Package 'ETDQualitizer'

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Type Package

Title Automated Eye Tracking Data Quality Determination for Screen-Based Eye Trackers

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Description Compute common data quality metrics for accuracy, precision and data loss for screen-based eye trackers. The package supports gaze input in screen pixels or degrees and reports angular measures in degrees where appropriate. If you use this package, please cite Niehorster, D.C., Nyström, M., Hessels, R.S., Benjamins, J.S., Andersson, R., and Hooge, I.T.C. (2026). The fundamentals of eye tracking, Part 7: Determining data quality. Behavior Research Methods. <doi:10.3758/s13428-026-03039-4>.

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Contents

accuracy 2
bcea 3
compute_data_quality_from_validation 3

DataQuality 5
data_loss_from_expected 9
data_loss_from_invalid 10
effective_frequency 11
ETDQ_version 11
Fick_to_vector 12
frechet_median_on_sphere 12
precision_using_moving_window 13
report_data_quality_table 14
rms_s2s 15
ScreenConfiguration 15
std 19
vector_to_Fick 20

Index **21**

`accuracy` *Compute Gaze Accuracy*

Description

Calculates the angular offset between gaze and target directions.

Usage

```
accuracy(azi, ele, target_azi, target_ele, central_tendency_fun = mean)
```

Arguments

`azi`	Gaze azimuth in degrees.
`ele`	Gaze elevation in degrees.
`target_azi`	Target azimuth in degrees.
`target_ele`	Target elevation in degrees.
`central_tendency_fun`	Function to compute central tendency (default: `mean`).

Value

A list with `offset`, `offset_azi`, and `offset_ele`, the total, horizontal and vertical offset of gaze from the target (in degrees).

Examples

```
accuracy(c(1, 2), c(1, 2), 0, 0)
```

bcea *Bivariate Contour Ellipse Area (BCEA)*

Description

Computes BCEA and ellipse parameters for gaze precision.

Usage

```
bcea(azi, ele, P = 0.68)
```

Arguments

azi	Azimuth values in degrees.
ele	Elevation values in degrees.
P	Cumulative probability (default: 0.68).

Value

A list with the BCEA (area) and additional info about the BCEA ellipse: orientation, ax1, ax2, and aspect_ratio.

Examples

```
bcea(rnorm(100), rnorm(100))
```

compute_data_quality_from_validation *Compute Data Quality Metrics from Validation Data*

Description

This function computes a set of data quality metrics for gaze data collected during the PsychoPy validation procedure that is provided in the ETDQualitizer repository on github (https://github.com/dcnieho/ETDQualitizer/tree/
It evaluates accuracy, precision, and optionally data loss and effective sampling frequency, per eye and per target.

Usage

```
compute_data_quality_from_validation(
  gaze,
  unit,
  screen = NULL,
  advanced = FALSE,
  include_data_loss = FALSE
)
```

Arguments

gaze	A ‘data.frame‘ containing gaze data. Must include columns ‘target_id‘, ‘tar_x‘, ‘tar_y‘, ‘timestamp‘, and eye-specific columns such as ‘left_x‘, ‘left_y‘, ‘right_x‘, ‘right_y‘. Timestamps should be provided in milliseconds.
unit	A character string specifying the unit of measurement for gaze and target coordinates in the gaze data.frame. Must be either ‘"pixels"‘ or ‘"degrees"‘.
screen	An optional ‘ScreenConfiguration‘ object or numeric scalar used to convert pixel coordinates to degrees. Required if ‘unit == "pixels"‘.
advanced	Logical. If ‘TRUE‘, all available metrics are returned. If ‘FALSE‘, only a simplified subset is included (default is FALSE).
include_data_loss	Logical. If ‘TRUE‘, includes data loss and effective frequency metrics in the output (default is FALSE).

Details

This function uses the following methods in the ‘DataQuality‘ class to compute the returned results: ‘accuracy()‘, ‘precision_RMS_S2S()‘, ‘precision_STD()‘, ‘precision_BCEA()‘, ‘data_loss_from_invalid()‘, and ‘effective_frequency()‘.

