            const Target & y )
```

Fit model.

Returns

BaseModel

5.3.3.2 predict()

```
const Target BaseModel::predict (
            const Features & X ) const
```

Predict target variable with fitted model.

Parameters

X	Matrix of feature variables

Returns

const Types::Target

5.3.3.3 is_fitted()

```
const bool BaseModel::is_fitted ( ) const
```

Check if model is fitted.

Returns

true

false

5.3.3.4 get_name()

```
const std::string BaseModel::get_name ( ) const
```

Get model's name.

Returns

std::string

5.3.3.5 mark_as_fitted_()

```
void BaseModel::mark_as_fitted_ ( )  [protected]
```

Mark model as fitted.

5.3.4 Member Data Documentation

5.3.4.1 name_

```
std::string BaseModel::name_  [protected]
```

Model's name (string).

5.3.4.2 fitted_

```
bool BaseModel::fitted_  [private]
```

Model is fitted flag.

5.3.4.3 y_mean_

```
Target BaseModel::y_mean_  [private]
```

Base predictions – simply the mean value of target variable.

The documentation for this class was generated from the following file:

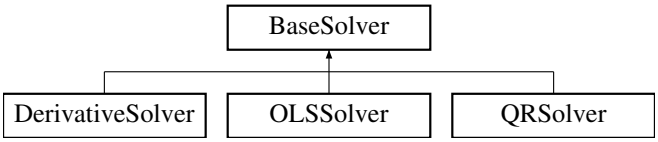
- base_model.hpp

5.4 BaseSolver Class Reference

Base Solver class. All concrete solver classes must inherit from this class.

```
#include <base_solver.hpp>
```

Inheritance diagram for BaseSolver:



Public Member Functions

- BaseSolver (const bool verbose=false)
  Construct a new Base Solver object.
- virtual ~BaseSolver ()
  Destroy the Base Solver object.
- const Weights optimize (Weights &w, const Features &X, const Target &y)
  Return optimized weights.
- const std::string get_name () const
  Get solver's name.

Protected Attributes

- std::string name_
  Solver's name (string).
- bool verbose_
  Show solver's steps flag.

5.4.1 Detailed Description

Base Solver class. All concrete solver classes must inherit from this class.

5.4.2 Constructor & Destructor Documentation

5.4.2.1 BaseSolver()

```
BaseSolver::BaseSolver (
            const bool verbose = false )
```

Construct a new Base Solver object.

Parameters

verbose	Show solver's steps flag

5.4.2.2 ~BaseSolver()

```
virtual BaseSolver::~BaseSolver ( )  [virtual]
```

Destroy the Base Solver object.

5.4.3 Member Function Documentation

5.4.3.1 optimize()

```
const Weights BaseSolver::optimize (
            Weights & w,
            const Features & X,
            const Target & y )
```

Return optimized weights.

Parameters

w	Column vector of weights
X	Matrix of feature variables
y	Column vector of target variable

Returns

Types::Weights

5.4.3.2 get_name()

```
const std::string BaseSolver::get_name ( ) const
```

Get solver's name.

Returns

std::string

5.4.4 Member Data Documentation

5.4.4.1 name_

```
std::string BaseSolver::name_  [protected]
```

Solver's name (string).

5.4.4.2 verbose_

```
bool BaseSolver::verbose_  [protected]
```

Show solver's steps flag.

The documentation for this class was generated from the following file:

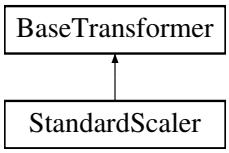
- base_solver.hpp

5.5 BaseTransformer Class Reference

Base Transformer class. All concrete transformer classes must inherit from this class.

`#include <base_transformer.hpp>`

Inheritance diagram for BaseTransformer:



Public Member Functions

- BaseTransformer ()
  Construct a new Base Transformer object.
- virtual ~BaseTransformer ()
  Destroy the Base Transformer object.
- BaseTransformer fit (Features &X)
  Fit transformer.
- const Features transform (Features &X)
  Transform feature variables with fitted model.
- const Features fit_transform (Features &X)
  Fit transformer, then transform feature variables.
- const bool is_fitted () const
  Check if transformer is fitted.
- const std::string get_name () const
  Get transformer's name.

Protected Member Functions

- void mark_as_fitted_ ()

  Mark transformer as fitted.

Protected Attributes

- std::string name_

  Transformer's name (string).

Private Attributes

- bool fitted_

5.5.1 Detailed Description

Base Transformer class. All concrete transformer classes must inherit from this class.

5.5.2 Constructor & Destructor Documentation

5.5.2.1 BaseTransformer()

```
BaseTransformer::BaseTransformer ( )
```

Construct a new Base Transformer object.

5.5.2.2 ~BaseTransformer()

```
virtual BaseTransformer::~BaseTransformer ( )  [virtual]
```

Destroy the Base Transformer object.

5.5.3 Member Function Documentation

5.5.3.1 fit()

```
BaseTransformer BaseTransformer::fit (
            Features & X )
```

Fit transformer.

Returns

BaseTransformer

5.5.3.2 transform()

```
const Features BaseTransformer::transform (
            Features & X )
```

Transform feature variables with fitted model.

Parameters

X	Matrix of feature variables

Returns

const Types::Target

5.5.3.3 fit_transform()

```
const Features BaseTransformer::fit_transform (
            Features & X )
```

Fit transformer, then transform feature variables.

Parameters

X	Matrix of feature variables

Returns

const Types::Features

5.5.3.4 is_fitted()

```
const bool BaseTransformer::is_fitted ( ) const
```

Check if transformer is fitted.

Returns

true

false

5.5.3.5 get_name()

```
const std::string BaseTransformer::get_name ( ) const
```

Get transformer's name.

Returns

std::string

5.5.3.6 mark_as_fitted_()

```
void BaseTransformer::mark_as_fitted_ ( )  [protected]
```

Mark transformer as fitted.

5.5.4 Member Data Documentation

5.5.4.1 name_

```
std::string BaseTransformer::name_  [protected]
```

Transformer's name (string).

5.5.4.2 fitted_

```
bool BaseTransformer::fitted_  [private]
```

Transformer is fitted flag.

The documentation for this class was generated from the following file:

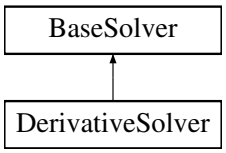
- base_transformer.hpp

5.6 DerivativeSolver Class Reference

Derivative Solver class. Inherits from BaseSolver class.

`#include <derivative_solver.hpp>`

Inheritance diagram for DerivativeSolver:



Public Member Functions

- DerivativeSolver (const std::function< Derivative(const Weights &, const Features &, const Target &)> &diff↩ _loss_func, const double learning_rate, const size_t max_iter, const double min_grad_size, const bool verbose)

  Construct a new Derivative Solver object.
- const Weights optimize (Weights &w, const Features &X, const Target &y)

  Return learned weights by using gradient descent for MSE loss function.
- const Derivative compute_derivative (const Weights &w, const Features &X, const Target &y)

  Compute derivative of loss function.

Public Member Functions inherited from BaseSolver

- BaseSolver (const bool verbose=false)

  Construct a new Base Solver object.
- virtual ~BaseSolver ()

  Destroy the Base Solver object.
- const Weights optimize (Weights &w, const Features &X, const Target &y)

  Return optimized weights.
- const std::string get_name () const

  Get solver's name.

Private Attributes

- const std::function< Derivative(const Weights &, const Features &, const Target &)> & diff_loss_func_

  Derivative of loss function used for computing optimization step.
- const double learning_rate_

  Learning rate.
- const size_t max_iter_

  Max number of optimization iterations.
- const double min_derivative_size_

  Min size of the vector of derivative.

Additional Inherited Members

Protected Attributes inherited from BaseSolver

- std::string name_

  Solver's name (string).
- bool verbose_

  Show solver's steps flag.

5.6.1 Detailed Description

Derivative Solver class. Inherits from BaseSolver class.

5.6.2 Constructor & Destructor Documentation

5.6.2.1 DerivativeSolver()

