Package 'DVHmetrics'

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Type Package

Title Analyze Dose-Volume Histograms and Check Constraints

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Description Functionality for analyzing dose-volume histograms (DVH) in radiation oncology: Read DVH text files, calculate DVH metrics as well as generalized equivalent uniform dose (gEUD), biologically effective dose (BED), equivalent dose in 2 Gy fractions (EQD2), normal tissue complication probability (NTCP), and tumor control probability (TCP). Show DVH diagrams, check and visualize quality assurance constraints for the DVH. Includes web-based graphical user interface.

License GPL (>= 2)

URL https://github.com/dwoll/DVHmetrics/

NeedsCompilation no

Author Daniel Wollschlaeger [aut, cre],
Heiko Karle [aut],
Heinz Schmidberger [ctb]

Maintainer Daniel Wollschlaeger <wollschlaeger@uni-mainz.de>

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`DVHmetrics-package` *Analyze Dose-Volume Histograms and Check Constraints*

Description

Functionality for analyzing dose-volume histograms (DVH) in radiation oncology: Read DVH text files, calculate DVH metrics, gEUD, BED, EQD2, NTCP, TCP, show DVH diagrams, check and visualize quality assurance constraints for the DVH. Includes web-based graphical user interface.

Details

Package:	DVHmetrics
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Version:	0.4.1
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License:	GPL (>= 2)

Author(s)

Daniel Wollschlaeger and Heiko Karle

Maintainer: Daniel Wollschlaeger <wollschlaeger@uni-mainz.de>

References

For a solution that also reads files in DICOM-RT format, see the RadOnc package: https://CRAN.R-project.org/package=RadOnc.

Examples

```
showDVH(dataMZ[[1]])
checkConstraint(dataMZ, "D1CC < 10Gy")
```

---

checkConstraint *Check constraints on dose-volume histograms (DVH)*

Description

Simultaneously checks one or more quality assurance constraints on one or more DVHs. Reports compliance with each constraint as well as observed difference between linearly interpolated DVH and the given constraints in terms of (relative) dose, (relative) volume, and (relative) minimal Euclidean distance.

Usage

```
checkConstraint(x, constr, byPat=TRUE, semSign=FALSE,
                sortBy=c("none", "observed", "compliance", "structure",
                         "constraint", "patID", "deltaV", "deltaD",
                         "dstMin", "dstMinRel"),
                interp=c("linear", "spline", "smooth"), ...)

## S3 method for class 'DVHs'
checkConstraint(x, constr, byPat=TRUE, semSign=FALSE,
                sortBy=c("none", "observed", "compliance", "structure",
                         "constraint", "patID", "deltaV", "deltaD",
                         "dstMin", "dstMinRel"),
                interp=c("linear", "spline", "smooth"), ...)

## S3 method for class 'DVHLst'
checkConstraint(x, constr, byPat=TRUE, semSign=FALSE,
                sortBy=c("none", "observed", "compliance", "structure",
                         "constraint", "patID", "deltaV", "deltaD",
                         "dstMin", "dstMinRel"),
```

```
                interp=c("linear", "spline", "smooth"), ...)

## S3 method for class 'DVHLstLst'
checkConstraint(x, constr, byPat=TRUE, semSign=FALSE,
                sortBy=c("none", "observed", "compliance", "structure",
                         "constraint", "patID", "deltaV", "deltaD",
                         "dstMin", "dstMinRel"),
                interp=c("linear", "spline", "smooth"), ...)
```

Arguments

x	A single DVH (object of class DVHs), multiple DVHs from one patient/structure (object of class DVHLst), or multiple DVHs from many patients/structures (object of class DVHLstLst). See readDVH.
constr	One or more constraints - given as a character vector or as a data.frame. See Details.
byPat	logical. Relevant if multiple DVHs are given. If x has class DVHLst: byPat=TRUE means that the DVHs are for one patient with multiple structures. byPat=FALSE means that the DVHs are for one structure from multiple patients. If x has class DVHLstLst: byPat=TRUE means that the DVHs are for multiple patients (list components of x) with multiple structures. byPat=FALSE means that the DVHs are for multiple structures (list components of x) from multiple patients.
semSign	logical. Meaning of the sign of the observed dose/volume differences between DVHs and constraints. semSign=TRUE means that negative differences indicate constraint compliance, positive differences indicate constraint violations. With semSign=FALSE, the algebraic differences are returned as is.
sortBy	character vector. Sorting criteria for the output data frame.
interp	character. Method of interpolation between DVH points: Linear interpolation using approx, monotone Hermite spline interpolation using spline, or local polynomial regression using locpoly with kernel bandwidth chosen by the direct plug-in method using dpill.
...	Additional parameters passed to getMetric. Use for constraints on EUD (see getEUD for parameter names), TCP (see getTCP), and NTCP (see getNTCP).

Details

A DVH constraint is a character string that consists of three parts: The DVH metric, the comparison operator (<, >, <=, >=), and the reference value together with the measurement unit. See getMetric for defining a DVH metric, as well as for possible measurement units for dose and volume. For constraints involving the relative dose, the DVH must contain the prescription dose.

Some example constraints are "V10Gy > 80%" (more than 80% of the structure should have received 10Gy), "V20% < 10CC" (less than 10cm^3 of the structure should have received 20% of the prescription dose), or "D10CC > 500cGy" (The "hottest" 10cm^3 of the structure should have received more than 500cGy).

For constraints on DEUD, DNTCP and DTCP (see getMetric), the reference measurement unit must be Gy, cGy, even though NTCP and TCP are probabilities. Example: "DNTCP < 0.5Gy".

A DVH constraint can apply to a specific patient or to all patients, and to a specific structure or to all structures.

- If constraints apply to all patients/structures in `x`, `constr` can be a `character` vector with elements like the examples above.
- If constraints apply only to some patients/structures, `constr` must be a data frame with variables `constraint`, `patID` and `structure`. Each row then defines one constraint and its scope: `constraint` must be a character string with one constraint definition as in the examples above. `patID` must be either a character string with a valid patient ID or `"*"` if the the constraint applies to all patients. `structure` must be either a character string with a valid structure or `"*"` if the the constraint applies to all structures. If variable `patID` is missing from the data frame, the constraints apply to all available patients. If variable `structure` is missing from the data frame, the constraints apply to all available structures. See `readConstraint` for reading appropriate constraint `data.frames` from external text files.

For calculating the minimal Euclidean distance between the constraint point and the DVH, the constraint point is orthogonally projected onto each DVH segment between (interpolated) DVH nodes. The relative Euclidean distance is the minimum of these distances divided by the distance of the constraint point to the closer one of both axes (dose and volume).

If volume or dose values outside the range of possible values for a structure are requested, metrics cannot be calculated, and the result will be `NA` with a warning.

Value

A data frame with details on constraint compliance / violation.

`patID`	Patient ID
`structure`	Structure
`constraint`	The checked constraint
`observed`	The observed value for the metric given in the constraint
`compliance`	Does the DVH satisfy the constraint?
`deltaV`	Volume difference between constraint and observed DVH (for the constraint dose) in measurement unit specified by constraint
`deltaVpc`	Percent volume difference between constraint and observed DVH (for the constraint dose) relative to constraint volume
`deltaD`	Dose difference between constraint and observed DVH (for the constraint volume) in measurement unit specified by constraint
`deltaDpc`	Percent dose difference between constraint and observed DVH (for the constraint volume) relative to constraint dose
`dstMin`	Minimal Euclidean distance between constraint and the cumulative DVH, using linear interpolation
`ptMinD`	Dose coordinate of closest point on cumulative DVH to constraint
`ptMinV`	Volume coordinate of closest point on cumulative DVH to constraint

See Also

`getMetric`, `getEUD`, `getNTCP`, `getTCP`, `readConstraint`, `saveConstraint`, `showConstraint`

Examples

```
res <- checkConstraint(dataMZ, c("D10CC < 10Gy", "V20Gy < 20%"))
head(res)

# define constraints
constr <- data.frame(
    patID=c("P123", "P234"),
    structure=c("HEART", "*"),
    constraint=c("D1CC < 20Gy", "V10% > 8CC"),
    stringsAsFactors=FALSE)       # this is important
checkConstraint(dataMZ, constr=constr)
```

---

convertDVH *Convert between differential and cumulative DVH*

Description

Convert between differential and cumulative DVH as well as between dose units.