Value

A ‘data.frame‘ with one row per eye-target combination, containing computed metrics: - ‘eye‘, ‘target_id‘: identifiers - ‘accuracy‘, ‘accuracy_x‘, ‘accuracy_y‘: accuracy metrics (‘accuracy_x‘, ‘accuracy_y‘ only if ‘advanced‘ is ‘TRUE‘) - ‘rms_s2s‘, ‘rms_s2s_x‘, ‘rms_s2s_y‘: precision (RMS sample-to-sample) (‘rms_s2s_x‘, ‘rms_s2s_y‘ only if ‘advanced‘ is ‘TRUE‘) - ‘std‘, ‘std_x‘, ‘std_y‘: precision (standard deviation) (‘std_x‘, ‘std_y‘ only if ‘advanced‘ is ‘TRUE‘) - ‘bcea‘, ‘bcea_orientation‘, ‘bcea_ax1‘, ‘bcea_ax2‘, ‘bcea_aspect_ratio‘: precision (BCEA metrics) (‘bcea_orientation‘, ‘bcea_ax1‘, ‘bcea_ax2‘, ‘bcea_aspect_ratio‘ only if ‘advanced‘ is ‘TRUE‘) - ‘data_loss‘, ‘effective_frequency‘: optional metrics if ‘include_data_loss = TRUE‘

Examples

```
## Not run:
# NB: this example requires a gaze data table to run. See the complete example at
# https://github.com/dcnieho/ETDQualitizer/blob/master/example/R.R for how to prepare
# the input data for this function
dq <- compute_data_quality_from_validation(gaze_data, unit = "pixels", screen = my_screen_config)

## End(Not run)
```

DataQuality *R6 class for calculating Data Quality from a gaze data segment*

Description

Provides methods for assessing the quality of gaze data, including accuracy, precision, data loss, and effective sampling frequency.

Public fields

`timestamps` Vector of timestamps in seconds. Samples with missing data should not be removed, or the RMS calculation would be incorrect.

`azi` Vector of azimuth angles in degrees (Fick angles). Missing data should be coded as NA, not using some special value such as (0,0) or (-xres,-yres).

`ele` Vector of elevation angles in degrees (Fick angles). Missing data should be coded as NA, not using some special value such as (0,0) or (-xres,-yres).

Methods

Public methods:

- `DataQuality$new()`
- `DataQuality$accuracy()`
- `DataQuality$precision_RMS_S2S()`
- `DataQuality$precision_STD()`
- `DataQuality$precision_BCEA()`
- `DataQuality$data_loss_from_invalid()`
- `DataQuality$data_loss_from_expected()`
- `DataQuality$effective_frequency()`
- `DataQuality$get_duration()`
- `DataQuality$precision_using_moving_window()`
- `DataQuality$clone()`

Method `new()`**:** Creates a new DataQuality object from gaze data and timestamps.

Usage:

```
DataQuality$new(gaze_x, gaze_y, timestamps, unit, screen = NULL)
```

Arguments:

`gaze_x` Horizontal gaze positions (pixels or degrees).

`gaze_y` Vertical gaze positions (pixels or degrees).

`timestamps` Vector of timestamps in seconds.

`unit` Unit of gaze data: either `"pixels"` or `"degrees"`.

`screen` Optional `ScreenConfiguration` object, required if unit is `"pixels"`.

Returns: A new DataQuality object.

Examples:

```
dq <- DataQuality$new(gaze_x, gaze_y, timestamps, unit = "pixels", screen = sc)
```

Method `accuracy()`**:** Calculates the accuracy of gaze data relative to a known target location.

Usage:

```
DataQuality$accuracy(target_azi, target_ele, central_tendency_fun = mean)
```

Arguments:

`target_azi` Target azimuth in degrees.

`target_ele` Target elevation in degrees.

`central_tendency_fun` Function to compute central tendency (e.g., `mean`, `median`).

Returns: Accuracy in degrees.

Examples:

```
dq$accuracy(0, 0)
```

Method `precision_RMS_S2S()`**:** Calculates precision as root mean square of sample-to-sample distances

Usage:

```
DataQuality$precision_RMS_S2S(central_tendency_fun = mean)
```

Arguments:

`central_tendency_fun` Function to compute central tendency (e.g., `mean`, `median`).

Returns: Precision in degrees.

Examples:

```
dq$precision_RMS_S2S()
```

Method `precision_STD()`**:** Calculates precision as standard deviation of gaze positions.

Usage:

```
DataQuality$precision_STD()
```

Returns: Standard deviation in degrees.

Examples:

```
dq$precision_STD()
```

Method `precision_BCEA()`**:** Calculates the Bivariate Contour Ellipse Area (BCEA) and ellipse parameters for gaze precision.

