

Package ‘DeepLearningCausal’

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Type Package

Title Causal Inference with Super Learner and Deep Neural Networks

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Maintainer Nguyen K. Huynh <khoinguyen.huynh@r.hit-u.ac.jp>

Description Functions to estimate Conditional Average Treatment Effects (CATE) and Population Average Treatment Effects on the Treated (PATT) from experimental or observational data using the Super Learner (SL) ensemble method and Deep neural networks. The package first provides functions to implement meta-learners such as the Single-learner (S-learner) and Two-learner (T-learner) described in Künzel et al. (2019) <[doi:10.1073/pnas.1804597116](https://doi.org/10.1073/pnas.1804597116)> for estimating the CATE. The S- and T-learner are each estimated using the SL ensemble method and deep neural networks. It then provides functions to implement the Ottoboni and Poulos (2020) <[doi:10.1515/jci-2018-0035](https://doi.org/10.1515/jci-2018-0035)> PATT-C estimator to obtain the PATT from experimental data with noncompliance by using the SL ensemble method and deep neural networks.

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Encoding UTF-8

LazyData true

Imports ROCR, caret, neuralnet, SuperLearner, class, xgboost, randomForest, glmnet, gam, e1071, gbm, Hmisc, weights

Suggests testthat, ggplot2, tidyr

RoxygenNote 7.2.3

Depends R (>= 4.1.0)

URL <https://github.com/hknd23/DeepLearningCausal>

BugReports <https://github.com/hknd23/DeepLearningCausal/issues>

NeedsCompilation no

Author Nguyen K. Huynh [aut, cre] (<<https://orcid.org/0000-0002-6234-7232>>),
Bumba Mukherjee [aut] (<<https://orcid.org/0000-0002-3453-601X>>),
Irvin (Chen-Yu) Lee [aut] (<<https://orcid.org/0009-0004-5913-8925>>)

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Contents

complier_mod	2
complier_predict	3
exp_data	3
exp_data_full	4
metalearner_deepneural	5
metalearner_ensemble	7
neuralnet_complier_mod	8
neuralnet_pattc_counterfactuals	9
neuralnet_predict	10
neuralnet_response_model	10
pattc_counterfactuals	11
pattc_deepneural	12
pattc_ensemble	14
pop_data	15
pop_data_full	16
response_model	17
Index	18

complier_mod	<i>Train complier model using ensemble methods</i>
--------------	--

Description

Train model using group exposed to treatment with compliance as binary outcome variable and covariates.

Usage

```
complier_mod(
  exp.data,
  complier.formula,
  treat.var,
  ID = NULL,
  SL.library = c("SL.glmnet", "SL.xgboost", "SL.ranger", "SL.nnet", "SL.glm")
)
```

Arguments

exp.data	list object of experimental data.
complier.formula	formula to fit compliance model ($c \sim x$) using complier variable and covariates
treat.var	string specifying the binary treatment variable
ID	string for name of identifier variable.
SL.library	vector of strings for ML classifier algorithms. If left NULL employs extreme gradient boosting, elastic net regression, random forest, and neural nets.

Value

model object of trained model.

complier_predict	<i>Complier model prediction</i>
------------------	----------------------------------

Description

Predict Compliance from control group in experimental data

Usage

```
complier_predict(complier.mod, exp.data, treat.var, compl.var)
```

Arguments

complier.mod	output from trained ensemble superlearner model
exp.data	data.frame object of experimental dataset
treat.var	string specifying the binary treatment variable
compl.var	string specifying binary complier variable

Value

data.frame object with true compliers, predicted compliers in the control group, and all compliers (actual + predicted).

exp_data	<i>Survey Experiment of Support for Populist Policy</i>
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Description

Shortened version of survey response data that incorporates a vignette survey experiment. The vignette describes an international crisis between country A and B. After reading this vignette, respondents are randomly assigned to the control group or to one of two treatments: policy prescription to said crisis by strong (populist) leader and centrist (non-populist) leader. The respondents are then asked whether they are willing to support the policy decision to fight a war against country A, which is the dependent variable.

Usage

```
data(exp_data)
```

Format

exp_data:

A data frame with 257 rows and 12 columns:

female Gender.

age Age of participant.

income Monthly household income.

religion Religious denomination

practicing_religion Importance of religion in life.

education Educational level of participant.

political_ideology Political ideology of participant.

employment Employment status of participant.

marital_status Marital status of participant.

job_loss Concern about job loss.

strong_leader Binary treatment measure of leader type.

support_war Binary outcome measure for willingness to fight war. #' ...