Usage

```
convertDVH(x, toType=c("asis", "cumulative", "differential"),
           toDoseUnit=c("asis", "GY", "CGY"),
           interp=c("asis", "linear"),
           nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'matrix'
convertDVH(x, toType=c("asis", "cumulative", "differential"),
           toDoseUnit=c("asis", "GY", "CGY"),
           interp=c("asis", "linear"),
           nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'DVHs'
convertDVH(x, toType=c("asis", "cumulative", "differential"),
           toDoseUnit=c("asis", "GY", "CGY"),
           interp=c("asis", "linear"),
           nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'DVHLst'
convertDVH(x, toType=c("asis", "cumulative", "differential"),
           toDoseUnit=c("asis", "GY", "CGY"),
           interp=c("asis", "linear"),
           nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'DVHLstLst'
convertDVH(x, toType=c("asis", "cumulative", "differential"),
           toDoseUnit=c("asis", "GY", "CGY"),
```

```
            interp=c("asis", "linear"),
            nodes=NULL, rangeD=NULL, perDose=TRUE)
```

Arguments

x	One DVH (object of class matrix or DVHs, multiple cumulative DVHs from one patient with multiple structures (object of class DVHLst), or multiple cumulative DVHs from many patients, each with multiple structures (object of class DVHLstLst). See readDVH.
toType	character. Convert the DVH to this type. "asis" keeps the current DVH type.
toDoseUnit	character. Convert the DVH to this dose unit. "asis" keeps the current dose unit.
interp	character. Interpolation method for the cumulative DVH. "asis" for no interpolation and "linear" for linear interpolation.
nodes	numeric. Minimum number of nodes to use in linear interpolation. Number of available nodes is kept as is for NULL or if larger than nodes.
rangeD	numeric. Dose range for linear interpolation method. If NULL it is determined individally for each DVH.
perDose	logical. Are the differential DVH volume values per unit dose?

Value

Depending on the input, an object of class matrix, DVHs, DVHLst, or DVHLstLst.

See Also

convertDVHsmooth, readDVH, showDVH

Examples

```
res <- convertDVH(dataMZ[[c(1, 1)]],
                  toType="cumulative",
                  toDoseUnit="CGY")
```

---

convertDVHsmooth *Convert between differential and cumulative DVH*

Description

Convert between differential and cumulative DVH as well as between dose units, using smoothng of the differential DVH.

Usage

```
convertDVHsmooth(x,
                 toType=c("asis", "cumulative", "differential"),
                 toDoseUnit=c("asis", "GY", "CGY"),
                 interp=c("asis", "linear", "spline", "ksmooth", "smoothSpl"),
                 nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'matrix'
convertDVHsmooth(x,
                 toType=c("asis", "cumulative", "differential"),
                 toDoseUnit=c("asis", "GY", "CGY"),
                 interp=c("asis", "linear", "spline", "ksmooth", "smoothSpl"),
                 nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'DVHs'
convertDVHsmooth(x,
                 toType=c("asis", "cumulative", "differential"),
                 toDoseUnit=c("asis", "GY", "CGY"),
                 interp=c("asis", "linear", "spline", "ksmooth", "smoothSpl"),
                 nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'DVHLst'
convertDVHsmooth(x,
                 toType=c("asis", "cumulative", "differential"),
                 toDoseUnit=c("asis", "GY", "CGY"),
                 interp=c("asis", "linear", "spline", "ksmooth", "smoothSpl"),
                 nodes=NULL, rangeD=NULL, perDose=TRUE)

## S3 method for class 'DVHLstLst'
convertDVHsmooth(x,
                 toType=c("asis", "cumulative", "differential"),
                 toDoseUnit=c("asis", "GY", "CGY"),
                 interp=c("asis", "linear", "spline", "ksmooth", "smoothSpl"),
                 nodes=NULL, rangeD=NULL, perDose=TRUE)
```

Arguments

x	One DVH (object of class `matrix` or `DVHs`, multiple cumulative DVHs from one patient with multiple structures (object of class `DVHLst`), or multiple cumulative DVHs from many patients, each with multiple structures (object of class `DVHLstLst`). See `readDVH`.
toType	`character`. Convert the DVH to this type. `"asis"` keeps the current DVH type.
toDoseUnit	`character`. Convert the DVH to this dose unit. `"asis"` keeps the current dose unit.
interp	`character`. Interpolation method for the differential DVH. `"asis"` and `"linear"` for no interpolation. `"spline"` for spline interpolation using `splinefun` (`"fmm"` for differential, `"monoH.FC"` for cumulative DVHs), `"ksmooth"` for local polynomial regression using `locpoly` with kernel bandwidth chosen by the direct

	plug-in method using dpill, "smoothSpl" for a smoothing spline using smooth.spline, with the smoothing parameter chosen by generalized crossvalidation.
nodes	numeric. Minimum number of nodes to use in interpolation for method "ksmooth". Number of available nodes is kept as is for NULL or if larger than nodes.
rangeD	numeric. Dose range for interpolation methods "linear", "spline", "smoothSpl". If NULL it is determined individually for each DVH.
perDose	logical. Are the differential DVH volume values per unit dose?

Value

Depending on the input, an object of class matrix, DVHs, DVHLst, or DVHLstLst.

See Also

convertDVH, readDVH, showDVH

Examples

```
res <- convertDVHsmooth(dataMZ[[c(1, 1)]],
                  toType="cumulative",
                  toDoseUnit="CGY")
```

---

dataConstr *Constraint data frame*

Description

Data frame with quality assurance constraints to use with built-in DVH object dataMZ.

Usage

```
data(dataConstr)
```

Format

A data frame with 6 entries for the following 3 variables.

constraint The constraint character string.

patID The patient ID character string or * wildcard.

structure The structure character string or * wildcard.

Details

See checkConstraint for the definition of a constraint.

See Also

readConstraint, checkConstraint, showConstraint

Examples

```
checkConstraint(dataMZ, constr=dataConstr)
```

---

dataMZ *DVH data from 3 patients*

Description

Data from 3 patients with radiotherapy. DVHs for 7 heart structures.

Usage

```
data(dataMZ)
```

Format

Object of class DVHLstLst with 3 components corresponding to 3 patients.

P123 Object of class DVHLst. 7 objects of class DVHs for structures AMYOCL (left anterior heart wall), AMYOCR (right anterior heart wall), AOVALVE (aortic valve), AVNODE (AV node), HEART (complete heart), PULMVALVE (pulmonary valve), MYOCARD (heart wall)

P234 Object of class DVHLst. 7 objects of class DVHs for the same structures as patient P123.

P345 Object of class DVHLst. 7 objects of class DVHs for the same structures as patient P123.

Details

Data courtesy of Department of Radiation Oncology (Prof. Dr. Schmidberger), University Medical Center Mainz, Germany.

See readDVH for classes DVHLstLst, DVHLst, and DVHs.

See Also

readDVH, print.DVHs

Examples

```
print(dataMZ, verbose=TRUE)
```

getBED *Calculate biologically effective dose (BED)*

Description

Calculate biologically effective dose (BED) according to the linear-quadratic model.

Usage

```
getBED(D=NULL, fd=NULL, fn=NULL, ab=NULL)

## Default S3 method:
getBED(D=NULL, fd=NULL, fn=NULL, ab=NULL)

## S3 method for class 'DVHs'
getBED(D=NULL, fd=NULL, fn=NULL, ab=NULL)

## S3 method for class 'DVHLst'
getBED(D=NULL, fd=NULL, fn=NULL, ab=NULL)

## S3 method for class 'DVHLstLst'
getBED(D=NULL, fd=NULL, fn=NULL, ab=NULL)
```

Arguments

D	Default: Total dose. If NULL, fn must be given. Alternative: One cumulative DVH (object of class DVHs, multiple cumulative DVHs from one patient with multiple structures (object of class DVHLst), or multiple cumulative DVHs from many patients, each with multiple structures (object of class DVHLstLst). See readDVH.
fd	Fractional dose. If D is some kind of DVH object, only the first element will be used.
fn	Number of fractions. If NULL, D must be the total dose. Ignored if D is some kind of DVH object.
ab	alpha/beta ratio for the relevant tissue. If some kind of DVH object, only the first element will be used.

