

Package ‘RGAN’

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Title Generative Adversarial Nets (GAN) in R

Version 0.1.1

Description An easy way to get started with Generative Adversarial Nets (GAN) in R. The GAN algorithm was initially described by Goodfellow et al. 2014 <<https://proceedings.neurips.cc/paper/2014/file/5ca3e9b122f61f8f06494c97b1afccf3-Paper.pdf>>. A GAN can be used to learn the joint distribution of complex data by comparison. A GAN consists of two neural networks a Generator and a Discriminator, where the two neural networks play an adversarial minimax game. Built-in GAN models make the training of GANs in R possible in one line and make it easy to experiment with different design choices (e.g. different network architectures, value functions, optimizers). The built-in GAN models work with tabular data (e.g. to produce synthetic data) and image data. Methods to post-process the output of GAN models to enhance the quality of samples are available.

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URL <https://github.com/mneunhoe/RGAN>

BugReports <https://github.com/mneunhoe/RGAN/issues>

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data_transformer	<i>Data Transformer</i>
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Description

Provides a class to transform data for RGAN. Method `$new()` initializes a new transformer, method `$fit(data)` learns the parameters for the transformation from data (e.g. means and sds). Methods `$transform()` and `$inverse_transform()` can be used to transform and back transform a data set based on the learned parameters. Currently, `DataTransformer` supports z-transformation (a.k.a. normalization) for numerical features/variables and one hot encoding for categorical features/variables. In your call to fit you just need to indicate which columns contain discrete features.

Value

A class to transform (normalize or one hot encode) tabular data for RGAN

Methods

Public methods:

- `data_transformer$new()`
- `data_transformer$fit_continuous()`
- `data_transformer$fit_discrete()`
- `data_transformer$fit()`
- `data_transformer$transform_continuous()`
- `data_transformer$transform_discrete()`

- `data_transformer$transform()`
- `data_transformer$inverse_transform_continuous()`
- `data_transformer$inverse_transform_discrete()`
- `data_transformer$inverse_transform()`
- `data_transformer$clone()`

Method `new()`: Create a new `data_transformer` object

Usage:

```
data_transformer$new()
```

Method `fit_continuous()`:

Usage:

```
data_transformer$fit_continuous(column = NULL, data = NULL)
```

Method `fit_discrete()`:

Usage:

```
data_transformer$fit_discrete(column = NULL, data = NULL)
```

Method `fit()`: Fit a `data_transformer` to data.

Usage:

```
data_transformer$fit(data, discrete_columns = NULL)
```

Arguments:

`data` The data set to transform

`discrete_columns` Column ids for columns with discrete/nominal values to be one hot encoded.

Examples:

```
data <- sample_toydata()
transformer <- data_transformer$new()
transformer$fit(data)
```

Method `transform_continuous()`:

Usage:

```
data_transformer$transform_continuous(column_meta, data)
```

Method `transform_discrete()`:

Usage:

```
data_transformer$transform_discrete(column_meta, data)
```

Method `transform()`: Transform data using a fitted `data_transformer`. (From original format to transformed format.)

Usage:

```
data_transformer$transform(data)
```

Arguments:

`data` The data set to transform

Examples:

```
data <- sample_toydata()
transformer <- data_transformer$new()
transformer$fit(data)
transformed_data <- transformer$transform(data)
```

Method inverse_transform_continuous():

Usage:

```
data_transformer$inverse_transform_continuous(meta, data)
```

Method inverse_transform_discrete():

Usage:

```
data_transformer$inverse_transform_discrete(meta, data)
```

Method inverse_transform(): Inverse Transform data using a fitted data_transformer. (From transformed format to original format.)

Usage:

```
data_transformer$inverse_transform(data)
```

Arguments:

data The data set to transform

Examples:

```
data <- sample_toydata()
transformer <- data_transformer$new()
transformer$fit(data)
transformed_data <- transformer$transform(data)
reconstructed_data <- transformer$inverse_transform(transformed_data)
```

Method clone(): The objects of this class are cloneable with this method.

Usage:

```
data_transformer$clone(deep = FALSE)
```

Arguments:

deep Whether to make a deep clone.