```
DerivativeSolver::DerivativeSolver (
            const std::function< Derivative(const Weights &, const Features &, const Target
&)> & diff_loss_func,
            const double learning_rate,
            const size_t max_iter,
            const double min_grad_size,
            const bool verbose )
```

Construct a new Derivative Solver object.

Parameters

diff_loss_func	Derivative of loss function
learning_rate	Learning rate
max_iter	Max number of optimization iterations
min_grad_size	Min size of the vector of derivative
verbose	

5.6.3 Member Function Documentation

5.6.3.1 optimize()

```
const Weights DerivativeSolver::optimize (
            Weights & w,
            const Features & X,
            const Target & y )
```

Return learned weights by using gradient descent for MSE loss function.

Parameters

w	Row vector of weights
X	Matrix of feature variables
y	Column vector of target variable

Returns

Types::Weights

5.6.3.2 compute_derivative()

```
const Derivative DerivativeSolver::compute_derivative (
            const Weights & w,
            const Features & X,
            const Target & y )
```

Compute derivative of loss function.

Parameters

w	Row vector of weights
X	Matrix of feature variables
y	Column vector of target variable

Returns

Types::Derivative

5.6.4 Member Data Documentation

5.6.4.1 diff_loss_func_

```
const std::function<Derivative(const Weights&, const Features&, const Target&)>& Derivative↩
Solver::diff_loss_func_  [private]
```

Derivative of loss function used for computing optimization step.

5.6.4.2 learning_rate_

```
const double DerivativeSolver::learning_rate_  [private]
```

Learning rate.

5.6.4.3 max_iter_

```
const size_t DerivativeSolver::max_iter_  [private]
```

Max number of optimization iterations.

5.6.4.4 min_derivative_size_

```
const double DerivativeSolver::min_derivative_size_  [private]
```

Min size of the vector of derivative.

The documentation for this class was generated from the following file:

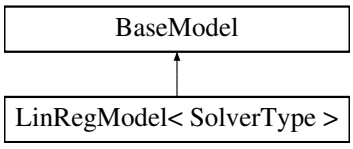
- derivative_solver.hpp

5.7 LinRegModel< SolverType > Class Template Reference

Linear Regression model class template. Inherits from BaseModel class.

```
#include <linreg_model.hpp>
```

Inheritance diagram for LinRegModel< SolverType >:



Public Member Functions

- LinRegModel (const SolverType &solver)
  Construct a new LinRegModel object.
- const Weights get_weights () const
  Get model's weights.
- const LinRegModel fit (Features &X, const Target &y)
  Fit model.
- const Target predict (const Features &X) const
  Predict target variable with fitted model.

Public Member Functions inherited from BaseModel

- BaseModel ()
  Construct a new BaseModel object.
- virtual ~BaseModel ()
  Destroy the BaseModel object.
- const BaseModel fit (const Features &X, const Target &y)
  Fit model.
- const Target predict (const Features &X) const
  Predict target variable with fitted model.
- const bool is_fitted () const
  Check if model is fitted.
- const std::string get_name () const
  Get model's name.

Private Attributes

- Weights weights_
  Row vector of model's weights.
- SolverType solver_
  Solver to fit model with.

Additional Inherited Members

Protected Member Functions inherited from BaseModel

- void mark_as_fitted_ ()
  Mark model as fitted.

Protected Attributes inherited from BaseModel

- std::string name_
  Model's name (string).

5.7.1 Detailed Description

template<typename SolverType>
class LinRegModel< SolverType >

Linear Regression model class template. Inherits from BaseModel class.

Template Parameters

SolverType	class of solver: BaseSolver, OLSSolver, QRSolver, DerivativeSolver

5.7.2 Constructor & Destructor Documentation

5.7.2.1 LinRegModel()

```
template<typename SolverType >
LinRegModel< SolverType >::LinRegModel (
            const SolverType & solver )
```

Construct a new LinRegModel object.

5.7.3 Member Function Documentation

5.7.3.1 get_weights()

```
template<typename SolverType >
const Weights LinRegModel< SolverType >::get_weights ( ) const
```

Get model's weights.

Returns

const Types::Weights

5.7.3.2 fit()

```
template<typename SolverType >
const LinRegModel LinRegModel< SolverType >::fit (
            Features & X,
            const Target & y )
```

Fit model.

Parameters

X	Matrix of feature variables
y	Column vector of target variable

Returns

LinRegModel

5.7.3.3 predict()

```
template<typename SolverType >
const Target LinRegModel< SolverType >::predict (
             const Features & X ) const
```

Predict target variable with fitted model.

Parameters

X	Matrix of feature variables

Returns

const Types::Target

5.7.4 Member Data Documentation

5.7.4.1 weights_

```
template<typename SolverType >
Weights LinRegModel< SolverType >::weights_  [private]
```

Row vector of model's weights.

5.7.4.2 solver_

```
template<typename SolverType >
SolverType LinRegModel< SolverType >::solver_  [private]
```

Solver to fit model with.

The documentation for this class was generated from the following file:

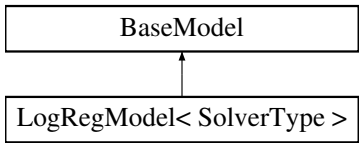
- linreg_model.hpp

5.8 LogRegModel< SolverType > Class Template Reference

Logistic Regression model class template. Inherits from BaseModel class.

```
#include <logreg_model.hpp>
```

Inheritance diagram for LogRegModel< SolverType >:



Public Member Functions

- LogRegModel (const SolverType &solver)
  Construct a new LogRegModel object.
- const Weights get_weights () const
  Get model's weights.
- const LogRegModel fit (Features &X, const Target &y)
  Fit model.
- const Target predict (const Features &X, const double &threshold=0.5) const
  Predict (classify) target variable's class with fitted model at given threshold.
- const Target predict_proba (const Features &X) const
  Predict probability of positive class of target variable with fitted model.

Public Member Functions inherited from BaseModel

- BaseModel ()
  Construct a new BaseModel object.
- virtual ~BaseModel ()
  Destroy the BaseModel object.
- const BaseModel fit (const Features &X, const Target &y)
  Fit model.
- const Target predict (const Features &X) const
  Predict target variable with fitted model.
- const bool is_fitted () const
  Check if model is fitted.
- const std::string get_name () const
  Get model's name.

Private Attributes

- Weights weights_
  Row vector of model's weights.
- SolverType solver_
  Solver to fit model with.

Additional Inherited Members

Protected Member Functions inherited from BaseModel

- void mark_as_fitted_ ()
  Mark model as fitted.

Protected Attributes inherited from BaseModel

- std::string name_
  Model's name (string).

5.8.1 Detailed Description

template<typename SolverType>
class LogRegModel< SolverType >

Logistic Regression model class template. Inherits from BaseModel class.

Template Parameters

SolverType	class of solver: BaseSolver, DerivativeSolver

5.8.2 Constructor & Destructor Documentation

5.8.2.1 LogRegModel()