Value

Default method: A data frame with variables BED, fractDose, ab.

If D is some kind of DVH object, the same kind of object is returned with the individual dose values converted to BED.

References

Fowler, J. F. (2010). 21 years of Biologically Effective Dose. British Journal of Radiology, 83, 554-568.

See Also

getEQD2, getIsoEffD

Examples

```
getBED(D=50, fd=2.5, ab=c(2, 3, 4))
getBED(D=dataMZ[[c(1, 1)]], fd=1.8, ab=3)
```

---

getDMEAN *DMEAN and other dose metrics*

Description

Calculate DMEAN and other dose metrics from the (interpolated) differential DVH without relying on the values exported by the TPS.

Usage

```
getDMEAN(x, interp=c("linear", "spline", "ksmooth", "smoothSpl"),
         nodes=5001L)

## S3 method for class 'DVHs'
getDMEAN(x, interp=c("linear", "spline", "ksmooth", "smoothSpl"),
         nodes=5001L)

## S3 method for class 'DVHLst'
getDMEAN(x, interp=c("linear", "spline", "ksmooth", "smoothSpl"),
         nodes=5001L)

## S3 method for class 'DVHLstLst'
getDMEAN(x, interp=c("linear", "spline", "ksmooth", "smoothSpl"),
         nodes=5001L)
```

Arguments

x	One DVH (object of class DVHs, multiple DVHs from one patient with multiple structures (object of class DVHLst), or multiple DVHs from many patients, each with multiple structures (object of class DVHLstLst). See readDVH.
interp	character. Method of interpolation between DVH points: Linear interpolation applies to the cumulative DVH (recommended). Spline interpolation with splinefun, local polynomial regression with locpoly, and smoothing splines with smooth.spline apply to the differential DVH (not recommended).
nodes	numeric. Minimum number of nodes to use in interpolation. Number of available nodes is kept as is for NULL or if larger than nodes.

Value

A data frame with the following value(s).

patID Patient ID.
structure Structure name.
doseMin Minimum dose.
doseMax Maximum dose.
doseAvg Mean dose.
doseMed Median dose.
doseSD Dose standard deviation.
doseMode Dose mode.
doseAvgTPS Mean dose as exported from the TPS (if available).
doseMedTPS Median dose as exported from the TPS (if available).
doseMinTPS Minimum dose as exported from the TPS (if available).
doseMaxTPS Maximum dose as exported from the TPS (if available).

See Also

getMetric, convertDVHsmooth, approxfun, splinefun, smooth.spline, dpill, locpoly

Examples

```
getDMEAN(dataMZ[[1]], interp="linear")
```

---

getEQD2 *2Gy fractions biologically equivalent dose (EQD2)*

Description

Calculate dose in 2Gy fractions biologically equivalent dose according to the linear-quadratic model, assuming a homogeneous dose distribution within the volume.

Usage

```
getEQD2(D=NULL, fd=NULL, fn=NULL, ab=NULL)

## Default S3 method:
getEQD2(D=NULL, fd=NULL, fn=NULL, ab=NULL)

## S3 method for class 'DVHs'
getEQD2(D=NULL, fd=NULL, fn=NULL, ab=NULL)

## S3 method for class 'DVHLst'
getEQD2(D=NULL, fd=NULL, fn=NULL, ab=NULL)

## S3 method for class 'DVHLstLst'
getEQD2(D=NULL, fd=NULL, fn=NULL, ab=NULL)
```

Arguments

D	Default: Total dose. If NULL, fn must be given. Alternative: One cumulative DVH (object of class DVHs), multiple cumulative DVHs from one patient with multiple structures (object of class DVHLst), or multiple cumulative DVHs from many patients, each with multiple structures (object of class DVHLstLst). See readDVH.
fd	Fractional dose. If D is some kind of DVH object, only the first element will be used.
fn	Number of fractions. If NULL, D must be given. Ignored if D is some kind of DVH object.
ab	alpha/beta ratio for the relevant tissue. If D is some kind of DVH object, only the first element will be used.

Details

EQD2 is a special case of isoeffective dose calculation with fractional dose d2=2, see getIsoEffD. The calculation assumes a homogeneous dose distribution within the volume.

Value

Default method: A data frame with variables EQD2, fractDose, ab.

If D is some kind of DVH object, the same kind of object is returned with the individual dose values converted to EQD2.

References

IAEA, & ICRU. (2008). Relative biological effectiveness in ion-beam therapy (Tech. Rep. No. IAEA-TR 461). Vienna, Austria: IAEA (International Atomic Energy Agency) and ICRU (International Commission on Radiation Units and Measurements).

See Also

getBED, getIsoEffD

Examples

```
getEQD2(D=50, fd=2.5, ab=c(2, 3, 4))
getEQD2(dataMZ[[c(1, 1)]], fd=1.8, ab=3)
```

getEUD *Generalized equivalent uniform dose (gEUD)*

Description

Calculate generalized equivalent uniform dose (gEUD). May be based on EQD2.

Usage

```
getEUD(x, EUDa, EUDfd=NULL, EUDab=NULL, ...)

## S3 method for class 'DVHs'
getEUD(x, EUDa, EUDfd=NULL, EUDab=NULL, ...)

## S3 method for class 'DVHLst'
getEUD(x, EUDa, EUDfd=NULL, EUDab=NULL, ...)

## S3 method for class 'DVHLstLst'
getEUD(x, EUDa, EUDfd=NULL, EUDab=NULL, ...)
```

Arguments

x	One cumulative DVH (object of class DVHs, multiple cumulative DVHs from one patient with multiple structures (object of class DVHLst), or multiple cumulative DVHs from many patients, each with multiple structures (object of class DVHLstLst). See readDVH.
EUDa	Exponential parameter a.
EUDfd	If gEUD should be based on EQD2: Fraction dose.
EUDab	If gEUD should be based on EQD2: alpha/beta ratio for the relevant tissue.
...	Ignored. Used to catch additional arguments passed from getMetric.

Value

A data frame with variables EUD, patID, and structure.

References

Niemierko, A. (1999). A generalized concept of equivalent uniform dose. Medical Physics, 26(6), 1100.

Wu et al. (2002). Optimization of intensity modulated radiotherapy plans based on the equivalent uniform dose. International Journal of Radiation Oncology Biology Physics, 52, 224-235.

See Also

getEQD2, getMetric

Examples

```
getEUD(dataMZ[[1]], EUDa=2)

# based on EQD2
getEUD(dataMZ[[1]], EUDa=2, EUDfd=1.8, EUDab=4)
```

`getIsoEffD` *Isoeffective dose calculation*

Description

Convert given (fractional) dose into a corresponding (fractional) dose for a different total dose / fractionation schedule according to the linear-quadratic model.

Usage

```
getIsoEffD(D1=NULL, D2=NULL, fd1=NULL, fd2=NULL, ab=NULL)

## Default S3 method:
getIsoEffD(D1=NULL, D2=NULL, fd1=NULL, fd2=NULL, ab=NULL)

## S3 method for class 'DVHs'
getIsoEffD(D1=NULL, D2=NULL, fd1=NULL, fd2=NULL, ab=NULL)

## S3 method for class 'DVHLst'
getIsoEffD(D1=NULL, D2=NULL, fd1=NULL, fd2=NULL, ab=NULL)

## S3 method for class 'DVHLstLst'
getIsoEffD(D1=NULL, D2=NULL, fd1=NULL, fd2=NULL, ab=NULL)
```

Arguments

`D1`	Default: `numeric` vector. Total dose 1. Alternative: One cumulative DVH (object of class `DVHs`, multiple cumulative DVHs from one patient with multiple structures (object of class `DVHLst`), or multiple cumulative DVHs from many patients, each with multiple structures (object of class `DVHLstLst`). See `readDVH`.
`D2`	`numeric` vector. Total dose 2. Ignored if `D` is some kind of `DVH` object.
`fd1`	`numeric` vector. Fractional dose 1. If `D` is some kind of `DVH` object, only the first element will be used.
`fd2`	`numeric` vector. Fractional dose 2. If `D` is some kind of `DVH` object, only the first element will be used.
`ab`	`numeric` vector. alpha/beta ratio for the relevant tissue in the linear-quadatic model. If `D` is some kind of `DVH` object, only the first element will be used.

