

# Package ‘coreCT’

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**Type** Package

**Title** Programmatic Analysis of Sediment Cores Using Computed Tomography Imaging

**Version** 1.3.0

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**Description** Computed tomography (CT) imaging is a powerful tool for understanding the composition of sediment cores. This package streamlines and accelerates the analysis of CT data generated in the context of environmental science. Included are tools for processing raw DICOM images to characterize sediment composition (sand, peat, etc.). Root analyses are also enabled, including measures of external surface area and volumes for user-defined root size classes. For a detailed description of the application of computed tomography imaging for sediment characterization, see: Davey, E., C. Wigand, R. Johnson, K. Sundberg, J. Morris, and C. Roman. (2011) <DOI: 10.1890/10-2037.1>.

**License** GPL-3

**URL** <https://github.com/troyhill/coreCT>

**BugReports** <https://github.com/troyhill/coreCT/issues>

**LazyData** true

**Depends** R (>= 3.0), raster, igraph, oro.dicom, plyr

**RoxygenNote** 6.1.1

**Suggests** knitr, rmarkdown, testthat, covr

**VignetteBuilder** knitr

**NeedsCompilation** no

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conv	<i>Convert a matrix of semi-processed DICOM images to mass and volume of material classes</i>
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### Description

Converts raw CT units to material classes for each CT slice.

### Usage

```
conv(mat.list, upperLim = 3045, lowerLim = -1025,
      pixelA, thickness = 0.625, # all in mm
      means = c(-850.3233, 63.912, 271.7827, 1345.0696),
      sds = c(77.6953, 14.1728, 39.2814, 45.4129),
      densities = c(0.0012, 1, 1.23, 2.2))
```

### Arguments

mat.list	list of DICOM images for a sediment core (values in Hounsfield Units)
upperLim	upper bound cutoff for pixels (Hounsfield Units)
lowerLim	lower bound cutoff for pixels (Hounsfield Units)
pixelA	pixel area (mm <sup>2</sup> )
thickness	slice thickness for computed tomography image series (mm)
means	mean values (units = Hounsfield Units) for calibration rods used.
sds	standard deviations (units = Hounsfield Units) for calibration rods used. Must be in the same order as means.
densities	numeric vector of known cal rod densities. Must be in the same order as means and sds.

## Details

Calculates average Hounsfield units, cross-sectional areas (cm<sup>2</sup>), volumes (cm<sup>3</sup>), and masses (g) of material classes for each CT slice. This function assumes that core walls and all non-sediment material have been removed from the raw DICOM imagery. This function converts data from raw x-ray attenuation values to Hounsfield Units, and then uses user-defined calibration rod inputs to categorize sediment components: air, roots and rhizomes, peat, water, particulates, sand, and rock/shell. The input style for calibration rods ensures sediment components are partitioned following the density divisions in Davey et al. 2011. Calibration rods are used to develop the calibration curve. Separately, the densities used for partitioning in Davey et al. 2011 (0.0012, 1, 1.23, 2.2 g/cm<sup>3</sup>) are converted to Hounsfield Units and used for partitioning sediment components. The standard deviation for the calibration rod nearest to the target value is used for the standard deviation for the division between two sediment components.

## Value

value conv returns a dataframe with one row per CT slice. Values returned are the average Hounsfield Unit value, the area (cm<sup>2</sup>), volume (cm<sup>3</sup>), and mass (grams) of 7 material classes: gas, peat, roots and rhizomes, particulates, sand, water, and rock/shell. If `rootData = TRUE`, data for specified root size classes are also returned. See `rootSize` for more detail on those values.

## See Also

`rootSize` operates similarly.