```
template<typename SolverType >
LogRegModel< SolverType >::LogRegModel (
            const SolverType & solver )
```

Construct a new LogRegModel object.

5.8.3 Member Function Documentation

5.8.3.1 get_weights()

```
template<typename SolverType >
const Weights LogRegModel< SolverType >::get_weights ( ) const
```

Get model's weights.

Returns

const Types::Weights

5.8.3.2 fit()

```
template<typename SolverType >
const LogRegModel LogRegModel< SolverType >::fit (
            Features & X,
            const Target & y )
```

Fit model.

Parameters

X	Matrix of feature variables
y	Column vector of target variable

Returns

LogRegModel

5.8.3.3 predict()

```
template<typename SolverType >
const Target LogRegModel< SolverType >::predict (
             const Features & X,
             const double & threshold = 0.5 ) const
```

Predict (classify) target variable's class with fitted model at given threshold.

Positive class is 1 and negative class is 0

Parameters

X	Matrix of feature variables
threshold	Threshold [0, 1] (double)

Returns

const Types::Target

5.8.3.4 predict_proba()

```
template<typename SolverType >
const Target LogRegModel< SolverType >::predict_proba (
             const Features & X ) const
```

Predict probability of positive class of target variable with fitted model.

Parameters

X	Matrix of feature variables

Returns

const Types::Target

5.8.4 Member Data Documentation

5.8.4.1 weights_

```
template<typename SolverType >
Weights LogRegModel< SolverType >::weights_  [private]
```

Row vector of model's weights.

5.8.4.2 solver_

```
template<typename SolverType >
SolverType LogRegModel< SolverType >::solver_  [private]
```

Solver to fit model with.

The documentation for this class was generated from the following file:

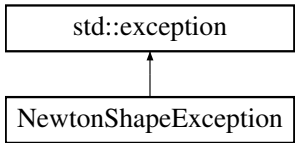
- logreg_model.hpp

5.9 NewtonShapeException Class Reference

NewtonShapeException class. Inherits from std::exception class.

```
#include <exceptions.hpp>
```

Inheritance diagram for NewtonShapeException:



Public Member Functions

- NewtonShapeException ()

  Construct a new NewtonShapeException object.
- const std::string what ()

  Return detailed description of exception.

5.9.1 Detailed Description

NewtonShapeException class. Inherits from std::exception class.

5.9.2 Constructor & Destructor Documentation

5.9.2.1 NewtonShapeException()

```
NewtonShapeException::NewtonShapeException ( )  [inline]
```

Construct a new NewtonShapeException object.

5.9.3 Member Function Documentation

5.9.3.1 what()

```
const std::string NewtonShapeException::what ( )  [inline]
```

Return detailed description of exception.

Returns

const std::string

The documentation for this class was generated from the following file:

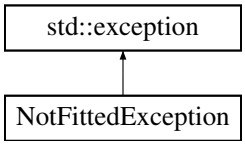
- exceptions.hpp

5.10 NotFittedException Class Reference

NotFittedException class. Inherits from std::exception class.

`#include <exceptions.hpp>`

Inheritance diagram for NotFittedException:



Public Member Functions

- NotFittedException (const std::string &obj_name)
  Construct a new NotFittedException object.
- const std::string what ()
  Return detailed description of exception.

Private Attributes

- std::string obj_name_
  Object's name.

5.10.1 Detailed Description

NotFittedException class. Inherits from std::exception class.

5.10.2 Constructor & Destructor Documentation

5.10.2.1 NotFittedException()

```
NotFittedException::NotFittedException (
            const std::string & obj_name )  [inline]
```

Construct a new NotFittedException object.

Parameters

obj_name	Object's name

5.10.3 Member Function Documentation

5.10.3.1 what()

```
const std::string NotFittedException::what ( )  [inline]
```

Return detailed description of exception.

Returns

const std::string

5.10.4 Member Data Documentation

5.10.4.1 obj_name_

```
std::string NotFittedException::obj_name_  [private]
```

Object's name.

The documentation for this class was generated from the following file:

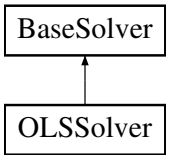
- exceptions.hpp

5.11 OLSSolver Class Reference

Ordinary Least Squares solver class. Inherits from BaseSolver class.

```
#include <ols_solver.hpp>
```

Inheritance diagram for OLSSolver:



Public Member Functions

- OLSSolver ()

  Construct a new Ordinary Least Squares Solver object.
- const Weights optimize (Weights &w, const Features &X, const Target &y)

  Return optimized weights using ordinary least squares closed-form formula.

Public Member Functions inherited from BaseSolver

- BaseSolver (const bool verbose=false)

  Construct a new Base Solver object.
- virtual ~BaseSolver ()

  Destroy the Base Solver object.
- const Weights optimize (Weights &w, const Features &X, const Target &y)

  Return optimized weights.
- const std::string get_name () const

  Get solver's name.

Additional Inherited Members

Protected Attributes inherited from BaseSolver

- std::string name_

  Solver's name (string).
- bool verbose_

  Show solver's steps flag.

5.11.1 Detailed Description

Ordinary Least Squares solver class. Inherits from BaseSolver class.

Template Parameters

SolverType	Type (class) of solver

5.11.2 Constructor & Destructor Documentation

5.11.2.1 OLSSolver()

```
OLSSolver::OLSSolver ( )
```

Construct a new Ordinary Least Squares Solver object.

5.11.3 Member Function Documentation

5.11.3.1 optimize()

```
const Weights OLSSolver::optimize (
            Weights & w,
            const Features & X,
            const Target & y )
```

Return optimized weights using ordinary least squares closed-form formula.

Parameters

w	Row vector of weights – not used
X	Matrix of feature variables
y	Column vector of target variable

Returns

Types::Weights

The documentation for this class was generated from the following file:

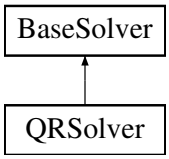
- ols_solver.hpp

5.12 QRSolver Class Reference

QR-decomposition solver class. Inherits from BaseSolver class.

`#include <qr_solver.hpp>`

Inheritance diagram for QRSolver:



Public Member Functions

- QRSolver ()
  Construct a new QR Solver object.
- const Weights optimize (Weights &w, const Features &X, const Target &y)
  Return optimized weights using QR-decomposition closed-form formula.

Public Member Functions inherited from BaseSolver

- BaseSolver (const bool verbose=false)
  Construct a new Base Solver object.
- virtual ~BaseSolver ()
  Destroy the Base Solver object.
- const Weights optimize (Weights &w, const Features &X, const Target &y)
  Return optimized weights.
- const std::string get_name () const
  Get solver's name.

Additional Inherited Members

Protected Attributes inherited from BaseSolver

- std::string name_

  Solver's name (string).
- bool verbose_

  Show solver's steps flag.

5.12.1 Detailed Description

QR-decomposition solver class. Inherits from BaseSolver class.

Template Parameters

SolverType	Type (class) of solver

5.12.2 Constructor & Destructor Documentation

5.12.2.1 QRSolver()