Examples

```
## Not run:
# Before running the first time the torch backend needs to be installed
torch::install_torch()
# Load data
data <- sample_toydata()
# Build new transformer
transformer <- data_transformer$new()
# Fit transformer to data
transformer$fit(data)
# Transform data and store as new object
transformed_data <- transformer$transform(data)
# Train the default GAN
```

```

trained_gan <- gan_trainer(transformed_data)
# Sample synthetic data from the trained GAN
synthetic_data <- sample_synthetic_data(trained_gan, transformer)
# Plot the results
GAN_update_plot(data = data,
synth_data = synthetic_data,
main = "Real and Synthetic Data after Training")

## End(Not run)

## -----
## Method `data_transformer$fit`
## -----

data <- sample_toydata()
transformer <- data_transformer$new()
transformer$fit(data)

## -----
## Method `data_transformer$transform`
## -----

data <- sample_toydata()
transformer <- data_transformer$new()
transformer$fit(data)
transformed_data <- transformer$transform(data)

## -----
## Method `data_transformer$inverse_transform`
## -----

data <- sample_toydata()
transformer <- data_transformer$new()
transformer$fit(data)
transformed_data <- transformer$transform(data)
reconstructed_data <- transformer$inverse_transform(transformed_data)

```

DCGAN_Discriminator *DCGAN Discriminator*

Description

Provides a `torch::nn_module` with a simple deep convolutional neural net architecture, for use as the default architecture for image data in RGAN. Architecture inspired by: https://pytorch.org/tutorials/beginner/dcgan_faces_tutorial.html

Usage

```
DCGAN_Discriminator(
  number_channels = 3,
```

```

    ndf = 64,
    dropout_rate = 0.5,
    sigmoid = FALSE
)

```

Arguments

number_channels	The number of channels in the image (RGB is 3 channels)
ndf	The number of feature maps in discriminator
dropout_rate	The dropout rate for each hidden layer
sigmoid	Switch between a sigmoid and linear output layer (the sigmoid is needed for the original GAN value function)

Value

A torch::nn_module for the DCGAN Discriminator

DCGAN_Generator	<i>DCGAN Generator</i>
-----------------	------------------------

Description

Provides a torch::nn_module with a simple deep convolutional neural net architecture, for use as the default architecture for image data in RGAN. Architecture inspired by: https://pytorch.org/tutorials/beginner/dcgan_faces_tutorial.html

Usage

```

DCGAN_Generator(
  noise_dim = 100,
  number_channels = 3,
  ngf = 64,
  dropout_rate = 0.5
)

```

Arguments

noise_dim	The length of the noise vector per example
number_channels	The number of channels in the image (RGB is 3 channels)
ngf	The number of feature maps in generator
dropout_rate	The dropout rate for each hidden layer

Value

A torch::nn_module for the DCGAN Generator

Discriminator *Discriminator*

Description

Provides a `torch::nn_module` with a simple fully connected neural net, for use as the default architecture for tabular data in RGAN.

Usage

```
Discriminator(
  data_dim,
  hidden_units = list(128, 128),
  dropout_rate = 0.5,
  sigmoid = FALSE
)
```

Arguments

<code>data_dim</code>	The number of columns in the data set
<code>hidden_units</code>	A list of the number of neurons per layer, the length of the list determines the number of hidden layers
<code>dropout_rate</code>	The dropout rate for each hidden layer
<code>sigmoid</code>	Switch between a sigmoid and linear output layer (the sigmoid is needed for the original GAN value function)

Value

A `torch::nn_module` for the Discriminator

`expert_sample_synthetic_data`
Sample Synthetic Data with explicit noise input

Description

Provides a function that makes it easy to sample synthetic data from a Generator

Usage

```
expert_sample_synthetic_data(g_net, z, device, eval_dropout = FALSE)
```

Arguments

g_net	A torch::nn_module with a Generator
z	A noise vector
device	The device on which synthetic data should be sampled (cpu or cuda)
eval_dropout	Should dropout be applied during inference

Value

Synthetic data

gan_trainer

gan_trainer

Description

Provides a function to quickly train a GAN model.

Usage

```
gan_trainer(
  data,
  noise_dim = 2,
  noise_distribution = "normal",
  value_function = "original",
  data_type = "tabular",
  generator = NULL,
  generator_optimizer = NULL,
  discriminator = NULL,
  discriminator_optimizer = NULL,
  base_lr = 1e-04,
  ttur_factor = 4,
  weight_clipper = NULL,
  batch_size = 50,
  epochs = 150,
  plot_progress = FALSE,
  plot_interval = "epoch",
  eval_dropout = FALSE,
  synthetic_examples = 500,
  plot_dimensions = c(1, 2),
  device = "cpu"
)
```


