

# Package: rTLsDeep (via r-universe)

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**Type** Package

**Title** Post-Hurricane Damage Severity Classification from TLS and AI

**Version** 0.0.5

**Description** Terrestrial laser scanning (TLS) data processing and post-hurricane damage severity classification at the individual tree level using deep Learning. Further details were published in Klauberg et al. (2023) <[doi:10.3390/rs15041165](https://doi.org/10.3390/rs15041165)>.

**License** GPL-3

**Encoding** UTF-8

**Depends** R (>= 3.5.0)

**Imports** caret, ggplot2, grDevices, lidR, keras, matrixStats, reticulate, rgl, sf, tensorflow

**Suggests** terra, viridis

**RoxygenNote** 7.2.3

**URL** <https://github.com/carlos-alberto-silva/rTLsDeep>

**BugReports** <https://github.com/carlos-alberto-silva/rTLsDeep/issues>

**NeedsCompilation** no

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confmatrix\_treedamage *Confusion matrix*

---

### Description

This function calculates a cross-tabulation of reference and predicted classes with associated statistics based on the deep learning models.

### Usage

```
confmatrix_treedamage(predict_class, test_classes, class_list)
```

### Arguments

predict_class	A vector with the predicted classes. This is the output from the predict_treedamage function.
test_classes	A vector with the predicted classes. This is the output from the get_validation_classes function.
class_list	A character string or numeric value describing the post-hurricane individual tree level damage classes, e.g.: c("1","2","3","4","5","6").

### Value

Returns the confusion matrix comparing predictions with the reference from validation dataset.

### See Also

<https://www.rdocumentation.org/packages/caret/versions/3.45/topics/confusionMatrix>



```

        weights=weights,
        target_size = c(256,256),
        class_list=class_list_test,
        batch_size = batch_size)

# Get damage classes for test datasets
classes<-get_validation_classes(file_path=test_image_files_path)

# Calculate, print and return confusion matrix
cm = confmatrix_treedamage(predict_class = tree_damage,
                           test_classes=classes,
                           class_list = class_list_test)

```

---

fit_dl_model	<i>Fitting deep learning models for post-hurricane individual tree level damage classification</i>
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---

### Description

This function fits deep learning models for post-hurricane individual tree level damage classification using TLS-derived 2D images

### Usage

```

fit_dl_model(
  model,
  train_input_path,
  test_input_path,
  output_path = tempdir(),
  target_size = c(256, 256),
  batch_size = 8,
  class_list,
  epochs = 20L,
  lr_rate = 1e-04
)

```

### Arguments

model	A model object output of the get_dl_model function. See [rTLsDeep::get_dl_model()].
train_input_path	A character string describing the path to the training dataset, e.g.: "C:/train_data/".
test_input_path	A character string describing the path to the testing dataset, e.g.: "C:/test_data/".
output_path	A character string describing the path where to save the weights for the neural network.
target_size	A vector of two values describing the image dimensions (Width and height) to be used in the model. Default: c(256,256)

batch_size	A numerical value indicating the number of images to be processed at the same time. Reduce the batch_size if the GPU is giving memory errors.
class_list	A character string or numeric value describing the post-hurricane individual tree level damage classes, e.g.: c("1","2","3","4","5","6").
epochs	A numeric value indicating the number of iterations to train the model. Use at least 20 for pre-trained models, and at least 200 for a model without pre-trained weights.
lr_rate	A numeric value indicating the learning rate. Default: 0.0001.

### Value

Returns a character string indicating the filename of the best weights trained for the chosen model.