```
QRSolver::QRSolver ( )
```

Construct a new QR Solver object.

https://en.wikipedia.org/wiki/QR_decomposition

5.12.3 Member Function Documentation

5.12.3.1 optimize()

```
const Weights QRSolver::optimize (
            Weights & w,
            const Features & X,
            const Target & y )
```

Return optimized weights using QR-decomposition closed-form formula.

Parameters

w	Row vector of weights – not used
X	Matrix of feature variables
y	Column vector of target variable

Returns

Types::Weights

The documentation for this class was generated from the following file:

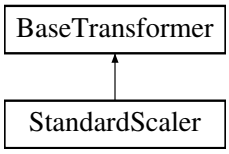
- qr_solver.hpp

5.13 StandardScaler Class Reference

Standard Scaler (z-score transformation) class. Inherits from BaseTransformer class.

`#include <standard_scaler.hpp>`

Inheritance diagram for StandardScaler:



Public Member Functions

- StandardScaler ()
  Construct a new Standard Scaler object.
- StandardScaler fit (Features &X)
  Fit scaler.
- const Features transform (Features &X)
  Transform feature variables with fitted scaler.
- const Features fit_transform (Features &X)
  Fit scaler, then transform feature variables.
- const Features get_means () const
  Return matrix of learned means with shape of features.
- const Features get_stddevs () const
  Return matrix of learned standard deviations with shape of features.

Public Member Functions inherited from BaseTransformer

- BaseTransformer ()
  Construct a new Base Transformer object.
- virtual ~BaseTransformer ()
  Destroy the Base Transformer object.
- BaseTransformer fit (Features &X)
  Fit transformer.
- const Features transform (Features &X)
  Transform feature variables with fitted model.
- const Features fit_transform (Features &X)
  Fit transformer, then transform feature variables.
- const bool is_fitted () const
  Check if transformer is fitted.
- const std::string get_name () const
  Get transformer's name.

Private Attributes

- Features means_

  Learned means of features.
- Features stddevs_

  Learned standard deviations of features.

Additional Inherited Members

Protected Member Functions inherited from BaseTransformer

- void mark_as_fitted_ ()

  Mark transformer as fitted.

Protected Attributes inherited from BaseTransformer

- std::string name_

  Transformer's name (string).

5.13.1 Detailed Description

Standard Scaler (z-score transformation) class. Inherits from BaseTransformer class.

Template Parameters

SolverType	Type (class) of solver

5.13.2 Constructor & Destructor Documentation

5.13.2.1 StandardScaler()

```
StandardScaler::StandardScaler ( )
```

Construct a new Standard Scaler object.

5.13.3 Member Function Documentation

5.13.3.1 fit()

```
StandardScaler StandardScaler::fit (
            Features & X )
```

Fit scaler.

Parameters

X	Matrix of feature variables

Returns

StandardScaler

5.13.3.2 transform()

```
const Features StandardScaler::transform (
            Features & X )
```

Transform feature variables with fitted scaler.

Parameters

X	Matrix of feature variables

Returns

const Types::Features

5.13.3.3 fit_transform()

```
const Features StandardScaler::fit_transform (
            Features & X )
```

Fit scaler, then transform feature variables.

Parameters

X	Matrix of feature variables

Returns

const Types::Features

5.13.3.4 get_means()

```
const Features StandardScaler::get_means ( ) const
```

Return matrix of learned means with shape of features.

Returns

const Types::Features

5.13.3.5 get_stddevs()

```
const Features StandardScaler::get_stddevs ( ) const
```

Return matrix of learned standard deviations with shape of features.

Returns

const Types::Features

5.13.4 Member Data Documentation

5.13.4.1 means_

```
Features StandardScaler::means_  [private]
```

Learned means of features.

5.13.4.2 stddevs_

```
Features StandardScaler::stddevs_  [private]
```

Learned standard deviations of features.

The documentation for this class was generated from the following file:

- standard_scaler.hpp

Chapter 6

File Documentation

6.1 autoreg_extractor.hpp File Reference

AutoRegExtractor class declarations.

```
#include ¨types.hpp¨
```

Classes

- class AutoRegExtractor

  Features and target extractor class for Autoregressive AR(p) model.

6.1.1 Detailed Description

AutoRegExtractor class declarations.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-04-25

Copyright

6.2 autoreg_model.hpp File Reference

AutoRegModel class declarations.

```
#include ¨types.hpp¨
#include ¨base_model.hpp¨
```

Classes

- class AutoRegModel< SolverType >

  Autoregressive AR(p) model class template. Inherits from BaseModel class.

6.2.1 Detailed Description

AutoRegModel class declarations.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-04-25

Copyright

6.3 base_model.hpp File Reference

BaseModel class declarations.

```
#include ¨types.hpp¨
```

Classes

- class BaseModel

  Base Model class. All concrete model classes must inherit from this class.

6.3.1 Detailed Description

BaseModel class declarations.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-03-20

Copyright

6.4 base_solver.hpp File Reference

BaseSolver class declarations.

```
#include <functional>
#include ¨types.hpp¨
```

Classes

- class BaseSolver

  Base Solver class. All concrete solver classes must inherit from this class.

6.4.1 Detailed Description

BaseSolver class declarations.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-03-20

Copyright

6.5 base_transformer.hpp File Reference

BaseTransformer class declarations.

```
#include ¨types.hpp¨
```

Classes

- class BaseTransformer

  Base Transformer class. All concrete transformer classes must inherit from this class.

6.5.1 Detailed Description

BaseTransformer class declarations.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-03-20

Copyright

6.6 derivative_solver.hpp File Reference

DerivativeSolver class declarations.

```
#include <functional>
#include ¨types.hpp¨
#include ¨base_solver.hpp¨
```

Classes

- class DerivativeSolver

  Derivative Solver class. Inherits from BaseSolver class.

6.6.1 Detailed Description

DerivativeSolver class declarations.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-03-28

Copyright

6.7 diff_loss_functions.hpp File Reference

Derivatives of loss functions declarations and implementation.