Source

Yadav and Mukherjee (2024)

exp_data_full

Survey Experiment of Support for Populist Policy

Description

Extended experiment data with 514 observations

Usage

```
data(exp_data_full)
```

Format

exp_data_full:

A data frame with 514 rows and 12 columns:

female Gender.

age Age of participant.

income Monthly household income.

religion Religious denomination

practicing_religion Importance of religion in life.

education Educational level of participant.

political_ideology Political ideology of participant.

employment Employment status of participant.

marital_status Marital status of participant.
job_loss Concern about job loss.
strong_leader Binary treatment measure of leader type.
support_war Binary outcome measure for willingness to fight war. #' ...

Source

Yadav and Mukherjee (2024)

```
metalearner_deepneural
      metalearner_deepneural
```

Description

metalearner_deepneural implements the S-learner and T-learner for estimating CATE using Deep Neural Networks. The Resilient back propagation (Rprop) algorithm is used for training neural networks.

Usage

```
metalearner_deepneural(
  data,
  cov.formula,
  treat.var,
  meta.learner.type,
  stepmax = 1e+05,
  nfolds = 5,
  algorithm = "rprop+",
  hidden.layer = c(4, 2),
  linear.output = FALSE,
  binary.outcome = TRUE
)
```

Arguments

data	data.frame object of data.
cov.formula	formula description of the model $y \sim x$ (list of covariates).
treat.var	string for the name of treatment variable.
meta.learner.type	string specifying is the S-learner and "T.Learner" for the T-learner model.
stepmax	maximum number of steps for training model.
nfolds	number of folds for cross-validation. Currently supports up to 5 folds.
algorithm	a string for the algorithm for the neural network. Default set to rprop+, the Resilient back propagation (Rprop) with weight backtracking algorithm for training neural networks.

`hidden.layer` vector of integers specifying layers and number of neurons.
`linear.output` logical specifying regression (TRUE) or classification (FALSE) model.
`binary.outcome` logical specifying predicted outcome variable will take binary values or proportions.

Value

list of predicted outcome values and CATEs estimated by the meta learners for each observation.
`#@export`

Examples

```

# load dataset
data(exp_data)
# estimate CATEs with S Learner
set.seed(123456)
slearner_nn <- metalearner_deepneural(cov.formula = support_war ~ age + income +
  employed + job_loss,
  data = exp_data,
  treat.var = "strong_leader",
  meta.learner.type = "S.Learner",
  stepmax = 2e+9,
  nfolds = 5,
  algorithm = "rprop+",
  hidden.layer = c(1),
  linear.output = FALSE,
  binary.outcome = TRUE)

```

```

# load dataset
set.seed(123456)
# estimate CATEs with T Learner
tlearner_nn <- metalearner_deepneural(cov.formula = support_war ~ age +
  income +
  employed + job_loss,
  data = exp_data,
  treat.var = "strong_leader",
  meta.learner.type = "T.Learner",
  stepmax = 1e+9,
  nfolds = 5,
  algorithm = "rprop+",
  hidden.layer = c(2,1),
  linear.output = FALSE,
  binary.outcome = TRUE)

```

metalearner_ensemble *metalearner_ensemble*

Description

metalearner_ensemble implements the S-learner and T-learner for estimating CATE using the super learner ensemble method. The super learner in this case includes the following machine learning algorithms: extreme gradient boosting, glmnet (elastic net regression), random forest and neural nets.

Usage

```
metalearner_ensemble(  
  data,  
  cov.formula,  
  treat.var,  
  meta.learner.type,  
  learners = c("SL.glmnet", "SL.xgboost", "SL.ranger", "SL.nnet"),  
  nfolds = 5,  
  binary.outcome = TRUE  
)
```

Arguments

data	data.frame object of data
cov.formula	formula description of the model $y \sim x$ (list of covariates)
treat.var	string for the name of treatment variable.
meta.learner.type	string specifying is the S-learner and "T.Learner" for the T-learner model.
learners	vector for super learner ensemble that includes extreme gradient boosting, glmnet, random forest, and neural nets.
nfolds	number of folds for cross-validation. Currently supports up to 5 folds.
binary.outcome	logical specifying predicted outcome variable will take binary values or proportions.

Value

list of predicted outcome values and CATEs estimated by the meta learners for each observation.