Arguments

data	Input a data set. Needs to be a matrix, array, torch::torch_tensor or torch::dataset.
noise_dim	The dimensions of the GAN noise vector z. Defaults to 2.
noise_distribution	The noise distribution. Expects a function that samples from a distribution and returns a torch_tensor. For convenience "normal" and "uniform" will automatically set a function. Defaults to "normal".
value_function	The value function for GAN training. Expects a function that takes discriminator scores of real and fake data as input and returns a list with the discriminator loss and generator loss. For reference see: . For convenience three loss functions "original", "wasserstein" and "f-wgan" are already implemented. Defaults to "original".
data_type	"tabular" or "image", controls the data type, defaults to "tabular".
generator	The generator network. Expects a neural network provided as torch::nn_module. Default is NULL which will create a simple fully connected neural network.
generator_optimizer	The optimizer for the generator network. Expects a torch::optim_xxx function, e.g. torch::optim_adam(). Default is NULL which will setup torch::optim_adam(g_net\$parameters, lr = base_lr).
discriminator	The discriminator network. Expects a neural network provided as torch::nn_module. Default is NULL which will create a simple fully connected neural network.
discriminator_optimizer	The optimizer for the generator network. Expects a torch::optim_xxx function, e.g. torch::optim_adam(). Default is NULL which will setup torch::optim_adam(g_net\$parameters, lr = base_lr * ttur_factor).
base_lr	The base learning rate for the optimizers. Default is 0.0001. Only used if no optimizer is explicitly passed to the trainer.
ttur_factor	A multiplier for the learning rate of the discriminator, to implement the two time scale update rule.
weight_clipper	The wasserstein GAN puts some constraints on the weights of the discriminator, therefore weights are clipped during training.
batch_size	The number of training samples selected into the mini batch for training. Defaults to 50.
epochs	The number of training epochs. Defaults to 150.
plot_progress	Monitor training progress with plots. Defaults to FALSE.
plot_interval	Number of training steps between plots. Input number of steps or "epoch". Defaults to "epoch".
eval_dropout	Should dropout be applied during the sampling of synthetic data? Defaults to FALSE.
synthetic_examples	Number of synthetic examples that should be generated. Defaults to 500. For image data e.g. 16 would be more reasonable.

plot_dimensions	If you monitor training progress with a plot which dimensions of the data do you want to look at? Defaults to c(1, 2), i.e. the first two columns of the tabular data.
device	Input on which device (e.g. "cpu" or "cuda") training should be done. Defaults to "cpu".

Value

gan_trainer trains the neural networks and returns an object of class trained_RGAN that contains the last generator, discriminator and the respective optimizers, as well as the settings.

Examples

```
## Not run:
# Before running the first time the torch backend needs to be installed
torch::install_torch()
# Load data
data <- sample_toydata()
# Build new transformer
transformer <- data_transformer$new()
# Fit transformer to data
transformer$fit(data)
# Transform data and store as new object
transformed_data <- transformer$transform(data)
# Train the default GAN
trained_gan <- gan_trainer(transformed_data)
# Sample synthetic data from the trained GAN
synthetic_data <- sample_synthetic_data(trained_gan, transformer)
# Plot the results
GAN_update_plot(data = data,
synth_data = synthetic_data,
main = "Real and Synthetic Data after Training")

## End(Not run)
```

GAN_update_plot

GAN_update_plot

Description

Provides a function to send the output of a DataTransformer to a torch tensor, so that it can be accessed during GAN training.

Usage

```
GAN_update_plot(data, dimensions = c(1, 2), synth_data, epoch, main = NULL)
```

Arguments

data	Real data to be plotted
dimensions	Which columns of the data should be plotted
synth_data	The synthetic data to be plotted
epoch	The epoch during training for the plot title
main	An optional plot title

Value

A function

Examples

```
## Not run:  
# Before running the first time the torch backend needs to be installed  
torch::install_torch()  
# Load data  
data <- sample_toydata()  
# Build new transformer  
transformer <- data_transformer$new()  
# Fit transformer to data  
transformer$fit(data)  
# Transform data and store as new object  
transformed_data <- transformer$transform(data)  
# Train the default GAN  
trained_gan <- gan_trainer(transformed_data)  
# Sample synthetic data from the trained GAN  
synthetic_data <- sample_synthetic_data(trained_gan, transformer)  
# Plot the results  
GAN_update_plot(data = data,  
synth_data = synthetic_data,  
main = "Real and Synthetic Data after Training")  
  
## End(Not run)
```

GAN_update_plot_image *GAN_update_plot_image*

Description

Provides a function to send the output of a DataTransformer to a torch tensor, so that it can be accessed during GAN training.