```
#include <functional>
#include <armadillo>
#include ¨types.hpp¨
#include ¨predict_functions.hpp¨
#include ¨exceptions.hpp¨
```

Functions

- static const Derivative DiffLoss::mean_squared_error_loss_grad (const Weights &w, const Features &X, const Target &y_true)

  Gradient (first derivative) of Mean Squared Error loss.
- static const Derivative DiffLoss::mean_squared_error_loss_lapl (const Features &X)

  Laplacian (second derivative) of Mean Squared Error loss.
- static const Derivative DiffLoss::mean_squared_error_loss_newton (const Weights &w, const Features &X, const Target &y_true)

  Gradient to Laplacian ratio (Newton) of Mean Squared Error loss.
- static const Derivative DiffLoss::log_likelihood_loss_grad (const Weights &w, const Features &X, const Target &y_true)

  Gradient (first derivative) of Log Likelihood loss.
- static const Derivative DiffLoss::log_likelihood_loss_lapl (const Weights &w, const Features &X)

  Laplacian (second derivative) of Log Likelihood loss.
- static const Derivative DiffLoss::log_likelihood_loss_newton (const Weights &w, const Features &X, const Target &y_true)

  Gradient to Laplacian ratio (Newton) of Log Likelihood loss.

Variables

- static const std::function< Derivative(const Weights &, const Features &, const Target &)> DiffLoss::MEAN_SQUARED_ERROR = mean_squared_error_loss_grad

  Alias for DiffLoss::mean_squared_error_loss_grad function.
- static const std::function< Derivative(const Weights &, const Features &, const Target &)> DiffLoss::MEAN_SQUARED_ERROR = mean_squared_error_loss_newton

  Alias for mean_squared_error_loss_newton function.
- static const std::function< Derivative(const Weights &, const Features &, const Target &)> DiffLoss::LOG_LIKELIHOOD_LOSS = log_likelihood_loss_grad

  Alias for log_likelihood_loss_grad function.
- static const std::function< Derivative(const Weights &, const Features &, const Target &)> DiffLoss::LOG_LIKELIHOOD_LOSS = log_likelihood_loss_newton

  Alias for log_likelihood_loss_newton function.

6.7.1 Detailed Description

Derivatives of loss functions declarations and implementation.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-03-20

Copyright

6.7.2 Function Documentation

6.7.2.1 mean_squared_error_loss_grad()

```
static const Derivative DiffLoss::mean_squared_error_loss_grad (
            const Weights & w,
            const Features & X,
            const Target & y_true )  [static]
```

Gradient (first derivative) of Mean Squared Error loss.

$\nabla L_{MSE} = -\frac{2}{n}\sum_{i=1}^{n} X^T(y_i - \hat{y}_i)$, where X is the features matrix, y is the target vector, $\hat{y}$ is the model's predictions vector, n is the number of predictions.

Parameters

w	Row vector of weights
X	Matrix of feature variables
y_true	Column vector of target variable

Returns

const Types::Derivative

6.7.2.2 mean_squared_error_loss_lapl()

```
static const Derivative DiffLoss::mean_squared_error_loss_lapl (
            const Features & X )  [static]
```

Laplacian (second derivative) of Mean Squared Error loss.

$\nabla(\nabla L_{MSE}) = \frac{2}{n}\sum X^T X$, where X is the features matrix, n is the number of observations.

Parameters

X	Matrix of feature variables

Returns

const Types::Derivative

6.7.2.3 mean_squared_error_loss_newton()

```
static const Derivative DiffLoss::mean_squared_error_loss_newton (
            const Weights & w,
            const Features & X,
            const Target & y_true )  [static]
```

Gradient to Laplacian ratio (Newton) of Mean Squared Error loss.

$$\text{Step} = \frac{\nabla L_{MSE}}{\nabla(\nabla L_{MSE})}$$

Parameters

w	Row vector of weights
X	Matrix of feature variables
y_true	Column vector of target variable

Returns

const Types::Derivative

6.7.2.4 log_likelihood_loss_grad()

```
static const Derivative DiffLoss::log_likelihood_loss_grad (
            const Weights & w,
            const Features & X,
            const Target & y_true )  [static]
```

Gradient (first derivative) of Log Likelihood loss.

$\nabla L_{LOG} = -\frac{1}{n}\sum_{i=1}^{n} X^T(y_i - \hat{y}_i)$, where X is the features matrix, y is the target vector, $\hat{y}$ is the model's predictions vector, n is the number of predictions.

Parameters

w	Row vector of weights
X	Matrix of feature variables
y_true	Column vector of target variable

Returns

const Types::Derivative

6.7.2.5 log_likelihood_loss_lapl()

```
static const Derivative DiffLoss::log_likelihood_loss_lapl (
            const Weights & w,
            const Features & X )  [static]
```

Laplacian (second derivative) of Log Likelihood loss.

$\nabla(\nabla L_{LOG}) = \frac{1}{n}\sum_{i=1}^{n} X^T\hat{y}_i(1-\hat{y}_i)^T$, where X is the features matrix, $\hat{y}$ is the model's predictions vector, n is the number of predictions.

Parameters

w	Row vector of weights
X	Matrix of feature variables

Returns

const Types::Derivative

6.7.2.6 log_likelihood_loss_newton()

```
static const Derivative DiffLoss::log_likelihood_loss_newton (
            const Weights & w,
            const Features & X,
            const Target & y_true )  [static]
```

Gradient to Laplacian ratio (Newton) of Log Likelihood loss.

$$\text{Step} = \frac{\nabla L_{LOG}}{\nabla(\nabla L_{LOG})}$$

Parameters

w	Row vector of weights
X	Matrix of feature variables
y_true	Column vector of target variable

Returns

const Types::Derivative

6.7.3 Variable Documentation

6.7.3.1 MEAN_SQUARED_ERROR_LOSS_GRAD

```
const std::function<Derivative(const Weights&, const Features&, const Target&)> DiffLoss::↩
MEAN_SQUARED_ERROR_LOSS_GRAD = mean_squared_error_loss_grad  [static]
```

Alias for DiffLoss::mean_squared_error_loss_grad function.

6.7.3.2 MEAN_SQUARED_ERROR_LOSS_NEWTON

```
const std::function<Derivative(const Weights&, const Features&, const Target&)> DiffLoss::↩
MEAN_SQUARED_ERROR_LOSS_NEWTON = mean_squared_error_loss_newton  [static]
```

Alias for mean_squared_error_loss_newton function.

6.7.3.3 LOG_LIKELIHOOD_LOSS_GRAD

```
const std::function<Derivative(const Weights&, const Features&, const Target&)> DiffLoss::↩
LOG_LIKELIHOOD_LOSS_GRAD = log_likelihood_loss_grad  [static]
```

Alias for log_likelihood_loss_grad function.

6.7.3.4 LOG_LIKELIHOOD_LOSS_NEWTON

```
const std::function<Derivative(const Weights&, const Features&, const Target&)> DiffLoss::↩
LOG_LIKELIHOOD_LOSS_NEWTON = log_likelihood_loss_newton  [static]
```

Alias for log_likelihood_loss_newton function.

6.8 exceptions.hpp File Reference

Custom exceptions declarations and implementation.

```
#include <string>
```

Classes

- class NotFittedException

  NotFittedException class. Inherits from std::exception class.
- class NewtonShapeException

  NewtonShapeException class. Inherits from std::exception class.

6.8.1 Detailed Description

Custom exceptions declarations and implementation.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-03-20

Copyright

Copyright (c) 2024

6.9 linreg_model.hpp File Reference

LinRegModel class declarations.

```
#include "types.hpp"
#include "base_model.hpp"
```

Classes

- class LinRegModel< SolverType >

  Linear Regression model class template. Inherits from BaseModel class.

6.9.1 Detailed Description

LinRegModel class declarations.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-03-20

Copyright

Copyright (c) 2024

6.10 logreg_model.hpp File Reference

LogRegModel class declarations.

```
#include ¨types.hpp¨
#include ¨base_model.hpp¨
#include ¨base_solver.hpp¨
#include ¨derivative_solver.hpp¨
```

Classes

- class LogRegModel< SolverType >

  Logistic Regression model class template. Inherits from BaseModel class.

6.10.1 Detailed Description

LogRegModel class declarations.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-03-27

Copyright

Copyright (c) 2024

6.11 metrics.hpp File Reference

Model metrics declarations and implementation.