Examples

```
# load dataset  
data(exp_data)  
#load SuperLearner package  
library(SuperLearner)  
# estimate CATEs with S Learner
```

```
set.seed(123456)
slearner <- metalearner_ensemble(cov.formula = support_war ~ age +
  income + employed + job_loss,
  data = exp_data,
  treat.var = "strong_leader",
  meta.learner.type = "S.Learner",
  learners = c("SL.glm"),
  nfolds = 5,
  binary.outcome = TRUE)

# estimate CATEs with T Learner
set.seed(123456)
tlearner <- metalearner_ensemble(cov.formula = support_war ~ age + income +
  employed + job_loss,
  data = exp_data,
  treat.var = "strong_leader",
  meta.learner.type = "T.Learner",
  learners = c("SL.xgboost", "SL.ranger",
    "SL.nnet"),
  nfolds = 5,
  binary.outcome = TRUE)
```

neuralnet_complier_mod

Train compliance model using neural networks

Description

Train model using group exposed to treatment with compliance as binary outcome variable and covariates.

Usage

```
neuralnet_complier_mod(
  complier.formula,
  exp.data,
  treat.var,
  algorithm = "rprop+",
  hidden.layer = c(4, 2),
  ID = NULL,
  stepmax = 1e+08
)
```


Arguments

<code>complier.formula</code>	formula for complier variable as outcome and covariates ($c \sim x$)
<code>exp.data</code>	<code>data.frame</code> for experimental data.
<code>treat.var</code>	string for treatment variable.
<code>algorithm</code>	string for algorithm for training neural networks. Default set to the Resilient back propagation with weight backtracking (<code>rprop+</code>). Other algorithms include <code>backprop</code> , <code>rprop-</code> , <code>'sag'</code> , or <code>'slr'</code> (see <code>neuralnet</code> package).
<code>hidden.layer</code>	vector for specifying hidden layers and number of neurons.
<code>ID</code>	string for identifier variable
<code>stepmax</code>	maximum number of steps.

Value

trained complier model object

`neuralnet_pattc_counterfactuals`

Assess Population Data counterfactuals

Description

Create counterfactual datasets in the population for compliers and noncompliers. Then predict potential outcomes using trained model from `neuralnet_response_model`.

Usage

```
neuralnet_pattc_counterfactuals(
  pop.data,
  neuralnet_response.mod,
  ID = NULL,
  cluster = NULL,
  binary.outcome = TRUE
)
```

Arguments

<code>pop.data</code>	population data.
<code>neuralnet_response.mod</code>	trained model from. <code>neuralnet_response_model</code> .
<code>ID</code>	string for identifier variable.
<code>cluster</code>	string for clustering variable (currently unused).
<code>binary.outcome</code>	logical specifying predicted outcome variable will take binary values or proportions.

Value

data.frame of predicted outcomes of response variable from counterfactuals.

neuralnet_predict	<i>Predicting Compliance from experimental data</i>
-------------------	---

Description

Predicting Compliance from control group experimental data

Usage

```
neuralnet_predict(neuralnet.complier.mod, exp.data, treat.var, compl.var)
```

Arguments

neuralnet.complier.mod	results from neuralnet_complier_mod
exp.data	data.frame of experimental data
treat.var	string for treatment variable
compl.var	string for compliance variable

Value

data.frame object with true compliers, predicted compliers in the control group, and all compliers (actual + predicted).

neuralnet_response_model	<i>Modeling Responses from experimental data Using Deep NN</i>
--------------------------	--

Description

Model Responses from all compliers (actual + predicted) in experimental data using neural network.

Usage

```
neuralnet_response_model(
  response.formula,
  exp.data,
  neuralnet.compliers,
  compl.var,
  algorithm = "rprop+",
  hidden.layer = c(4, 2),
  stepmax = 1e+08
)
```

Arguments

response.formula	formula for response variable and covariates ($y \sim x$)
exp.data	data.frame of experimental data.
neuralnet.compliers	data.frame of compliers (actual + predicted) from neuralnet_predict.
compl.var	string of compliance variable
algorithm	neural network algorithm, default set to "rprop+".
hidden.layer	vector specifying hidden layers and number of neurons.
stepmax	maximum number of steps for training model.

Value

trained response model object

pattc_counterfactuals *Assess Population Data counterfactuals*

Description

Create counterfactual datasets in the population for compliers and noncompliers. Then predict potential outcomes from counterfactuals.

Usage

```
pattc_counterfactuals(
  pop.data,
  response.mod,
  ID = NULL,
  cluster = NULL,
  binary.outcome = TRUE
)
```

Arguments

pop.data	population dataset
response.mod	trained model from response_model.
ID	string for identifier variable
cluster	string for clustering variable
binary.outcome	logical specifying whether predicted outcomes are proportions or binary (0-1).