### Examples

```
# Set directory to tensorflow (python environment)
# This is required if running deep learning local computer with GPU
# Guide to install here: https://doi.org/10.5281/zenodo.3929709
tensorflow_dir = NA

# define model type
model_type = "simple"
#model_type = "vgg"
#model_type = "inception"
#model_type = "resnet"
#model_type = "densenet"
#model_type = "efficientnet"

train_image_files_path = system.file('extdata', 'train', package='rTLsDeep')
test_image_files_path = system.file('extdata', 'validation', package='rTLsDeep')
img_width <- 256
img_height <- 256
class_list_train = unique(list.files(train_image_files_path))
class_list_test = unique(list.files(test_image_files_path))
lr_rate = 0.0001
target_size <- c(img_width, img_height)
channels <- 4
batch_size = 8L
epochs = 2L

# get model
if (reticulate::py_module_available('tensorflow') == FALSE)
{
  tensorflow::install_tensorflow()
}

model = get_dl_model(model_type=model_type,
                    img_width=img_width,
                    img_height=img_height,
                    channels=channels,
                    lr_rate = lr_rate,
```

```

tensorflow_dir = tensorflow_dir,
class_list = class_list_train)

# train model and return best weights
weights = fit_dl_model(model = model,
                       train_input_path = train_image_files_path,
                       test_input_path = test_image_files_path,
                       target_size = target_size,
                       batch_size = batch_size,
                       class_list = class_list_train,
                       epochs = epochs,
                       lr_rate = lr_rate)

unlink('epoch_history', recursive = TRUE)
unlink('weights', recursive = TRUE)
unlink('weights_r_save', recursive = TRUE)

```

---

gcmplot

*Plot confusion matrix*


---

## Description

This function plots the confusion matrix for classification assessment

## Usage

```

gcmplot(
  cm,
  colors = c(low = "white", high = "#009194"),
  title = "cm",
  prop = TRUE
)

```

## Arguments

cm	An confusion matrix object of class "confusionMatrix". Output of the [rTLs-Deep::confmatrix_damage()] function.
colors	A vector defining the low and high colors. Default is c(low="white", high="#009194").
title	A character defining the title of the figure.
prop	If TRUE percentage values will be plotted to the figure otherwise Freq.

## Value

Returns an object of class gg and ggplot and plot of the confusion matrix.

**Examples**

```
# Path to rds file
rdsfile <- system.file("extdata", "cm_vgg.rds", package="rTLsDeep")

# Read RDS fo;e
cm_vgg<-readRDS(rdsfile)

# Plot confusion matrix
gcmlplot_vgg<-gcmlplot(cm_vgg,
                       colors=c(low="white", high="#009194"),
                       title="densenet")
```

---

get_best_angle	<i>Get best angle for plotting the tree</i>
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**Description**

Calculates the minimum oriented bounding box using the rotating calipers algorithm and extracts the angle

**Usage**

```
get_best_angle(las)
```

**Arguments**

las                    An object of class LAS [lidR::readLAS()].

**Value**

Returns a list containing the model object with the required parameters and model\_type used.

**Examples**

```
lasfile <- system.file("extdata", "tree_c2.laz", package = "rTLsDeep")
las <- lidR::readLAS(lasfile)

(get_best_angle(las))
```

---

get\_dl\_model                      *Selecting deep learning modeling approaches*

---

### Description

This function selects and returns the deep learning approach to be used with the fit\_dl\_model function for post-hurricane individual tree-level damage classification.

### Usage

```
get_dl_model(
  model_type = "vgg",
  img_width = 256,
  img_height = 256,
  lr_rate = 1e-04,
  tensorflow_dir = NA,
  channels,
  class_list
)
```

### Arguments

model_type	A character string describing the deep learning model to be used. Available models: "vgg", "resnet", "inception", "densenet", "efficientnet", "simple".
img_width	A numeric value describing the width of the image used for training. Default: 256.
img_height	A numeric value describing the height of the image used for training. Default: 256.
lr_rate	A numeric value indicating the learning rate. Default: 0.0001.
tensorflow_dir	A character string indicating the directory for the tensorflow python environment. Guide to install the environment here: <a href="https://doi.org/10.5281/zenodo.3929709">https://doi.org/10.5281/zenodo.3929709</a> . Default = NA.
channels	A numeric value for the number of channels/bands of the input images.
class_list	A character string or numeric value describing the post-hurricane individual tree level damage classes, e.g.: c("1","2","3","4","5","6").

### Value

Returns a list containing the model object with the required parameters and model\_type used.