Details

DVH methods: Calculate D2 based on D1, fd1, fd2, and ab. The default method can also calculate fd2 based on D1, D2, fd1, and ab.

Value

The (vector of) corresponding (fractional) dose value(s). If D is some kind of DVH object, the same kind of object is returned with the individual dose values converted to D2.

References

IAEA, & ICRU. (2008). Relative biological effectiveness in ion-beam therapy (Tech. Rep. No. IAEA-TR 461). Vienna, Austria: IAEA (International Atomic Energy Agency) and ICRU (International Commission on Radiation Units and Measurements).

See Also

getBED, getEQD2

Examples

```
# reference: 70Gy in 2Gy fractions
# new fractionation: 3Gy fractions
# calculate corresponding dose
(D2 <- getIsoEffD(D1=70, fd1=2, fd2=3, ab=c(3.5, 10)))

getIsoEffD(D1=dataMZ[[c(1, 1)]], fd1=1.8, fd2=2, ab=3.5)
```

---

getMeanDVH *Point-wise mean DVH with point-wise SDs*

Description

Returns the point-wise mean and median DVH with the point-wise standard deviation for a given list of input DVHs. Other point-wise measures may be calculated as well.

Usage

```
getMeanDVH(x, fun=list(mean=mean, median=median, sd=sd),
           cumul=TRUE, thin=1, byPat=TRUE, patID=NULL, structure=NULL,
           fixed=TRUE)

## S3 method for class 'DVHs'
getMeanDVH(x, fun=list(mean=mean, median=median, sd=sd),
           cumul=TRUE, thin=1, byPat=TRUE, patID=NULL, structure=NULL,
           fixed=TRUE)

## S3 method for class 'DVHLst'
```

```
getMeanDVH(x, fun=list(mean=mean, median=median, sd=sd),
           cumul=TRUE, thin=1, byPat=TRUE, patID=NULL, structure=NULL,
           fixed=TRUE)

## S3 method for class 'DVHLstLst'
getMeanDVH(x, fun=list(mean=mean, median=median, sd=sd),
           cumul=TRUE, thin=1, byPat=TRUE, patID=NULL, structure=NULL,
           fixed=TRUE)
```

Arguments

x	A single DVH (object of class DVHs), multiple DVHs from one patient/structure (object of class DVHLst), or multiple DVHs from many patients/structures (object of class DVHLstLst). See readDVH.
fun	Named list of functions that should be applied to yield 1 point-wise DVH measure. Functions must have exactly 1 return value.
cumul	logical. Get point-wise mean and SD for cumulative or differential (per unit dose) DVH?
thin	numeric. The number of DVH nodes (dose values) is reduced by 1/thin of the maximum number of nodes in x before interpolating and averaging.
byPat	logical. Relevant if multiple DVHs are given. byPat=TRUE means that for each patient, DVHs for multiple structures are averaged point wise. byPat=FALSE means that for each structure, DVHs for multiple patients averaged point wise.
patID	character vector. Include DVHs for these patients only when calculating mean/SD. If missing, all patients are used. Can be a regular expression with fixed=FALSE, see regex.
structure	character vector. Include DVHs for these structures only when calculating mean/SD. If missing, all structures are used. Can be a regular expression with fixed=FALSE, see regex.
fixed	logical. Use fixed=FALSE for regular expression matching of patID and structure.

Details

Before calculating the point-wise mean and SD, DVHs in x are first linearly interpolated with convertDVH using the same set of nodes.

Value

Returns a data frame with point-wise mean DVH averaged over structures (byPat=TRUE) or over patients (byPat=FALSE) including the point-wise standard deviation or other measures as controlled by fun.

See Also

showDVH, convertDVH

Examples

```
res1 <- getMeanDVH(dataMZ, byPat=TRUE, structure=c("HEART", "AMYOCL"))
head(res1)

# average differential DVHs
# matches patients P123 and P234
res2 <- getMeanDVH(dataMZ, fun=list(min=min, max=max),
                   cumul=FALSE, byPat=FALSE,
                   patID="23", fixed=FALSE)
head(res2)
```

`getMetric` *Calculate dose-volume-histogram metrics*

Description

Simultaneously calculates multiple metrics for multiple cumulative DVHs.

Usage

```
getMetric(x, metric, patID, structure,
          sortBy=c("none", "observed", "patID", "structure", "metric"),
          splitBy=c("none", "patID", "structure", "metric"),
          interp=c("linear", "spline", "ksmooth"), fixed=TRUE, ...)

## S3 method for class 'DVHs'
getMetric(x, metric, patID, structure,
          sortBy=c("none", "observed", "patID", "structure", "metric"),
          splitBy=c("none", "patID", "structure", "metric"),
          interp=c("linear", "spline", "ksmooth"), fixed=TRUE, ...)

## S3 method for class 'DVHLst'
getMetric(x, metric, patID, structure,
          sortBy=c("none", "observed", "patID", "structure", "metric"),
          splitBy=c("none", "patID", "structure", "metric"),
          interp=c("linear", "spline", "ksmooth"), fixed=TRUE, ...)

## S3 method for class 'DVHLstLst'
getMetric(x, metric, patID, structure,
          sortBy=c("none", "observed", "patID", "structure", "metric"),
          splitBy=c("none", "patID", "structure", "metric"),
          interp=c("linear", "spline", "ksmooth"), fixed=TRUE, ...)
```

Arguments

x	One cumulative DVH (object of class `DVHs`, multiple cumulative DVHs from one patient with multiple structures (object of class `DVHLst`), or multiple cumulative DVHs from many patients, each with multiple structures (object of class `DVHLstLst`). See `readDVH`.

metric	character vector defining one or more DVH metrics. See Details for their definition. For metrics involving the relative dose, the DVH must contain the prescription dose.
patID	character vector. Calculate given DVH metrics for these patients only. If missing, DVH metrics are calculated for all patients. Can be a regular expression if additional argument fixed=FALSE is supplied as well, see regex.
structure	character vector. Calculate given DVH metrics for these structures only. If missing, DVH metrics are calculated for all structures. Can be a regular expression if additional argument fixed=FALSE is supplied as well, see regex.
sortBy	character vector giving the sorting criteria for the output data frame.
splitBy	character vector. Split results into a list of data frames where list components are defined by groups from combining these variables.
interp	character. Method of interpolation between DVH points: Linear interpolation using approx, monotone Hermite spline interpolation using splinefun, or local polynomial regression using locpoly with kernel bandwidth chosen by the direct plug-in method using dpill.
fixed	logical. Use fixed=FALSE for regular expression matching of patID and structure.
...	Further arguments passed to getEUD (for metric="DEUD"), getTCP (for metric="DTCP"), or getNTCP (for metric="DNTCP").

Details

A *pre-specified* DVH metric is one of the following character strings:

- "DMEAN": The volume-weighted mean dose of the structure.
- "DMEDIAN": Median dose, equal to D50%
- "DMIN": The minimum dose of the non-zero-dose voxels in the structure.
- "DMAX": The maximum dose of the non-zero-dose voxels in the structure.
- "DSD": The standard deviation of the dose in the structure.
- "DRX": The prescription dose.
- "DHI": The Homogeneity Index according to ICRU 83: (D2%-D98%)/D50%.
- "DEUD": The generalized equivalent uniform dose (gEUD). See getEUD for mandatory and optional parameters.
- "DNTCP": The normal tissue complication probability (NTCP). See getNTCP for mandatory and optional parameters.
- "DTCP": The tumor control probability (TCP). See getNTCP for mandatory and optional parameters.