Usage

```
GAN_update_plot_image(mfrow = c(4, 4), synth_data)
```

Arguments

<code>mfrom</code>	The dimensions of the grid of images to be plotted
<code>synth_data</code>	The synthetic data (images) to be plotted

Value

A function

<code>gan_update_step</code>	<i>gan_update_step</i>
------------------------------	------------------------

Description

Provides a function to send the output of a DataTransformer to a torch tensor, so that it can be accessed during GAN training.

Usage

```
gan_update_step(
    data,
    batch_size,
    noise_dim,
    sample_noise,
    device = "cpu",
    g_net,
    d_net,
    g_optim,
    d_optim,
    value_function,
    weight_clipper
)
```

Arguments

<code>data</code>	Input a data set. Needs to be a matrix, array, <code>torch::torch_tensor</code> or <code>torch::dataset</code> .
<code>batch_size</code>	The number of training samples selected into the mini batch for training. Defaults to 50.
<code>noise_dim</code>	The dimensions of the GAN noise vector <code>z</code> . Defaults to 2.
<code>sample_noise</code>	A function to sample noise to a <code>torch::tensor</code>
<code>device</code>	Input on which device (e.g. "cpu" or "cuda") training should be done. Defaults to "cpu".
<code>g_net</code>	The generator network. Expects a neural network provided as <code>torch::nn_module</code> . Default is NULL which will create a simple fully connected neural network.
<code>d_net</code>	The discriminator network. Expects a neural network provided as <code>torch::nn_module</code> . Default is NULL which will create a simple fully connected neural network.

g_optim	The optimizer for the generator network. Expects a torch::optim_xxx function, e.g. torch::optim_adam(). Default is NULL which will setup torch::optim_adam(g_net\$parameters, = base_lr).
d_optim	The optimizer for the generator network. Expects a torch::optim_xxx function, e.g. torch::optim_adam(). Default is NULL which will setup torch::optim_adam(g_net\$parameters, = base_lr * ttur_factor).
value_function	The value function for GAN training. Expects a function that takes discriminator scores of real and fake data as input and returns a list with the discriminator loss and generator loss. For reference see: . For convenience three loss functions "original", "wasserstein" and "f-wgan" are already implemented. Defaults to "original".
weight_clipper	The wasserstein GAN puts some constraints on the weights of the discriminator, therefore weights are clipped during training.

Value

A function

GAN_value_fct	<i>GAN Value Function</i>
---------------	---------------------------

Description

Implements the original GAN value function as a function to be called in gan_trainer. The function can serve as a template to implement new value functions in RGAN.

Usage

```
GAN_value_fct(real_scores, fake_scores)
```

Arguments

real_scores	The discriminator scores on real examples ($D(x)$)
fake_scores	The discriminator scores on fake examples ($D(G(z))$)

Value

The function returns a named list with the entries d_loss and g_loss

 Generator
*Generator***Description**

Provides a torch::nn_module with a simple fully connected neural net, for use as the default architecture for tabular data in RGAN.

Usage

```
Generator(
  noise_dim,
  data_dim,
  hidden_units = list(128, 128),
  dropout_rate = 0.5
)
```

Arguments

noise_dim	The length of the noise vector per example
data_dim	The number of columns in the data set
hidden_units	A list of the number of neurons per layer, the length of the list determines the number of hidden layers
dropout_rate	The dropout rate for each hidden layer

Value

A torch::nn_module for the Generator

 KLWGAN_value_fct
*KLWGAN Value Function***Description**

Provides a function to send the output of a DataTransformer to a torch tensor, so that it can be accessed during GAN training.

Usage

```
KLWGAN_value_fct(real_scores, fake_scores)
```

Arguments

real_scores	The discriminator scores on real examples ($D(x)$)
fake_scores	The discriminator scores on fake examples ($D(G(z))$)

Value

The function returns a named list with the entries d_loss and g_loss

kl_fake	<i>KL WGAN loss on fake examples</i>
---------	--------------------------------------

Description

Utility function for the kl WGAN loss for fake examples as described in <https://arxiv.org/abs/1910.09779> and implemented in python in <https://github.com/ermongroup/f-wgan>.