Value

data.frame object of predicted outcomes of counterfactual groups.

pattc_deepneural *Estimate PATT_C using Deep NN*

Description

estimates the Population Average Treatment Effect of the Treated from experimental data with noncompliers using Deep Neural Networks.

Usage

```
pattc_deepneural(
  response.formula,
  exp.data,
  pop.data,
  treat.var,
  compl.var,
  compl.algorithm = "rprop+",
  response.algorithm = "rprop+",
  compl.hidden.layer = c(4, 2),
  response.hidden.layer = c(4, 2),
  compl.stepmax = 1e+08,
  response.stepmax = 1e+08,
  ID = NULL,
  cluster = NULL,
  bootse = FALSE,
  bootp = FALSE,
  bootn = 999,
  binary.outcome = TRUE
)
```

Arguments

response.formula	formula of response variable as outcome and covariates ($y \sim x$)
exp.data	data.frame of experimental data. Must include binary treatment and compliance variables.
pop.data	data.frame of population data. Must include binary compliance variable
treat.var	string for treatment variable.
compl.var	string for compliance variable
compl.algorithm	string for algorithm to train neural network for compliance model. Default set to "rprop+". See (neuralnet package for available algorithms).
response.algorithm	string for algorithm to train neural network for response model. Default set to "rprop+". See (neuralnet package for available algorithms).

`compl.hidden.layer` vector for specifying hidden layers and number of neurons in complier model.
`response.hidden.layer` vector for specifying hidden layers and number of neurons in response model.
`compl.stepmax` maximum number of steps for complier model
`response.stepmax` maximum number of steps for response model
`ID` string for identifier variable
`cluster` string for cluster variable.
`bootse` logical for bootstrapped standard erros.
`bootp` logical for bootstrapped p values.
`bootn` logical for number of bootstraps.
`binary.outcome` logical specifying predicted outcome variable will take binary values or proportions.

Value

results of t test as PATTC estimate.

Examples

```

# load datasets
data(exp_data) #experimental data
data(pop_data) #population data
# specify models and estimate PATTC
set.seed(123456)
pattc_neural <- pattc_deepneural(response.formula = support_war ~ age + female +
                                income + education + employed + married +
                                hindu + job_loss,
                                exp.data = exp_data,
                                pop.data = pop_data,
                                treat.var = "strong_leader",
                                compl.var = "compliance",
                                compl.algorithm = "rprop+",
                                response.algorithm = "rprop+",
                                compl.hidden.layer = c(4,2),
                                response.hidden.layer = c(4,2),
                                compl.stepmax = 1e+09,
                                response.stepmax = 1e+09,
                                ID = NULL,
                                cluster = NULL,
                                bootse = FALSE,
                                bootp = FALSE,
                                bootn = 999,
                                binary.outcome = TRUE)

summary(pattc_neural)

```

pattc_ensemble *PATT_C SL Ensemble*

Description

pattc_ensemble estimates the Population Average Treatment Effect of the Treated from experimental data with noncompliers using the super learner ensemble that includes extreme gradient boosting, glmnet (elastic net regression), random forest and neural nets.

Usage

```
pattc_ensemble(
  response.formula,
  exp.data,
  pop.data,
  treat.var,
  compl.var,
  SL.library = c("SL.glmnet", "SL.xgboost", "SL.ranger", "SL.nnet", "SL.glm"),
  ID = NULL,
  cluster = NULL,
  bootse = FALSE,
  bootp = FALSE,
  bootn = 999,
  binary.outcome = TRUE
)
```

Arguments

response.formula	formula for the effects of covariates on outcome variable ($y \sim x$).
exp.data	data.frame object for experimental data. Must include binary treatment and compliance variable.
pop.data	data.frame object for population data. Must include binary compliance variable.
treat.var	string for binary treatment variable.
compl.var	string for binary compliance variable.
SL.library	vector of names of ML algorithms used for ensemble model.
ID	string for name of identifier.
cluster	string for name of cluster variable.
bootse	logical for bootstrapped standard errors.
bootp	logical for bootstrapped p values.
bootn	number of bootstrap sample.
binary.outcome	logical specifying predicted outcome variable will take binary values or proportions.

Value

results of t test as PATTC estimate.