A *free* DVH metric is a character string which has three mandatory elements and one optional element in the following order (AAPM TG263 2018, section 9.2, note that complementary / cold metrics are not yet implemented):

- 1st letter "D" or "V": "D" If the requested value is a dose, "V" if it is a volume.

- 2nd element <number>: If the first letter is "D", this gives the volume for which the dose value of the cumulative DVH should be reported. If the first letter is "V", this gives the dose for which the volume value of the cumulative DVH should be reported.
- 3rd element <measurement unit>: The measurement unit for the 2nd element of the metric. Absolute volumes are indicated by "CC" for cubic centimeter, relative volumes by "%". Absolute doses are indicated by "Gy" for Gray, "cGy" for Centigray, or "eV/g" for uncalibrated dose in DVHs exported by PRIMO. Relative doses are indicated by "%".
- Optional 4th element _<measurement unit>: The measurement unit of the output value. Possible units are as for the 3rd element. If missing, dose is reported as absolute dose in the measurement unit used in the DVH. Volume is reported as relative volume in %.

Examples:

- "D1%": Minimal absolute dose for the "hottest" 1% of the structure, i.e., the maximally irradiated 1% of the structure was exposed to at least this absolute dose.
- "D1CC_%": Minimal relative dose (% of prescription dose) for the maximally irradiated cm^3 of the structure.
- "V500cGy": Relative structure volume in % that was exposed to at least 500cGy.
- "V10%_CC": Absolute structure volume in cm^3 that was exposed to at least 10% of prescription dose.

If volume or dose values outside the range of possible values for a structure are requested, metrics cannot be calculated, and the result will be NA with a warning.

DMEAN, DMEDIAN, DMIN, DMAX, DSD are taken from the exported DVH if present. Otherwise, the differential DVH is generated and used for calculating these metrics.

Value

A data frame or a list with details on the calculated metrics.

patID	Patient ID
structure	Structure
metric	The calculated DVH metric
observed	The observed value for the DVH metric

References

American Association of Physicists in Medicine (AAPM) Task Group TG263 (2018). Standardizing Nomenclatures in Radiation Oncology. https://www.aapm.org/pubs/reports/RPT_263.pdf (section 9.2 "Guidelines for DVH metrics")

Rancati et al. (2004). Fitting late rectal bleeding data using different NTCP models: results from an Italian multi-centric study (AIROPROS0101). Radiotherapy Oncology, 73, 21-32.

Wu et al. (2002). Optimization of intensity modulated radiotherapy plans based on the equivalent uniform dose. International Journal of Radiation Oncology Biology Physics, 52, 224-235.

See Also

saveMetric, getEUD, getNTCP, getTCP, getEQD2, approxfun, splinefun, dpill, locpoly

Examples

```
getMetric(dataMZ, c("D1CC", "V10%_CC"),
          sortBy=c("metric", "structure", "observed"))

# matching patients are P123 and P234
# matching structures are AMYOCL and AMYOCR
getMetric(dataMZ, c("D1CC", "V10%_CC"),
          patID="23",
          structure=c("AMYOC", "VALVE"),
          splitBy="patID",
          fixed=FALSE)

# gEUD with a=2
getMetric(dataMZ[[c(1, 1)]], "DEUD", EUDa=2)

# gEUD based on EQD2 with a=2, 20 fractions
getMetric(dataMZ[[c(1, 1)]], "DEUD", EUDa=2, EUDfd=1.8)

# NTCP Lyman probit model with TD50=20, m=4, n=0.5
getMetric(dataMZ[[c(1, 1)]], "DNTCP",
          NTCPtd50=20, NTCPm=4, NTCPn=0.5, NTCPtype="probit")
```

---

getNTCP *Normal tissue complication probability (NTCP)*

Description

Calculate normal tissue complication probability (NTCP) from Lyman's probit model, Niemierko's logit model, or the Poisson model. May be based on EQD2.

Usage

```
getNTCP(x, NTCPtd50=NULL, NTCPm=NULL, NTCPn=NULL, NTCPgamma50=NULL,
        EUDa=NULL, EUDfn=NULL, EUDab=NULL,
        NTCPtype=c("probit", "logit", "poisson"), ...)

## S3 method for class 'DVHs'
getNTCP(x, NTCPtd50=NULL, NTCPm=NULL, NTCPn=NULL, NTCPgamma50=NULL,
        EUDa=NULL, EUDfn=NULL, EUDab=NULL,
        NTCPtype=c("probit", "logit", "poisson"), ...)

## S3 method for class 'DVHLst'
getNTCP(x, NTCPtd50=NULL, NTCPm=NULL, NTCPn=NULL, NTCPgamma50=NULL,
        EUDa=NULL, EUDfn=NULL, EUDab=NULL,
        NTCPtype=c("probit", "logit", "poisson"), ...)

## S3 method for class 'DVHLstLst'
getNTCP(x, NTCPtd50=NULL, NTCPm=NULL, NTCPn=NULL, NTCPgamma50=NULL,
```

```
EUDa=NULL, EUDfn=NULL, EUDab=NULL,
NTCPtype=c("probit", "logit", "poisson"), ...)
```

Arguments

x	One cumulative DVH (object of class DVHs, multiple cumulative DVHs from one patient with multiple structures (object of class DVHLst), or multiple cumulative DVHs from many patients, each with multiple structures (object of class DVHLstLst). See readDVH.
NTCPtd50	Tolerance dose with 50% complication probability.
NTCPm	Probit/logit Parameter m. Equal to 1 / (NTCPgamma50*sqrt(2*pi)).
NTCPn	Parameter n. Equal to 1/a with exponential gEUD paramter a.
NTCPgamma50	Poisson parameter gamma50. Equal to 1 / (NTCPm*sqrt(2*pi))
EUDa	If gEUD should be based on EQD2: Exponential parameter a.
EUDfn	If gEUD should be based on EQD2: Number of fractions.
EUDab	If gEUD should be based on EQD2: alpha/beta ratio for the relevant tissue.
NTCPtype	"probit" - Lyman probit model, "logit" - Niemierko logit model, "poisson" - Poisson model.
...	Ignored. Used to catch additional arguments passed from getMetric.

Details

For DVH reduction, gEUD is used. This is equivalent to the Kutcher-Burman DVH reduction scheme. The probit model is given in equation (1), the logit model in eqation (2), and the Poisson model in equation (3) in Kaellman (1992), with gEUD plugged in for D.

Value

A data frame with variables NTCP, patID, and structure.

References

Kaellman, P., Agren, A., & Brahme, A. (1992). Tumor and normal tissue responses to fractionated non-uniform dose delivery. International Journal of Radiation Biology, 62(2), 249-262.

Kutcher, G. J., Burman, C., Brewster L., Goitein, M., & Mohan, R. (1991). Histogram reduction method for calculating complication probabilities for threedimensional treatment planning evaluations. International Journal of Radiation Oncology Biology Physics, 21(1), 137-146.

Lyman, J. T. (1985). Complication probability as assessed from dose volume histograms. Radiation Research, 104(2), S13-19.

Niemierko, A. (1999). A generalized concept of equivalent uniform dose. Medical Physics, 26(6), 1100.

Rancati et al. (2004). Fitting late rectal bleeding data using different NTCP models: results from an Italian multi-centric study (AIROPROS0101). Radiotherapy Oncology, 73, 21-32.

See Also

getTCP, getEUD, getMetric

Examples

```
getNTCP(dataMZ[[1]],
        NTCPtd50=40, NTCPm=0.6, NTCPn=0.5, NTCPtype="probit")
```

---

getTCP *Tumor control probability (TCP)*

Description

Calculate tumor control probability (TCP) from Lyman's probit model, Niemierko's logit model, or Kaellman's Poisson model. May be based on EQD2.