```
#include <armadillo>
#include ¨types.hpp¨
#include ¨predict_functions.hpp¨
```

Functions

- static const double Metrics::mse (const Target &y_true, const Target &y_pred)

  Compute Mean Squared Error of predictions.
- static const double Metrics::sse (const Target &y_true, const Target &y_pred)

  Compute Sum Squared Error of predictions. In fact, $nMSE(y, \hat{y})$.
- static const double Metrics::sst (const Target &y_true)

  Compute Sum Squared Total variance of target. In fact, $nVar(y)$.
- static const double Metrics::r2 (const Target &y_true, const Target &y_pred)

  Coefficient of determination of predictions.
- static const double Metrics::accuracy (const Target &y_true, const Target &y_pred)

  Normalized accuracy score of predictions for binary classifier.
- static const size_t Metrics::tp_count (const Target &y_true, const Target &y_pred)

  True Positives count.
- static const size_t Metrics::fp_count (const Target &y_true, const Target &y_pred)

  False Positives count.
- static const size_t Metrics::tn_count (const Target &y_true, const Target &y_pred)

  True Negatives count.
- static const size_t Metrics::fn_count (const Target &y_true, const Target &y_pred)

  False Negatives count.
- static const ConfusionMatrix Metrics::confusion_matrix (const Target &y_true, const Target &y_pred)

  Return confusion matrix.
- static const double Metrics::precision (const Target &y_true, const Target &y_pred)

  Precision (Positive class).
- static const double Metrics::recall (const Target &y_true, const Target &y_pred)

  Recall (Positive class). Same as True Positive Rate. Same as Sensitivity.
- static const double Metrics::fpr (const Target &y_true, const Target &y_pred)

  False Positive Rate. Same as Fall-out. Same as probability of Type I error (falsely rejecting correct null hypothesis).
- static const double Metrics::f1_score (const Target &y_true, const Target &y_pred)

  F1-score (Positive class).
- static const PRCurve Metrics::pr_curve (const Target &y_true, const Target &y_pred_proba, const size_t num=101)

  Compute Precision-Recall curve: Metrics::precision vs Metrics::recall for different classification thresholds.
- static const ROCCurve Metrics::roc_curve (const Target &y_true, const Target &y_pred_proba, const size_t num=101)

  Compute Receiver Operating Characteristic (ROC) curve: Metrics::recall vs Metrics::fpr for different classification thresholds.
- static const TPs Metrics::tp_curve (const Target &y_true, const Target &y_pred_proba, const size_t num=101)

  Compute True Positives curve: Metrics::tp_count vs classification threshold.
- static const FPs Metrics::fp_curve (const Target &y_true, const Target &y_pred_proba, const size_t num=101)

  Compute False Positives curve: Metrics::fp_count vs classification threshold.

- static const TNs Metrics::tn_curve (const Target &y_true, const Target &y_pred_proba, const size_t num=101)

  Compute True Negatives curve: Metrics::tn_count vs classification threshold.
- static const FNs Metrics::fn_curve (const Target &y_true, const Target &y_pred_proba, const size_t num=101)

  Compute False Negatives curve: Metrics::fn_count vs classification threshold.
- static const double Metrics::auc (const std::pair< const arma::drowvec, const arma::drowvec > &pair)

  Area Under Curve for Metrics::pr_curve or Metrics::roc_curve.

6.11.1 Detailed Description

Model metrics declarations and implementation.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-03-20

Copyright

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6.11.2 Function Documentation

6.11.2.1 mse()

```
static const double Metrics::mse (
            const Target & y_true,
            const Target & y_pred )  [static]
```

Compute Mean Squared Error of predictions.

$MSE(y, \hat{y}) = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2$, where y is the target vector, $\hat{y}$ is model's predictions vector, n is the number of predictions.

Parameters

y_true	Column vector of ground truth target
y_pred	Column vector of predicted target

Returns

const double

6.11.2.2 sse()

```
static const double Metrics::sse (
            const Target & y_true,
            const Target & y_pred )  [static]
```

Compute Sum Squared Error of predictions. In fact, $nMSE(y, \hat{y})$.

$SSE(y, \hat{y}) = \sum_{i=1}^{n}(y_i - \hat{y}_i)^2$, where y is the target vector, $\hat{y}$ is model's predictions vector, n is the number of predictions.

Parameters

y_true	Column vector of ground truth target
y_pred	Column vector of predicted target

Returns

const double

6.11.2.3 sst()

```
static const double Metrics::sst (
            const Target & y_true )  [static]
```

Compute Sum Squared Total variance of target. In fact, $nVar(y)$.

$SST(y) = \sum_{i=1}^{n}(y_i - \bar{y})^2$, where y is the target vector, $\bar{y}$ is target vector's mean, n is the number of predictions.

Parameters

y_true	Column vector of ground truth target

Returns

const double

6.11.2.4 r2()

```
static const double Metrics::r2 (
            const Target & y_true,
            const Target & y_pred )  [static]
```

Coefficient of determination of predictions.

$R^2 = 1 - \frac{SSE(y, \hat{y})}{SST(y)}$. Can also be expressed as $R^2 = 1 - \frac{nMSE(y, \hat{y})}{nVar(y)} = 1 - \frac{MSE(y, \hat{y})}{Var(y)}$, where SSE is Metrics::sse, SST is Metrics::sst, MSE is Metrics::mse.

Parameters

y_true	Column vector of ground truth target
y_pred	Column vector of predicted target

Returns

const double

6.11.2.5 accuracy()

```
static const double Metrics::accuracy (
            const Target & y_true,
            const Target & y_pred )  [static]
```

Normalized accuracy score of predictions for binary classifier.

$Acc = \frac{1}{n} \sum_{i=1}^{n} [\hat{y} = y]$, where y is the target vector, $\hat{y}$ is the model's predictions vector, n is the number of predictions.

Parameters

y_true	Column vector of ground truth target
y_pred	Column vector of predicted target

Returns

const double

6.11.2.6 tp_count()

```
static const size_t Metrics::tp_count (
            const Target & y_true,
            const Target & y_pred )  [static]
```

True Positives count.

$TP = |\{y|y = 1\} \cap \{\hat{y}|\hat{y} = 1\}|$, where y is the target vector, $\hat{y}$ is the model's predictions vector.

Parameters

y_true	Column vector of ground truth target
y_pred	Column vector of predicted target

Returns

const size_t

6.11.2.7 fp_count()

```
static const size_t Metrics::fp_count (
            const Target & y_true,
            const Target & y_pred )  [static]
```

False Positives count.

$FP = |\{y|y = 0\} \cap \{\hat{y}|\hat{y} = 1\}|$, where y is the target vector, $\hat{y}$ is the model's predictions vector.

Parameters

y_true	Column vector of ground truth target
y_pred	Column vector of predicted target

Returns

const size_t

6.11.2.8 tn_count()

```
static const size_t Metrics::tn_count (
            const Target & y_true,
            const Target & y_pred )  [static]
```

True Negatives count.

$TN = |\{y|y = 0\} \cap \{\hat{y}|\hat{y} = 0\}|$, where y is the target vector, $\hat{y}$ is the model's predictions vector.

Parameters

y_true	Column vector of ground truth target
y_pred	Column vector of predicted target

Returns

const size_t

6.11.2.9 fn_count()