Examples

```
# load datasets
data(exp_data_full) # full experimental data
data(exp_data) #experimental data
data(pop_data) #population data
#attach SuperLearner (model will not recognize learner if package is not loaded)
library(SuperLearner)
set.seed(123456)
#specify models and estimate PATTC
pattc <- pattc_ensemble(response.formula = support_war ~ age + income +
                        education + employed + job_loss,
                        exp.data = exp_data_full,
                        pop.data = pop_data,
                        treat.var = "strong_leader",
                        compl.var = "compliance",
                        SL.library = c("SL.glmnet", "SL.xgboost",
                                       "SL.ranger", "SL.nnet",
                                       "SL.glm"),
                        ID = NULL,
                        cluster = NULL,
                        bootse = FALSE,
                        bootp = FALSE,
                        bootn = 999,
                        binary.outcome = TRUE)

summary(pattc)
```

pop_data

World Value Survey India Sample

Description

World Value Survey (WVS) Data for India in 2022. The variables drawn from the said WVS India data match the covariates from the India survey experiment sample.

Usage

```
data(pop_data)
```

Format

pop_data:

A data frame with 846 rows and 13 columns:

female Respondent's Sex.

age Age of respondent.
income income group of Household.
religion Religious denomination
practicing_religion Importance of religion in respondent's life.
education Educational level of respondent.
political_ideology Political ideology of respondent.
employment Employment status and full-time employee.
marital_status Marital status of respondent.
job_loss Concern about job loss.
support_war Binary (Yes/No) outcome measure for willingness to fight war.
strong_leader Binary measure of preference for strong leader. ...

Source

Haerpfer, C., Inglehart, R., Moreno, A., Welzel, C., Kizilova, K., Diez-Medrano J., M. Lagos, P. Norris, E. Ponarin & B. Puranen et al. (eds.). 2020. World Values Survey: Round Seven – Country-Pooled Datafile. Madrid, Spain & Vienna, Austria: JD Systems Institute & WVSA Secretariat. <doi.org/10.14281/18241.1>

pop_data_full	<i>World Value Survey India Sample</i>
---------------	--

Description

Extended World Value Survey (WVS) Data for India in 1995, 2001, 2006, 2012, and 2022.

Usage

```
data(pop_data_full)
```

Format

pop_data_full:
A data frame with 11,813 rows and 13 columns:
female Respondent's Sex.
age Age of respondent.
income income group of Household.
religion Religious denomination
practicing_religion Importance of religion in respondent's life.
education Educational level of respondent.
political_ideology Political ideology of respondent.
employment Employment status and full-time employee.
marital_status Marital status of respondent.
job_loss Concern about job loss.
support_war Binary (Yes/No) outcome measure for willingness to fight war.
strong_leader Binary measure of preference for strong leader. ...

Source

Haerpfer, C., Inglehart, R., Moreno, A., Welzel, C., Kizilova, K., Diez-Medrano J., M. Lagos, P. Norris, E. Ponarin & B. Puranen et al. (eds.). 2020. World Values Survey: Round Seven – Country-Pooled Datafile. Madrid, Spain & Vienna, Austria: JD Systems Institute & WVSA Secretariat. <doi.org/10.14281/18241.1>

 response_model

Response model from experimental data using SL ensemble

Description

Train response model (response variable as outcome and covariates) from all compliers (actual + predicted) in experimental data using SL ensemble.

Usage

```
response_model(
  response.formula,
  exp.data,
  compl.var,
  exp.compliers,
  family = "binomial",
  ID = NULL,
  SL.library = c("SL.glmnet", "SL.xgboost", "SL.ranger", "SL.nnet", "SL.glm")
)
```

Arguments

response.formula	formula to fit the response model ($y \sim x$) using binary outcome variable and covariates
exp.data	experimental dataset.
compl.var	string specifying binary complier variable
exp.compliers	data.frame object of compliers from complier_predict.
family	string for "gaussian" or "binomial".
ID	string for identifier variable.
SL.library	vector of names of ML algorithms used for ensemble model.

Value

trained response model.

Index

* dataset

- exp_data, [3](#)
- exp_data_full, [4](#)
- pop_data, [15](#)
- pop_data_full, [16](#)

- complier_mod, [2](#)
- complier_predict, [3](#)

- exp_data, [3](#)
- exp_data_full, [4](#)

- metalearner_deepneural, [5](#)
- metalearner_ensemble, [7](#)

- neuralnet_complier_mod, [8](#)
- neuralnet_pattc_counterfactuals, [9](#)
- neuralnet_predict, [10](#)
- neuralnet_response_model, [10](#)

- pattc_counterfactuals, [11](#)
- pattc_deepneural, [12](#)
- pattc_ensemble, [14](#)
- pop_data, [15](#)
- pop_data_full, [16](#)

- response_model, [17](#)