Usage

```
getTCP(x, TCPtcd50=NULL, TCPm=NULL, TCPn=NULL, TCPgamma50=NULL,
       EUDa=NULL, EUDfn=NULL, EUDab=NULL,
       TCPtype=c("probit", "logit", "poisson"), ...)
```

Arguments

x	One cumulative DVH (object of class DVHs, multiple cumulative DVHs from one patient with multiple structures (object of class DVHLst), or multiple cumulative DVHs from many patients, each with multiple structures (object of class DVHLstLst). See readDVH.
TCPtcd50	Tolerance dose with 50% tumor control probability.
TCPm	Probit/logit Parameter m. Equal to 1 / (NTCPgamma50*sqrt(2*pi)).
TCPn	Parameter n. Equal to 1/a with exponential gEUD paramter a.
TCPgamma50	Poisson parameter gamma50. Equal to 1 / (NTCPm*sqrt(2*pi))
EUDa	If gEUD should be based on EQD2: Exponential parameter a.
EUDfn	If gEUD should be based on EQD2: Number of fractions.
EUDab	If gEUD should be based on EQD2: alpha/beta ratio for the relevant tissue.
TCPtype	"probit" - Lyman probit model, "logit" - Niemierko logit model, "poisson" - Kaellman Poisson (relative seriality) model.
...	Ignored. Used to catch additional arguments passed from getMetric.

Details

For DVH reduction, gEUD is used. This is equivalent to the Kutcher-Burman DVH reduction scheme.

Value

A data frame with variables `TCP`, `patID`, and `structure`.

References

Kaellman, P., Agren, A., & Brahme, A. (1992). Tumor and normal tissue responses to fractionated non-uniform dose delivery. International Journal of Radiation Biology, 62(2), 249-262.

Kutcher, G. J., Burman, C., Brewster L., Goitein, M., & Mohan, R. (1991). Histogram reduction method for calculating complication probabilities for threedimensional treatment planning evaluations. International Journal of Radiation Oncology Biology Physics, 21(1), 137-146.

Lyman, J. T. (1985). Complication probability as assessed from dose volume histograms. Radiation Research, 104(2), S13-19.

Niemierko, A. (1999). A generalized concept of equivalent uniform dose. Medical Physics, 26(6), 1100.

Rancati et al. (2004). Fitting late rectal bleeding data using different NTCP models: results from an Italian multi-centric study (AIROPROS0101). Radiotherapy Oncology, 73, 21-32.

See Also

`getNTCP`, `getEUD`, `getMetric`

Examples

```
getTCP(dataMZ[[1]],
       TCPtcd50=40, TCPm=0.6, TCPn=0.5, TCPtype="probit")
```

---

mergeDVH *Merge existing DVH objects*

Description

Combine several existing DVH objects into one object.

Usage

```
mergeDVH(...)
```

Arguments

`...`	`DVHLstLst` objects.

Details

The first object determines whether the resulting object is organized by patient or by structure. Objects need not originally come from the same treatment planning system.

Value

Returns an object of class DVHLstLst.

Examples

```
## Not run:
# pick some DVH files interactively
a <- readDVH(type="Cadplan")

# pick other DVH files interactively
b <- readDVH(type="Eclipse")

# combine DVH data
res <- mergeDVH(a, b)
res

## End(Not run)
```

---

print.DVHs *Print basic information about one or more DVHs*

Description

Print basic information (patients, structures, dose range) about one or more DVHs.

Usage

```
## S3 method for class 'DVHs'
print(x, ...)

## S3 method for class 'DVHLst'
print(x, ...)

## S3 method for class 'DVHLstLst'
print(x, ...)
```

Arguments

x	A single DVH (object of class DVHs), multiple DVHs from one patient/structure (object of class DVHLst), or multiple DVHs from many patients/structures (object of class DVHLstLst). See readDVH.
...	Further arguments: print.DVHLst(x,verbose=TRUE) prints more information about each DVH.

Value

Prints summary information about the DVHs.

See Also

readDVH

Examples

```
print(dataMZ)
print(dataMZ, verbose=TRUE)
```

---

readConstraint *Read constraint definitions from text file*

Description

Reads the definition of quality assurance constraints from a text file.

Usage

```
readConstraint(x, ...)
```

Arguments

x	character string giving the path to a single text file with the constraint definition. May contain globbing symbols understood by Sys.glob. If missing and in interactive mode, readDVH opens a file selector widget. See Details.
...	Further arguments passed to read.table, e.g., sep="\t" to define the column sepator as tab.

Details

This is a wrapper for read.table.

The text file should contain three columns with the column names patID, structure, constraint in the first line. Each further line then defines one constraint and the scope it applies to in terms of patients and structures. See checkConstraint for the definition of a constraint and for the definition of a scope. Example content:

```
"patID" "structure" "constraint"
"*" "HEART" "D1CC < 20Gy"
"234" "*" "V10% > 8CC"
```

Value

A data.frame with columns patID, structure, constraint that can be used in functions checkConstraint and showConstraint.

See Also

read.table, checkConstraint, saveConstraint, showConstraint

Examples

```
## Not run:
readConstraint("constraint.txt")
readConstraint()

## End(Not run)
```

---

readDVH *Read DVH text files*

Description

Reads single or multiple DVH text files as exported from Varian Eclipse(TM), CadPlan(TM), OnCentra MasterPlan(TM), Philipps Pinnacle3 (TM), Elekta Monaco (TM), Tomo HiArt (TM), RaySearch Labs RayStation (TM), or Medcom ProSoma (TM). Supports cumulative and differential DVHs.

Usage

```
readDVH(x,
        type=c("Eclipse", "Cadplan", "Masterplan",
               "Pinnacle", "Monaco", "HiArt",
               "RayStation", "ProSoma", "PRIMO"),
        planInfo=FALSE, courseAsID=FALSE, add, ...)
```

Arguments

x	character vector giving paths to DVH text files. May contain globbing symbols understood by Sys.glob. If missing and in interactive mode, readDVH opens a file selector widget. Under Windows, this widget allows selecting multiple files simultaneously. For type="Pinnacle", x should be one of the following: A directory with information for one patient, a directory with several sub-directories (one for each patient), or a zip file of such directories. Under Windows, if x is missing and type="Pinnacle", readDVH opens a folder selector widget.
type	character. Indicates which program the DVH text files were exported from. Supported: "Cadplan" (tested with version 6.4.7), "Eclipse" (tested with Varian Eclipse version 10-15), "Masterplan" (tested with OnCentra MasterPlan version 4.3), "Pinnacle" (tested with Pinnacle3 version 9, see Details), "Monaco" (tested with Elekta Monaco version 5), "HiArt" (TomoTherapy HiArt), "RayStation" (RaySearch Labs RayStation), "ProSoma" (Medcom ProSoma), "PRIMO" (tested with version 0.3.1.1558).
planInfo	Experimental: Either FALSE or character string. In the latter case, readDVH tries to extract additional information from the Plan field in the DVH file, e.g., the prescription dose for a sum plan or the boost quadrant. Undocumented, see source.

courseAsID — logical. If TRUE, the Course entry in the header section of a DVH file is appended to the regular patient ID. Currently supported only for type="Eclipse".

add — DVHLstLst object. Existing object that should be merged with the new data from the files.

... — Additional arguments passed on to file. Specify UTF-8 file encoding with encoding="UTF-8" or encoding="UTF-8-BOM" (when a byte-order-mark is used). Passing additional arguments is currently not supported when reading Pinnacle files. Additional arguments are also used for type="HiArt" where a list hiart may be supplied that specifies patient IDs, absolute structure volumes, and prescription dose. If Eclipse uncertainty plans are present, specify uncertainty=TRUE (see Details).

Details

Absolute dose values need to be given in Gy, cGy, or eV/g for uncalibrated dose in DVHs exported by PRIMO. Absolute volume values need to be given in in cm^3.

Differential DVHs are automatically converted to cumulative DVHs, but the differential DVH information is kept.

Sum plans are supported.

For Eclipse starting with version 13, the date format is locale dependent as it uses words for day and month. Importing those dates as class Date requires that the correct locale is set (see Sys.setlocale), and that files containing accents are read using the correct encoding (see above). Otherwise, date is stored as a character string.

For RayStation, only cumulative DVHs with absolute volume are currently supported. Volume is assumed to be measured in cm^3.

For files with absolute volume exported from Masterplan and Tomo HiArt, you can specify volume_from_dvh=TRUE if the structure volume should be guessed from the maximal volume given in the DVH for each structure.

Since files from HiArt, ProSoma and PRIMO do not contain info on patient ID, the current workaround is to generate a random ID.