## Examples

```
ct.slope <- unique(extractHeader(core_426$hdr, "RescaleSlope"))
ct.int <- unique(extractHeader(core_426$hdr, "RescaleIntercept"))
# convert raw units to Hounsfield units
HU_426 <- lapply(core_426$img, function(x) x*ct.slope + ct.int)

materials <- conv(HU_426, pixelA = 0.0596)

## Not run:
# plot using "ggplot" package after transforming with "reshape2" package
mass.long <- reshape2::melt(materials, id.vars = c("depth"),
  measure.vars = grep(".g", names(materials)))
ggplot2::ggplot(data = mass.long, ggplot2::aes(y = -depth, x = value,
  color = variable)) + ggplot2::geom_point() + ggplot2::theme_classic() +
  ggplot2::xlab("mass per section (g)")

## End(Not run)
```

convDir

*Convert a directory of raw DICOM images to material classes***Description**

Calculates the area and volume of material classes for each CT slice in a directory

**Usage**

```
convDir(directory = file.choose(), upperLim = 3045, lowerLim = -1025,
means    = c(-850.3233, 63.912, 271.7827, 1345.0696),
sds      = c(77.6953, 14.1728, 39.2814, 45.4129),
densities = c(0.0012, 1, 1.23, 2.2),
rootData = TRUE,
diameter.classes = c(1, 2, 2.5, 10),
class.names = diameter.classes,
pixel.minimum = 4)
```

**Arguments**

directory	a character string that can be a matrix of DICOM images or the address of an individual DICOM file in a folder of DICOM images. The default action is <code>file.choose()</code> ; a browser menu appears so the user can select the the desired directory by identifying a single DICOM file in the folder of images.
upperLim	upper bound cutoff for pixels (Hounsfield Units)
lowerLim	lower bound cutoff for pixels (Hounsfield Units)
means	mean values (units = Hounsfield Units) for calibration rods used.
sds	standard deviations (units = Hounsfield Units) for calibration rods used. Must be in the same order as means.
densities	numeric vector of known cal rod densities. Format must be c(air, water, Si, glass)
rootData	if TRUE, rootSize is also called on the matrix
diameter.classes	if rootData is TRUE, this argument provides an integer vector of diameter cut points used by rootSize. Units are mm (zero is added in automatically).
class.names	placeholder, not used presently
pixel.minimum	minimum number of pixels needed for a clump to be identified as a root

**Details**

Calculates the area and volume of material classes for each CT slice in a directory. Unlike [conv](#), [convDir](#) accepts a folder of raw values and makes the conversion to Hounsfield Units using the metadata associated with the DICOM images.

**Value**

value convDir returns a dataframe with one row per CT slice. Values returned are the area and volume of seven material classes: gas, peat, roots and rhizomes, rock and shell, fine mineral particles, sand, and water. If rootData = TRUE, the output will also contain data on the abundance (number of particles), volume (cm<sup>3</sup>), and external surface area (cm<sup>2</sup>) of the root size classes specified in the diameter.classes argument.

**See Also**

[convDir](#) is a wrapper for [conv.rootSizeDir](#) operates similarly.

**Examples**

```
materials <- convDir("core_426", rootData = FALSE)

## Not run:
# plot using "ggplot" package after transforming with "reshape2" package
mass.long <- reshape2::melt(materials, id.vars = c("depth"),
  measure.vars = grep(".g", names(materials)))
ggplot2::ggplot(data = mass.long, ggplot2::aes(y = -depth, x = value,
  color = variable)) + ggplot2::geom_point() + ggplot2::theme_classic() +
  ggplot2::xlab("mass per section (g)")

## End(Not run)
```

---

 coreHist

*Whole-core frequency distribution of Hounsfield units*


---

**Description**

Provides the raw data and plots a frequency distribution for Hounsfield Units in the entire core, also delineating material classes.

**Usage**

```
coreHist(directory = file.choose(),
  units = "percent",
  upperLim = 3045, lowerLim = -1025,
  means = c(-850.3233, 63.912, 271.7827, 1345.0696),
  sds = c(77.6953, 14.1728, 39.2814, 45.4129),
  densities = c(0.0012, 1, 1.23, 2.2),
  returnData = TRUE, pngName = NULL)
```

**Arguments**

directory	a character string that can be (1) a matrix of DICOM images that exists in the global environment, or (2) the address of an individual DICOM file in a folder of DICOM images. The default action is <code>file.choose()</code> ; a browser menu appears so the user can select the the desired directory by identifying a single DICOM file in the folder of images.
units	units to be used for plotting purposes: either "percent" (the default) or "absolute"
upperLim	upper bound cutoff for pixels (Hounsfield Units); upper bound is inclusive
lowerLim	lower bound cutoff for pixels (Hounsfield Units); lower bound is exclusive
means	mean values (units = Hounsfield Units) for calibration rods used.
sds	standard deviations (units = Hounsfield Units) for calibration rods used. Must be in the same order as means.
densities	numeric vector of known cal rod densities. Must be in the same order as means and sds.
returnData	if TRUE, voxel counts for each Hounsfield unit from lowerLim to upperLim are returned, as are material class definitions. These are the data needed to re-create and modify the frequency plot.
pngName	if this is not NULL, the frequency plot is saved to disk. In that case, pngName should be a character string containing the name and address of the file.