Usage

```
kl_fake(dis_fake)
```

Arguments

dis_fake Discriminator scores on fake examples ($D(G(z))$)

Value

The loss

kl_gen	<i>KL WGAN loss for Generator training</i>
--------	--

Description

Utility function for the kl WGAN loss for Generator training as described in <https://arxiv.org/abs/1910.09779> and implemented in python in <https://github.com/ermongroup/f-wgan>.

Usage

```
kl_gen(dis_fake)
```

Arguments

dis_fake Discriminator scores on fake examples ($D(G(z))$)

Value

The loss

kl_real	<i>KL WGAN loss on real examples</i>
---------	--------------------------------------

Description

Utility function for the kl WGAN loss for real examples as described in <https://arxiv.org/abs/1910.09779> and implemented in python in <https://github.com/ermongroup/f-wgan>.

Usage

```
kl_real(dis_real)
```

Arguments

dis_real	Discriminator scores on real examples ($D(x)$)
----------	--

Value

The loss

sample_synthetic_data	<i>Sample Synthetic Data from a trained RGAN</i>
-----------------------	--

Description

Provides a function that makes it easy to sample synthetic data from a Generator

Usage

```
sample_synthetic_data(trained_gan, transformer = NULL)
```

Arguments

trained_gan	A trained RGAN object of class "trained_RGAN"
transformer	The transformer object used to pre-process the data

Value

Function to sample from a

Examples

```
## Not run:
# Before running the first time the torch backend needs to be installed
torch::install_torch()
# Load data
data <- sample_toydata()
# Build new transformer
transformer <- data_transformer$new()
# Fit transformer to data
transformer$fit(data)
# Transform data and store as new object
transformed_data <- transformer$transform(data)
# Train the default GAN
trained_gan <- gan_trainer(transformed_data)
# Sample synthetic data from the trained GAN
synthetic_data <- sample_synthetic_data(trained_gan, transformer)
# Plot the results
GAN_update_plot(data = data,
synth_data = synthetic_data,
main = "Real and Synthetic Data after Training")

## End(Not run)
```

sample_toydata

Sample Toydata

Description

Sample Toydata to reproduce the examples in the paper.

Usage

```
sample_toydata(n = 1000, sd = 0.3, seed = 20211111)
```

Arguments

n	Number of observations to generate
sd	Standard deviation of the normal distribution to generate y
seed	A seed for the pseudo random number generator

Value

A matrix with two columns x and y

Examples

```
## Not run:
# Before running the first time the torch backend needs to be installed
torch::install_torch()
# Load data
data <- sample_toydata()
# Build new transformer
transformer <- data_transformer$new()
# Fit transformer to data
transformer$fit(data)
# Transform data and store as new object
transformed_data <- transformer$transform(data)
# Train the default GAN
trained_gan <- gan_trainer(transformed_data)
# Sample synthetic data from the trained GAN
synthetic_data <- sample_synthetic_data(trained_gan, transformer)
# Plot the results
GAN_update_plot(data = data,
synth_data = synthetic_data,
main = "Real and Synthetic Data after Training")

## End(Not run)
```

torch_rand_ab

Uniform Random numbers between values a and b

Description

Provides a function to sample torch tensors from an arbitrary uniform distribution.

Usage

```
torch_rand_ab(shape, a = -1, b = 1, ...)
```

Arguments

shape	Vector of dimensions of resulting tensor
a	Lower bound of uniform distribution to sample from
b	Upper bound of uniform distribution to sample from
...	Potential additional arguments

Value

A sample from the specified uniform distribution in a tensor with the specified shape

WGAN_value_fct *WGAN Value Function*

Description

Implements the Wasserstein GAN (WGAN) value function as a function to be called in gan_trainer. Note that for this to work properly you also need to implement a weight clipper (or other procedure) to constrain the Discriminator weights.

Usage

```
WGAN_value_fct(real_scores, fake_scores)
```

Arguments

real_scores The discriminator scores on real examples ($D(x)$)
 fake_scores The discriminator scores on fake examples ($D(G(z))$)

Value

The function returns a named list with the entries d_loss and g_loss

WGAN_weight_clipper *WGAN Weight Clipper*

Description

A function that clips the weights of a Discriminator (for WGAN training).

Usage

```
WGAN_weight_clipper(d_net, clip_values = c(-0.01, 0.01))
```

Arguments

d_net A torch::nn_module (typically a discriminator/critic) for which the weights should be clipped
 clip_values A vector with the lower and upper bound for weight values. Any value outside this range will be set to the closer value.

Value

The function modifies the torch::nn_module weights in place

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