### Examples

```
# Set directory to tensorflow (python environment)
# This is required if running deep learning local computer with GPU
# Guide to install here: https://doi.org/10.5281/zenodo.3929709
tensorflow_dir = NA
```

```
# define model type
model_type = "simple"
#model_type = "vgg"
#model_type = "inception"
#model_type = "resnet"
#model_type = "densenet"
#model_type = "efficientnet"

train_image_files_path = system.file('extdata', 'train', package='rTLsDeep')
test_image_files_path = system.file('extdata', 'validation', package='rTLsDeep')
img_width <- 256
img_height <- 256
class_list_train = unique(list.files(train_image_files_path))
class_list_test = unique(list.files(test_image_files_path))
lr_rate = 0.0001
target_size <- c(img_width, img_height)
channels = 4

# get model
if (reticulate::py_module_available('tensorflow') == FALSE)
{
  tensorflow::install_tensorflow()
}
model = get_dl_model(model_type=model_type,
                     img_width=img_width,
                     img_height=img_height,
                     channels=channels,
                     lr_rate = lr_rate,
                     tensorflow_dir = tensorflow_dir,
                     class_list = class_list_train)
```

---

get\_validation\_classes

*Tree-level damage classes for validation datasets*

---

### Description

This function return the post-hurricane individual tree-level damage classes based on file names in a given directory.

### Usage

```
get_validation_classes(file_path)
```

### Arguments

**file\_path**      A character string indicating the path to the validation folders, one for each class. This folder must have sub folders with samples for each class.

**Value**

Returns the classes based on file names in a given folder.

**Examples**

```
# Image and model properties
val_image_files_path = system.file('extdata', 'validation', package='rTlsDeep')

# Get damage classes for validation datasets
classes = get_validation_classes(file_path=val_image_files_path)
```

---

getMinBBox	<i>Rotating calipers algorithm</i>
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**Description**

Calculates the minimum oriented bounding box using the rotating calipers algorithm.

**Usage**

```
getMinBBox(hull)
```

**Arguments**

hull	A matrix of xy values from a convex hull from which will calculate the minimum oriented bounding box.
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getTLS2D	<i>Grid snapshot</i>
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---

**Description**

This function captures a 2D grid snapshot of the TLS-derived 3D Point Cloud

**Usage**

```
getTLS2D(las, res = 0.05, by = "xz", func = ~list(Z = max(Z)), scale = TRUE)
```

**Arguments**

las	An object of class LAS [lidR::readLAS()].
res	Numeric defining the resolution or grid cell size of the 2D image.
by	Character defining the grid snapshot view: 'xz', 'yx' or 'xy'. Default: 'xz'.
func	formula defining the equation to be passed in each grid. Default: ~list(Z = max(Z)).
scale	if TRUE, the xyz coordinates will be scaled to local coordinates by subtracting their values to their corresponding minimum values (e.g. $x - \min(x)$ ). Default is TRUE.

**Value**

Returns an object of class SpatRaste containing the 2D grid snapshot of the TLS 3D point cloud.

**Examples**

```
#Loading lidR and viridis libraries
library(lidR)
library(viridis)

# Path to las file
lasfile <- system.file("extdata", "tree_c1.laz", package="rTLsDeep")

# Reading las file
las<-readLAS(lasfile)

# Visualizing las file
suppressWarnings(plot(las))

# Creating a 2D grid snapshot
func = ~list(Z = max(Z))
by="xz"
res=0.05
scale=TRUE

g<-getTLS2D(las, res=res, by=by, func = func, scale=scale)

# Visualizing 2D grid snapshot
plot(g, asp=TRUE, col=viridis::viridis(100),axes=FALSE, xlab="",ylab="")

# Exporting 2D grid snapshot as png file
output_png = paste0(tempfile(), '.png')
png(output_png, units="px", width=1500, height=1500)
terra::image(g, col=viridis::viridis(100))

dev.off()
```

---

predict\_treedamage      *Predict post-hurricane individual tree level damage*

---

### Description

This function predicts post-hurricane individual tree-level damage from TLS derived 2D images

### Usage

```
predict_treedamage(
  model,
  input_file_path,
  weights,
  target_size = c(256, 256),
  class_list,
  batch_size = 8
)
```

### Arguments

model	A model object output of the get_dl_model function. See [rTLsDeep::get_dl_model()].
input_file_path	A character string describing the path to the images to predict, e.g.: "C:/test_data/".
weights	A character string indicating the filename of the weights to use for prediction.
target_size	A vector of two values describing the image dimensions (Width and height) to be used in the model. Default: c(256,256)
class_list	A character string or numeric value describing the post-hurricane individual tree level damage classes, e.g.: c("1","2","3","4","5","6").
batch_size	A numerical value indicating the number of images to be processed at the same time. Reduce the batch_size if the GPU is giving memory errors.