**Value**

list if returnData = TRUE, a list is returned containing the frequencies for each Hounsfield unit value from lowerLim to upperLim, and (2) the boundaries for material classes. Lower boundaries for a component class are exclusive, while upper bounds are inclusive. These materials allow the frequency distribution to be plotted by the user. If returnData = FALSE the data are plotted in the graphics window, but nothing is preserved.

**Examples**

```
# data(core_426)
coreHist("core_426", returnData = FALSE)
```

---

core\_426

*Three computed tomography scans from a Spartina alterniflora core*

---

**Description**

Three computed tomography scans from a Spartina alterniflora core

**Usage**

```
data(core_426)
```

**Format**

A list of 3 matrices, each with two elements: header and image data

---

getSurface	<i>Remove artificial surface layers from processed CT data</i>
------------	--

---

**Description**

Identifies and removes artificial surface layers from processed CT data

**Usage**

```
getSurface(x, material = "particulates", threshold = 0.40,  
start = "top", thickness = 0.625)
```

**Arguments**

x	dataframe created by conv
material	material used for determining where the surface begins
threshold	decimal fraction of total area, used to determine the surface layer. Surface slices where material exceeds threshold value are removed.
start	should core be processed from the top, bottom, or both?
thickness	CT image thickness (mm)

**Details**

Identifies and removes artificial surface layers from processed CT data. Areas can be removed from one or both ends of the core (set by `start`), based on exceeding a threshold proportion of material (e.g., 75

**Value**

value `getSurface` shortens the output of `conv` to remove artificial surface layers. The output is thus a subset of the input, and identical in structure to the `/codeconv` output.

**See Also**

[conv](#)

**Examples**

```

### Not run:
## Not run: data(core_426)
ct.slope <- unique(extractHeader(core_426$hdr, "RescaleSlope"))
ct.int  <- unique(extractHeader(core_426$hdr, "RescaleIntercept"))
# convert raw units to Hounsfield units
HU_426 <- lapply(core_426$img, function(x) x*ct.slope + ct.int)

materials <- conv(HU_426)
head(materials[, 1:6], 20)

materials2 <- getSurface(materials)
head(materials2[, 1:6])

## End(Not run)

```

---

rootSize	<i>Convert a matrix of semi-processed DICOM images to root particle counts, volumes, and surface areas</i>
----------	--

---

**Description**

Calculates the number of root/rhizome particles, volumes, and surface areas, for different size classes

**Usage**

```

rootSize(mat.list, pixelA, diameter.classes = c(1, 2, 2.5, 10),
class.names = diameter.classes,
thickness = 0.625,
means     = c(-850.3233, 63.912, 271.7827, 1345.0696),
sds       = c(77.6953, 14.1728, 39.2814, 45.4129),
densities = c(0.0012, 1, 1.23, 2.2),
pixel.minimum = 4)

```

**Arguments**

mat.list	list of DICOM images for a sediment core (values in Hounsfield Units)
pixelA	pixel area (mm <sup>2</sup> )
diameter.classes	an integer vector of diameter cut points. Units are mm (zero is added in automatically).
class.names	not used presently
thickness	slice thickness for computed tomography image series (mm)
means	mean values (units = Hounsfield Units) for calibration rods used.



sds	standard deviations (units = Hounsfield Units) for calibration rods used. Must be in the same order as means.
densities	numeric vector of known cal rod densities. Must be in the same order as means and sds.
pixel.minimum	minimum number of pixels needed for a clump to be identified as a root

## Details

Calculates the number of root/rhizome particles, volumes, and surface areas, for different size classes. This function requires that values be Hounsfield Units (i.e., data must be semi-processed from the raw DICOM imagery).

## Value

value rootSize returns a dataframe with one row per CT slice. Values returned are the number, volume (cm<sup>3</sup>), and surface area (cm<sup>2</sup>) of particles in each size class with an upper bound defined in diameter.classes.