To export data from Tomo HiArt, copy to clipboard and then save to file from a text editor. Support for Tomo HiArt files is currently limited to those with absolute dose. Please send an anonymized sample file if you need to read files with relative dose. You can provide a list hiart with more information about patients and structures. The list should have one component for each file you import. Each component itself has to be a named list with optional components

- patName - a character string for patient name
- patID - a character string for patient ID
- doseRx - a numeric value like 50.4 for prescription dose in the same dose unit as used in the DVHs
- structVol - a named list like list("PTV 52Gy"=750,"LUNG"=1250) giving the absolute structure volumes with names equal to structure names and numeric components of length 1
- volumeUnit - a character string like "CC" for the structure volume unit)

Pinnacle3 files have to be exported using its own scripting facility such that information from one patient is contained in one directory. A suitable export script is available on request from the package authors. The directory layout for one patient has to be as follows (experimental, likely to change in future versions):

- Files (CSV format with column headers):
  - `DoseInfo.csv` (variables `"PrescriptionDose cGy"`, `"NumberOfFractions"`, `"Dosis cGy"`)
  - `PatInfo.csv` (variables `"LastName"`, `"FirstName"`, `"MedicalRecordNumber"`)
  - `PlanInfo.csv` (variable `"PlanName"`)
- Directory: `Data`:
  - `Info.csv` (variables `"Filename"`, `"RegionOfInterestName"`, `"DoseMin cGy"`, `"DoseMax cGy"`, `"DoseMean cGy"`, `"Volume ccm"`)
  - DVH1.csv, DVH2.csv, ... - the actual DVH data files with names defined in `Info.csv` variable `"Filename"`. They should look like NumberOfDimensions = 2;
    NumberOfPoints = 431;
    Points[] ={
    0,0
    10,0
    ...
    4000,100
    };

Value

Returns an object of class `DVHLstLst`. This is a list (one component with class `DVHLst` for each original file from one patient) of lists (each component is an object of class `DVHs`). A `DVHs` object is a list with the following components:

`dvh matrix` - cumulative DVH values

`dvhDiff matrix` - differential DVH values, only created a) if original file contained a differential DVH or b) by `convertDVH`

`patID character` string - patient ID

`date character` string - date of DVH export

`type character` string - cumulative or differential DVH

`plan character` string - plan name

`course character` string - course - currently Eclipse only

`structure character` string - structure name

`structVol numeric` - structure volume

`doseUnit character` string - measurement unit dose

`volumeUnit character` string - measurement unit volume

`doseRx numeric` - prescription dose

`isoDoseRx numeric` - iso-dose percentage

`doseMin numeric` - minimum dose from DVH file

`doseMax numeric` - maximum dose from DVH file

`doseAvg numeric` - average dose from DVH file

`doseMed numeric` - median dose from DVH file

`doseSD numeric` - dose standard deviation from DVH file

See Also

`Sys.glob`, `readLines`, `print.DVHs`, `showDVH`, `getMetric`, `checkConstraint`, `convertDVH`

Examples

```
## Not run:
# pick DVH files interactively
res <- readDVH()
res

# read all txt files in subdirectory DVH
res <- readDVH("DVH/*.txt", type="Eclipse")
res

## End(Not run)
```

`runGUI` *Open web-based GUI in browser*

Description

Opens the web-based GUI in an external browser.

Usage

```
runGUI(...)
```

Arguments

`...`	Arguments passed to `runApp`. Supply `port=80` if a web browser refuses to connect to the randomly chosen port for security reasons.

Details

This function calls `runApp` to run the included DVHshiny application. See `vignette("DVHshiny")` for documentation.

See Also

`runApp`

Examples

```
## Not run:
runGUI()

## End(Not run)
```

---

saveConstraint *Save constraint result to file*

Description

Saves results from checkConstraint to a text file.

Usage

```
saveConstraint(x, ...)
```

Arguments

x	data.frame - the result from checkConstraint.
...	Further arguments passed to write.table - e.g., file="<filename>" for the output filename, dec="." to define the decimal separator as point or sep="\t" to define the column sepator as tab.

Details

This is a wrapper for write.table.

See Also

write.table, checkConstraint

Examples

```
res <- checkConstraint(dataMZ, c("D10CC < 10Gy", "V20Gy < 20%"))
## Not run:
saveConstraint(res, file="constrResults.txt", sep="\t")

## End(Not run)
```

saveDVH *Save DVH diagram to file*

Description

Saves one or multiple DVH diagrams to file.

Usage

```
saveDVH(x, file="", ...)
```

Arguments

x	A single ggplot object or a list of multiple ggplot objects as returned by showDVH or showConstraint.
file	character. Path to file. The file-ending determines what kind of file is written, e.g., "filename.pdf" will write a pdf document, "filename.jpg" a JPEG image.
...	Further arguments passed to ggsave, e.g., width and height to determine the figure size.

Details

This is a wrapper for ggsave.

Value

If x is a list of ggplot objects, one file is written for each list component. If x is a single ggplot object, one file is written.

See Also

ggsave, showDVH, showConstraint

Examples

```
res <- showDVH(dataMZ, byPat=TRUE, structure=c("HEART", "AMYOCL"))
## Not run:
saveDVH(res, "out.pdf")

## End(Not run)
```

saveMetric *Save DVH metrics to file*

Description

Saves results from getMetric to a text file.

Usage

```
saveMetric(x, file = "", ...)

## S3 method for class 'data.frame'
saveMetric(x, file = "", ...)

## S3 method for class 'list'
saveMetric(x, file = "", ...)
```

Arguments

x	data.frame or list - the result from getMetric.
file	character. Path to file.
...	Further arguments passed to write.table - e.g., dec="." to define the decimal separator as point or sep="\t" to define the column sepator as tab.

Details

This is a wrapper for write.table.

Value

If x is a list, one text file is written for each list component. If x is a data.frame, one file is written.

See Also

write.table, getMetric

Examples

```
res <- getMetric(dataMZ, c("D1CC", "V10%_CC"),
                 sortBy=c("metric", "structure"),
                 splitBy="patID")
## Not run:
# not run
saveMetric(res, file="metricsResults.txt", sep="\t")

## End(Not run)
```

showConstraint *Display constraints for cumulative dose-volume histograms*

Description

Displays quality assurance constraints for cumulative dose-volume histograms: Either one diagram per patient - including multiple structures. Or one diagram per structure - including multiple patients.

Usage

```
showConstraint(x, constr, byPat=TRUE, rel=TRUE, guessX=TRUE, guessY=TRUE,
               thresh=1, show=TRUE, visible=FALSE)

## S3 method for class 'DVHs'
showConstraint(x, constr, byPat=TRUE, rel=TRUE, guessX=TRUE, guessY=TRUE,
               thresh=1, show=TRUE, visible=FALSE)

## S3 method for class 'DVHLst'
showConstraint(x, constr, byPat=TRUE, rel=TRUE, guessX=TRUE, guessY=TRUE,
               thresh=1, show=TRUE, visible=FALSE)

## S3 method for class 'DVHLstLst'
showConstraint(x, constr, byPat=TRUE, rel=TRUE, guessX=TRUE, guessY=TRUE,
               thresh=1, show=TRUE, visible=FALSE)
```

Arguments

x	A single DVH (object of class DVHs), multiple DVHs from one patient/structure (object of class DVHLst), or multiple DVHs from many patients/structures (object of class DVHLstLst). See readDVH. See Details.
constr	One or more constraints - given as a character vector or as a data.frame. See checkConstraint for their definition.
byPat	logical. Relevant if multiple DVHs are given. If x has class DVHLstLst: byPat=TRUE means that one diagram shows DVHs from one patient with multiple structures. byPat=FALSE means that one diagram shows DVHs for one structure from multiple patients.
rel	logical. Show relative volume?
guessX	logical. Try to guess the best x-axis limits for better visibility of main DVH range? If FALSE, x-axis runs from 0 to maximum dose. If TRUE, x-axis runs from 0 to dose value where volume approaches 0. If a single number is given, it is interpreted as the maximum value. If a vector of two numbers is given, it is interpreted as the range of the axis.
guessY	logical. Try to guess the best y-axis limits? If a single number is given, it is interpreted as the maximum value. If a vector of two numbers is given, it is interpreted as the range of the axis.

thresh	numeric value. Relative volume threshold used with guessX=TRUE. Clip x-axis (+10%) such that the "highest" DVH is cut off at this relative volume.
show	logical. If TRUE, diagrams are shown, if FALSE diagrams are not shown - only ggplot diagram objects are silently returned.
visible	logical. Return ggplot diagram object visibly or invisibly. show=FALSE with visible=TRUE is useful for zooming in shiny apps.