```
static const size_t Metrics::fn_count (
            const Target & y_true,
            const Target & y_pred )  [static]
```

False Negatives count.

$FN = |\{y|y = 1\} \cap \{\hat{y}|\hat{y} = 0\}|$, where y is the target vector, $\hat{y}$ is the model's predictions vector.

Parameters

y_true	Column vector of ground truth target
y_pred	Column vector of predicted target

Returns

const size_t

6.11.2.10 confusion_matrix()

```
static const ConfusionMatrix Metrics::confusion_matrix (
            const Target & y_true,
            const Target & y_pred )  [static]
```

Return confusion matrix.

	$y = 1$	$y = 0$
$\hat{y} = 1$	Metrics::tp_count	Metrics::fp_count
$\hat{y} = 0$	Metrics::fn_count	Metrics::tn_count

Parameters

y_true	Column vector of ground truth target
y_pred	Column vector of predicted target

Returns

const Types::ConfusionMatrix

6.11.2.11 precision()

```
static const double Metrics::precision (
            const Target & y_true,
            const Target & y_pred )  [static]
```

Precision (Positive class).

$Precision = P(y = 1|\hat{y} = 1) = \frac{P(y = 1 \cap \hat{y} = 1)}{P(\hat{y}) = 1} = \frac{TP}{TP + FP}$, where y is the target vector, $\hat{y}$ is the model's predictions vector.

Parameters

y_true	Column vector of ground truth target
y_pred	Column vector of predicted target

Returns

const double

6.11.2.12 recall()

```
static const double Metrics::recall (
            const Target & y_true,
            const Target & y_pred )  [static]
```

Recall (Positive class). Same as True Positive Rate. Same as Sensitivity.

$Recall = P(y = 1|\hat{y} = 1) = \frac{P(y = 1 \cap \hat{y} = 1)}{P(y) = 1} = \frac{TP}{TP + FN}$, where y is the target vector, $\hat{y}$ is the model's predictions vector.

Parameters

y_true	Column vector of ground truth target
y_pred	Column vector of predicted target

Returns

const double

6.11.2.13 fpr()

```
static const double Metrics::fpr (
            const Target & y_true,
            const Target & y_pred )  [static]
```

False Positive Rate. Same as Fall-out. Same as probability of Type I error (falsely rejecting correct null hypothesis).

$Fallout = P(y = 0|\hat{y} = 1) = \frac{P(y = 0 \cap \hat{y} = 1)}{P(y) = 0} = \frac{FP}{FP + TN}$, where y is the target vector, $\hat{y}$ is the model's predictions vector.

Parameters

y_true	Column vector of ground truth target
y_pred	Column vector of predicted target

Returns

const double

6.11.2.14 f1_score()

```
static const double Metrics::f1_score (
            const Target & y_true,
            const Target & y_pred )  [static]
```

F1-score (Positive class).

$$F_1 = 2 \times \frac{Precision \times Recall}{Precision + Recall}$$

Parameters

y_true	Column vector of ground truth target
y_pred	Column vector of predicted target

Returns

const double

6.11.2.15 pr_curve()

```
static const PRCurve Metrics::pr_curve (
            const Target & y_true,
            const Target & y_pred_proba,
            const size_t num = 101 )  [static]
```

Compute Precision-Recall curve: Metrics::precision vs Metrics::recall for different classification thresholds.

Parameters

y_true	Column vector of ground truth target
y_pred_proba	Column vector of predicted probabilities of positive class
num	Number of thresholds

Returns

const Types::PrecisionsRecalls

6.11.2.16 roc_curve()

```
static const ROCCurve Metrics::roc_curve (
            const Target & y_true,
            const Target & y_pred_proba,
            const size_t num = 101 )  [static]
```

Compute Receiver Operating Characteristic (ROC) curve: Metrics::recall vs Metrics::fpr for different classification thresholds.

Parameters

y_true	Column vector of ground truth target
y_pred_proba	Column vector of predicted probabilities of positive class
num	Number of thresholds

Returns

const Types::PrecisionsRecalls

6.11.2.17 tp_curve()

```
static const TPs Metrics::tp_curve (
            const Target & y_true,
            const Target & y_pred_proba,
            const size_t num = 101 )  [static]
```

Compute True Positives curve: Metrics::tp_count vs classification threshold.

Parameters

y_true	Column vector of ground truth target
y_pred_proba	Column vector of predicted probabilities of positive class
num	Number of thresholds

Returns

const Types::TPs

6.11.2.18 fp_curve()

```
static const FPs Metrics::fp_curve (
            const Target & y_true,
            const Target & y_pred_proba,
            const size_t num = 101 )  [static]
```

Compute False Positives curve: Metrics::fp_count vs classification threshold.

Parameters

y_true	Column vector of ground truth target
y_pred_proba	Column vector of predicted probabilities of positive class
num	Number of thresholds

Returns

const Types::FPs

6.11.2.19 tn_curve()

```
static const TNs Metrics::tn_curve (
            const Target & y_true,
            const Target & y_pred_proba,
            const size_t num = 101 )  [static]
```

Compute True Negatives curve: Metrics::tn_count vs classification threshold.

Parameters

y_true	Column vector of ground truth target
y_pred_proba	Column vector of predicted probabilities of positive class
num	Number of thresholds

Returns

const Types::TNs

6.11.2.20 fn_curve()

```
static const FNs Metrics::fn_curve (
            const Target & y_true,
            const Target & y_pred_proba,
            const size_t num = 101 )  [static]
```

Compute False Negatives curve: Metrics::fn_count vs classification threshold.

Parameters

y_true	Column vector of ground truth target
y_pred_proba	Column vector of predicted probabilities of positive class
num	Number of thresholds

Returns

const Types::FNs

6.11.2.21 auc()

```
static const double Metrics::auc (
            const std::pair< const arma::drowvec, const arma::drowvec > & pair )  [static]
```

Area Under Curve for Metrics::pr_curve or Metrics::roc_curve.

$$AUC_{PR} = \int_0^1 Precision(Recall) \mathrm{d}Recall$$

$$AUC_{ROC} = \int_0^1 Recall(Fallout) \mathrm{d}Fallout$$

Parameters

pair	Metrics::PRCurve or Metrics::ROCCurve (arma::drowvec)

Returns

const double

6.12 ols_solver.hpp File Reference

OLSSolver class declarations.

```
#include ¨types.hpp¨
#include ¨base_solver.hpp¨
```

Classes

- class OLSSolver

  Ordinary Least Squares solver class. Inherits from BaseSolver class.

6.12.1 Detailed Description

OLSSolver class declarations.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-03-20

Copyright

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6.13 predict_functions.hpp File Reference

Prediction functions declarations and implementation.