### Value

Returns a character string with the prediction classes.

### Examples

```
# Set directory to tensorflow (python environment)
# This is required if running deep learning local computer with GPU
# Guide to install here: https://doi.org/10.5281/zenodo.3929709
tensorflow_dir = NA

# define model type
model_type = "simple"
#model_type = "vgg"
#model_type = "inception"
#model_type = "resnet"
```

```
#model_type = "densenet"
#model_type = "efficientnet"

train_image_files_path = system.file('extdata', 'train', package='rTLsDeep')
test_image_files_path = system.file('extdata', 'validation', package='rTLsDeep')
img_width <- 256
img_height <- 256
class_list_train = unique(list.files(train_image_files_path))
class_list_test = unique(list.files(test_image_files_path))
lr_rate = 0.0001
target_size <- c(img_width, img_height)
channels = 4
batch_size = 8L
epochs = 20L

# get model
model = get_dl_model(model_type=model_type,
                    img_width=img_width,
                    img_height=img_height,
                    lr_rate = lr_rate,
                    tensorflow_dir = tensorflow_dir,
                    channels = channels,
                    class_list = class_list_train)

# train model and return best weights
weights = fit_dl_model(model = model,
                    train_input_path = train_image_files_path,
                    test_input_path = test_image_files_path,
                    target_size = target_size,
                    batch_size = batch_size,
                    class_list = class_list_train,
                    epochs = epochs,
                    lr_rate = lr_rate)

# Predicting post-hurricane damage at the tree-level
tree_damage<-predict_treedamage(model=model,
                    input_file_path=test_image_files_path,
                    weights=weights,
                    target_size = c(256,256),
                    class_list=class_list_test,
                    batch_size = batch_size)

unlink('epoch_history', recursive = TRUE)
unlink('weights', recursive = TRUE)
unlink('weights_r_save', recursive = TRUE)
```

---

---

rTLsDeep	<i>rTLsDeep: Set of tools for post-hurricane individual tree-level damage classification from terrestrial laser scanning and deep learning.</i>
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### Description

The rTLsDeep package provides options for: i) rotating and deriving 2D images from TLS 3D point clouds ii) calibrating and validating convolutional neural network (CNN) architectures and iii) predicting post-hurricane damage severity at the individual tree level

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tlsrotate3d	<i>Rotate TLS-derived 3D Point Clouds</i>
-------------	---

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### Description

This function rotates TLS-derived 3D Point Clouds

### Usage

```
tlsrotate3d(las, theta, by = "z", scale = TRUE)
```

### Arguments

las	An object of class LAS [lidR::readLAS()].
theta	Numeric defining the angle in degrees (from 0 to 360) for rotating the 3d point cloud.
by	Character defining the rotation around x ('x'), y ('y') or z ('z') axis. Default: around z-axis.
scale	if TRUE, the xyz coordinates will be scaled to local coordinates by subtracting their values to their corresponding minimum values (e.g. x - min(x)). Default is TRUE.

### Value

Returns an object of class LAS containing the rotated 3d point cloud.

### Examples

```
# Path to las file
lasfile <- system.file("extdata", "tree_c1.laz", package="rTLsDeep")

# Reading las file
las<-lidR::readLAS(lasfile)

# Visualizing las file
suppressWarnings(lidR::plot(las))
```

```
# Rotating 3d point cloud around Z-axis
lasr<-tlsrotate3d(las,theta=180, by="x", scale=TRUE)

# Visualizing rotated las file
suppressWarnings(lidR::plot(lasr))

if (!rgl::rgl.useNULL())
  rgl::play3d(rgl::spin3d(axis = c(0, 0, 1), rpm = 5), duration = 10)
```

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