Details

Constraints are shown as points in the cumulative DVH with an additional arrow indicating where the cumulative DVH curve should lie relative to the constraint. On each DVH curve, the point with the minimal Euclidean distance to the constraint is indicated. Note that, visually, this point only has the minimal apparent distance if the aspect ratio of the diagram is 1.

If multiple diagrams are produced, they are shown in the same graphics device. If interactive inspection is required, make sure you use an R development environment that saves previous diagrams and allows navigating between them - e.g., RStudio or OpenAnalytics Architect.

Value

Silently returns a ggplot diagram object, or - when multiple diagrams are constructed - a list of ggplot diagram objects.

See Also

checkConstraint, saveDVH

Examples

```
data(dataMZ)

# define constraints
constr <- data.frame(
    patID=c("P123", "P234"),
    structure=c("HEART", "*"),
    constraint=c("D1CC < 20Gy", "V10% > 8CC"),
    stringsAsFactors=FALSE)       # this is important
showConstraint(dataMZ, constr=constr, byPat=FALSE)
```

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showDVH *Display dose volume histograms*

Description

Displays dose volume histograms: Either one diagram per patient - including multiple structures. Or one diagram per structure - including multiple patients.

Usage

```
showDVH(x, cumul=TRUE, byPat=TRUE, patID=NULL, structure=NULL,
        rel=TRUE, guessX=TRUE, guessY=TRUE, thresh=1, addMSD=FALSE,
        show=TRUE, visible=FALSE, fixed=TRUE)

## S3 method for class 'DVHs'
showDVH(x, cumul=TRUE, byPat=TRUE, patID=NULL, structure=NULL,
        rel=TRUE, guessX=TRUE, guessY=TRUE, thresh=1, addMSD=FALSE,
        show=TRUE, visible=FALSE, fixed=TRUE)

## S3 method for class 'DVHLst'
showDVH(x, cumul=TRUE, byPat=TRUE, patID=NULL, structure=NULL,
        rel=TRUE, guessX=TRUE, guessY=TRUE, thresh=1, addMSD=FALSE,
        show=TRUE, visible=FALSE, fixed=TRUE)

## S3 method for class 'DVHLstLst'
showDVH(x, cumul=TRUE, byPat=TRUE, patID=NULL, structure=NULL,
        rel=TRUE, guessX=TRUE, guessY=TRUE, thresh=1, addMSD=FALSE,
        show=TRUE, visible=FALSE, fixed=TRUE)
```

Arguments

x	A single DVH (object of class DVHs), multiple DVHs from one patient/structure (object of class DVHLst), or multiple DVHs from many patients/structures (object of class DVHLstLst). See readDVH. See Details.
cumul	logical. Show cumulative or differential (per unit dose) DVH?
byPat	logical. Relevant if multiple DVHs are given. If x has class DVHLstLst: byPat=TRUE means that one diagram shows DVHs from one patient with multiple structures. byPat=FALSE means that one diagram shows DVHs for one structure from multiple patients.
patID	character vector. Show diagram for these patients only. If missing, all patients are shown. Can be a regular expression with fixed=FALSE, see regex.
structure	character vector. Show diagram for these structures only. If missing, all structures are shown. Can be a regular expression with fixed=FALSE, see regex.
rel	logical. Show relative volume?
guessX	logical. Try to guess the best x-axis limits for better visibility of main DVH range? If FALSE, x-axis runs from 0 to maximum dose. If TRUE, x-axis runs from 0 to dose value where volume approaches 0. If a single number is given, it is interpreted as the maximum value. If a vector of two numbers is given, it is interpreted as the range of the axis.
guessY	logical. Try to guess the best y-axis limits? If a single number is given, it is interpreted as the maximum value. If a vector of two numbers is given, it is interpreted as the range of the axis.
thresh	numeric value. Relative volume threshold used with guessX=TRUE. Clip x-axis (+5%) such that the "highest" DVH is cut off at this relative volume.

addMSD	logical. If TRUE, diagram shows the point-wise mean DVH as well as shaded areas for point-wise 1-standard deviation and 2-standard deviations around this mean. See details.
show	logical. If TRUE, diagrams are shown, if FALSE diagrams are not shown - only ggplot diagram objects are silently returned.
visible	logical. Return ggplot diagram object visibly or invisibly. show=FALSE with visible=TRUE is useful for zooming in shiny apps.
fixed	logical. Use fixed=FALSE for regular expression matching of patID and structure.

Details

If multiple diagrams are produced, they are shown in the same graphics device. If interactive inspection is required, make sure you use an R development environment that saves previous diagrams and allows navigating between them - e.g., RStudio or OpenAnalytics Architect.

For addMSD=TRUE, the number of DVH nodes (dose values) is reduced by 1/3 of the maximum number of nodes in x. Before calculating the point-wise mean and SD, DVHs in x are first linearly interpolated using the same set of nodes.

Value

Silently returns a ggplot diagram object, or - when multiple diagrams are constructed - a list of ggplot diagram objects.

See Also

ggplot, readDVH, saveDVH, getMeanDVH

Examples

```
showDVH(dataMZ, byPat=TRUE, structure=c("HEART", "AMYOCL"))

# matches patients P123 and P234
showDVH(dataMZ, byPat=FALSE, patID="23", fixed=FALSE)
```

---

showMeanDVH *Show average dose volume histograms*

Description

Displays average dose volume histograms grouped by patients or structures.

Usage

```
showMeanDVH(x, byPat=TRUE, patID=NULL, structure=NULL,
            rel=TRUE, guessX=TRUE, thresh=1, show=TRUE, fixed=TRUE,
            showSD=TRUE, color=TRUE, facet=TRUE)
```

Arguments

x	A data frame as returned by getMeanDVH or a list of such data frames.
byPat	logical. Relevant if multiple DVHs are given. If x has class DVHLstLst: byPat=TRUE means that one diagram shows DVHs from one patient with multiple structures. byPat=FALSE means that one diagram shows DVHs for one structure from multiple patients.
patID	character vector. Show diagram for these patients only. If missing, all patients are shown. Can be a regular expression with fixed=FALSE, see regex.
structure	character vector. Show diagram for these structures only. If missing, all structures are shown. Can be a regular expression with fixed=FALSE, see regex.
rel	logical. Show relative volume?
guessX	logical. Try to clip the x-axis for better visibility of main DVH range?
thresh	numeric value. Relative volume threshold used with guessX=TRUE. Clip x-axis (+10%) such that the "highest" DVH is cut off at this relative volume.
show	logical. If TRUE, diagrams are shown, if FALSE diagrams are not shown - only ggplot diagram objects are silently returned.
fixed	logical. Use fixed=FALSE for regular expression matching of patID and structure.
showSD	logical. If TRUE, diagram shows shaded areas for point-wise 1-standard deviation and 2-standard deviations around this mean. See details.
color	logical. If TRUE, diagram uses color to distinguish groups. If FALSE, colors are greyscale, and line types are used to distinguish groups.
facet	logical. If TRUE, different structures (for byPat=FALSE or different patients (for byPat=TRUE go into separate panels using facet_grid. If FALSE, everything is shown in the same panel.

Details

TODO

Value

Silently returns a ggplot diagram object, or - when multiple diagrams are constructed - a list of ggplot diagram objects.

See Also

ggplot, showDVH, getMeanDVH

Examples

```
# mean DVH for HEART and AMYOCL averaged over patients
res <- getMeanDVH(dataMZ, byPat=FALSE, structure=c("HEART", "AMYOCL"))
showMeanDVH(res)
```

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