```
#include <armadillo>
#include ¨types.hpp¨
```

Functions

- static const Target Predict::linreg (const Features &X, const Weights &w)
  Predict function for linear regression.
- static const Target Predict::logistic_function (const Target &z)
  Logistic function.
- static const Target Predict::logreg_proba (const Features &X, const Weights &w)
  Predict probability of positive class for logistic regression.
- static const Target Predict::logreg_class (const Target &y_pred_proba, const double threshold)
  Predict class for logistic regression. Positive class = 1. Negative class = 0.
- static const Weights Predict::ols (const Features &X, const Target &y_true)
  Compute weights for Ordinary Least Squares.
- static const Weights Predict::qr (const Features &X, const Target &y_true)
  Compute weights for QR-decomposition.

6.13.1 Detailed Description

Prediction functions declarations and implementation.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-03-20

Copyright

6.13.2 Function Documentation

6.13.2.1 linreg()

```
static const Target Predict::linreg (
            const Features & X,
            const Weights & w )  [static]
```

Predict function for linear regression.

$$\hat{y} = w_0 x_0 + w_1 x_1 + \ldots + w_n x_n = wX,$$

where X is the features matrix, w is the model's weights vector.

Parameters

X	Matrix of feature variables
w	Row vector of weights

Returns

const Types::Target

6.13.2.2 logistic_function()

```
static const Target Predict::logistic_function (
            const Target & z )  [static]
```

Logistic function.

$$\sigma(z) = \frac{1}{1 + e^{-z}}$$

Parameters

z	Column vector of target variable

Returns

const Types::Target

6.13.2.3 logreg_proba()

```
static const Target Predict::logreg_proba (
            const Features & X,
            const Weights & w )  [static]
```

Predict probability of positive class for logistic regression.

$$\hat{y}_{proba} = \sigma(-wX),$$

where $\sigma(x)$ is the logistic function X is the features matrix, w is the model's weights vector.

Parameters

X	Matrix of feature variables
w	Row vector of weights

Returns

const Types::Target

6.13.2.4 logreg_class()

```
static const Target Predict::logreg_class (
            const Target & y_pred_proba,
            const double threshold )  [static]
```

Predict class for logistic regression. Positive class = 1. Negative class = 0.

$$\hat{y}(\hat{y}_{proba}, t) = \begin{cases} 1, & \text{if } \hat{y}_{proba} \geq t \\ 0, & \text{if } \hat{y}_{proba} < t \end{cases},$$

where $\hat{y}_{proba}$ is the predicted probability of positive class, t is the decision threshold.

Parameters

y_pred_proba	Predicted probability of positive class
threshold	Decision threshold

Returns

const Types::Target

6.13.2.5 ols()

```
static const Weights Predict::ols (
            const Features & X,
            const Target & y_true )  [static]
```

Compute weights for Ordinary Least Squares.

$$w = (X^T X)^{-1} X y,$$

where X is the features matrix, y is the target vector.

Note: X must be full rank, i.e. features must be linearly independent Otherwise, its inverse is undefined, and thus solution is also undefined

Parameters

X	Matrix of feature variables
y_true	Column vector of target variable

Returns

const Types::Weights

6.13.2.6 qr()

```
static const Weights Predict::qr (
            const Features & X,
            const Target & y_true )  [static]
```

Compute weights for QR-decomposition.

$X = QR,$

$w = R^{-1}(Q^T y),$

where X is the features matrix, y is the target vector.

Parameters

X	Matrix of feature variables
y_true	Column vector of target variable

Returns

const Types::Weights

6.14 qr_solver.hpp File Reference

QRSolver class declarations.

```
#include ¨types.hpp¨
#include ¨base_solver.hpp¨
```

Classes

- class QRSolver

  QR-decomposition solver class. Inherits from BaseSolver class.

6.14.1 Detailed Description

QRSolver class declarations.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-03-20

Copyright

6.15 standard_scaler.hpp File Reference

StandardScaler class declarations.

```
#include ¨types.hpp¨
#include ¨base_transformer.hpp¨
```

Classes

- class StandardScaler

  Standard Scaler (z-score transformation) class. Inherits from BaseTransformer class.

6.15.1 Detailed Description

StandardScaler class declarations.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-03-20

Copyright

6.16 types.hpp File Reference

Custom types used in the library.

```
#include <boost/type_index.hpp>
#include <armadillo>
```

Typedefs

- using Types::Features = arma::dmat
- using Types::Target = arma::dvec
- using Types::Weights = arma::drowvec
- using Types::Derivative = arma::drowvec
- using Types::ConfusionMatrix = arma::umat
- using Types::Precisions = arma::drowvec
- using Types::Recalls = arma::drowvec
- using Types::Fallouts = arma::drowvec
- using Types::PRCurve = std::pair< const Precisions, const Recalls >

  Pair of row vectors of precisions and recalls – PR curve.
- using Types::ROCCurve = std::pair< const Recalls, const Fallouts >

  Pair of row vectors of recalls and fall-outs – ROC curve.
- using Types::TPs = arma::urowvec
- using Types::FPs = arma::urowvec
- using Types::TNs = arma::urowvec
- using Types::FNs = arma::urowvec

Functions

- template<typename T >
  std::string Types::get_name (T)

  Get the object's name as string representation of its type.

6.16.1 Detailed Description

Custom types used in the library.

Author

Andrei Batyrov (arbatyrov@edu.hse.ru)

Version

0.1

Date

2024-03-26

Copyright

6.16.2 Typedef Documentation

6.16.2.1 Features

```
using Types::Features = typedef arma::dmat
```

Matrix of feature variables (doubles).

6.16.2.2 Target

```
using Types::Target = typedef arma::dvec
```

Column vector of target variable (doubles).

6.16.2.3 Weights

```
using Types::Weights = typedef arma::drowvec
```

Row vector of model's weights (doubles).

6.16.2.4 Derivative

```
using Types::Derivative = typedef arma::drowvec
```

Row vector of n-th order derivative of loss function (doubles).

6.16.2.5 ConfusionMatrix

```
using Types::ConfusionMatrix = typedef arma::umat
```

Confusion Matrix (doubles).

6.16.2.6 Precisions

```
using Types::Precisions = typedef arma::drowvec
```

Row vector of precisions computed for different thresholds (doubles).

6.16.2.7 Recalls

```
using Types::Recalls = typedef arma::drowvec
```

Row vector of recalls computed for different thresholds (doubles).

6.16.2.8 Fallouts

```
using Types::Fallouts = typedef arma::drowvec
```

Row vector of fall-outs computed for different thresholds (doubles).

6.16.2.9 PRCurve

```
using Types::PRCurve = typedef std::pair<const Precisions, const Recalls>
```

Pair of row vectors of precisions and recalls – PR curve.

6.16.2.10 ROCCurve

```
using Types::ROCCurve = typedef std::pair<const Recalls, const Fallouts>
```

Pair of row vectors of recalls and fall-outs – ROC curve.

6.16.2.11 TPs

```
using Types::TPs = typedef arma::urowvec
```

Row vector of true positives computed for different thresholds (unsigned int).

6.16.2.12 FPs

```
using Types::FPs = typedef arma::urowvec
```

Row vector of false positives computed for different thresholds (unsigned int).

6.16.2.13 TNs

```
using Types::TNs = typedef arma::urowvec
```

Row vector of true negatives computed for different thresholds (unsigned int).

6.16.2.14 FNs

```
using Types::FNs = typedef arma::urowvec
```

Row vector of false negatives computed for different thresholds (unsigned int).

6.16.3 Function Documentation

6.16.3.1 get_name()

```
template<typename T >
std::string Types::get_name (
            T  )
```

Get the object's name as string representation of its type.

Template Parameters

T	

Returns

std::string

Index