## See Also

[conv](#)

## Examples

```
ct.slope <- unique(extractHeader(core_426$hdr, "RescaleSlope"))
ct.int   <- unique(extractHeader(core_426$hdr, "RescaleIntercept"))
# convert raw units to Hounsfield units
HU_426 <- lapply(core_426$img, function(x) x*ct.slope + ct.int)

rootChars <- rootSize(HU_426, pixelA = 0.0596,
  diameter.classes = c(2.5, 10))

## Not run:
# plot using "ggplot" package after transforming with "reshape2" package
area.long <- reshape2::melt(rootChars, id.vars = c("depth"),
  measure.vars = grep("Area", names(rootChars)))
ggplot2::ggplot(data = area.long, ggplot2::aes(y = -depth, x = value,
  color = variable)) + ggplot2::geom_point() + ggplot2::theme_classic() +
  ggplot2::xlab("root external surface area per slice (cm2)")

## End(Not run)
```

---

rootSizeDir	<i>Convert a directory of raw DICOM images to root particle counts and surface areas</i>
-------------	--

---

### Description

Calculates the number of root/rhizome particles and surface areas, for different size classes

### Usage

```
rootSizeDir(directory = file.choose(),
diameter.classes = c(1, 2, 5, 10, 20),
class.names = diameter.classes,
means      = c(-850.3233, 63.912, 271.7827, 1345.0696),
sds        = c(77.6953, 14.1728, 39.2814, 45.4129),
densities  = c(0.0012, 1, 1.23, 2.2),
pixel.minimum = 1)
```

### Arguments

directory	a character string that can be a matrix of DICOM images or the address of an individual DICOM file in a folder of DICOM images. The default action is <code>file.choose()</code> ; a browser menu appears so the user can select the the desired directory by identifying a single DICOM file in the folder of images.
diameter.classes	an integer vector of diameter cut points. Units are mm (zero is added in automatically).
class.names	not used presently
means	mean values (units = Hounsfield Units) for calibration rods used.
sds	standard deviations (units = Hounsfield Units) for calibration rods used. Must be in the same order as means.
densities	numeric vector of known cal rod densities. Must be in the same order as means and sds.
pixel.minimum	minimum number of pixels needed for a clump to be identified as a root

### Details

Calculates the number of root/rhizome particles and surface areas, for different size classes. Unlike [rootSize](#), [rootSizeDir](#) accepts a folder of raw values and makes the conversion to Hounsfield Units using the metadata associated with the DICOM images.

### Value

value `rootSize` returns a dataframe with one row per CT slice. Values returned are the number, volume (cm<sup>3</sup>), and surface area (cm<sup>2</sup>) of particles in each size class with an upper bound defined in `diameter.classes`.

**See Also**

`rootSizeDir` is a wrapper for `rootSize`. `rootSizeDir` operates similarly.

**Examples**

```
rootChars <- rootSizeDir("core_426", diameter.classes = c(2.5, 10))

## Not run:
# plot using "ggplot" package after transforming with "reshape2" package
area.long <- reshape2::melt(rootChars, id.vars = c("depth"),
  measure.vars = grep("Area", names(rootChars)))
ggplot2::ggplot(data = area.long, ggplot2::aes(y = -depth, x = value,
  color = variable)) + ggplot2::geom_point() + ggplot2::theme_classic() +
  ggplot2::xlab("root external surface area per slice (cm2)")

## End(Not run)
```

---

 voxDims

---

*Extract voxel dimensions from DICOM image*


---

**Description**

Extract pixel area and slice thickness from DICOM header to characterize voxel (3D pixel) dimensions.

**Usage**

```
voxDims(directory = file.choose())
```

**Arguments**

`directory` a character string that can be a matrix of DICOM images or the address of an individual DICOM file in a folder of DICOM images. The default action is `file.choose()`; a browser menu appears so the user can select the the desired directory by identifying a single DICOM file in the folder of images.

**Value**

value `voxDims` returns a two-column dataframe showing the pixel area and slice thickness. Values in the DICOM headers are assumed to be millimeters; pixel area and slice thickness columns are labeled based on this assumption.

**Examples**

```
# data(core_426)
voxDims("core_426")
```

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