Usage:

```
DataQuality$precision_BCEA(P = 0.68)
```

Arguments:

`P` Proportion of data to include in the ellipse (default is 0.68).

Returns: BCEA in degrees-squared.

Examples:

```
dq$precision_BCEA()
```

Method `data_loss_from_invalid()`**:** Calculates the proportion of missing data (coded as NA).

Usage:

```
DataQuality$data_loss_from_invalid()
```

Returns: Proportion of missing samples.

Examples:

```
dq$data_loss_from_invalid()
```

Method `data_loss_from_expected()`**:** Estimates data loss based on expected number of samples given the duration and sampling frequency.

Usage:

```
DataQuality$data_loss_from_expected(frequency)
```

Arguments:

`frequency` Expected sampling frequency in Hz.

Returns: Proportion of missing samples.

Examples:

```
dq$data_loss_from_expected(500)
```

Method `effective_frequency()`**:** Calculates the effective sampling frequency based on timestamps.

Usage:

```
DataQuality$effective_frequency()
```

Returns: Effective frequency in Hz.

Examples:

```
dq$effective_frequency()
```

Method `get_duration()`**:** Computes the total duration of the gaze recording, including the last sample.

Usage:

```
DataQuality$get_duration()
```

Returns: Duration in seconds.

Examples:

```
dq$get_duration()
```

Method `precision_using_moving_window()`**:** Calculates precision using a moving window approach.

Usage:

```
DataQuality$precision_using_moving_window(
  window_length,
  metric,
  aggregation_fun = median,
  ...
)
```

Arguments:

`window_length` Length of the moving window in number of samples.

`metric` Precision metric to use (`"RMS-S2S"`, `"STD"`, or `"BCEA"`).

`aggregation_fun` Function to aggregate windowed precision values (e.g., `median`).

`...` Additional arguments passed to the precision metric function.

Returns: Precision value.

Examples:

```
dq$precision_using_moving_window(20, "RMS-S2S")
```

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

Usage:

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

Arguments:

`deep` Whether to make a deep clone.

Examples

```
sc <- ScreenConfiguration$new(500, 300, 1920, 1080, 600)
gaze_x <- c(0, 1, -1)
gaze_y <- c(0, 1, -1)
timestamps <- c(0, 1, 2)
dq <- DataQuality$new(gaze_x, gaze_y, timestamps, unit = "pixels", screen = sc)
dq$accuracy(0, 0)
dq$precision_RMS_S2S()
dq$data_loss_from_invalid()


## ------------------------------------------------
## Method `DataQuality$new`
## ------------------------------------------------

dq <- DataQuality$new(gaze_x, gaze_y, timestamps, unit = "pixels", screen = sc)

## ------------------------------------------------
## Method `DataQuality$accuracy`
## ------------------------------------------------

dq$accuracy(0, 0)

## ------------------------------------------------
## Method `DataQuality$precision_RMS_S2S`
## ------------------------------------------------

dq$precision_RMS_S2S()

## ------------------------------------------------
## Method `DataQuality$precision_STD`
## ------------------------------------------------
```

```
dq$precision_STD()

## ------------------------------------------------
## Method `DataQuality$precision_BCEA`
## ------------------------------------------------

dq$precision_BCEA()

## ------------------------------------------------
## Method `DataQuality$data_loss_from_invalid`
## ------------------------------------------------

dq$data_loss_from_invalid()

## ------------------------------------------------
## Method `DataQuality$data_loss_from_expected`
## ------------------------------------------------

dq$data_loss_from_expected(500)

## ------------------------------------------------
## Method `DataQuality$effective_frequency`
## ------------------------------------------------

dq$effective_frequency()

## ------------------------------------------------
## Method `DataQuality$get_duration`
## ------------------------------------------------

dq$get_duration()

## ------------------------------------------------
## Method `DataQuality$precision_using_moving_window`
## ------------------------------------------------

dq$precision_using_moving_window(20, "RMS-S2S")
```

`data_loss_from_expected` *Compute Data Loss from Expected Sample Count*

Description

Calculates data loss based on expected number of samples.

Usage

```
data_loss_from_expected(a, b, duration, frequency)
```

Arguments

a	Horizontal gaze values (e.g. azimuth or horizontal coordinate in pixels or mm).
b	Vertical gaze values (e.g. azimuth or horizontal coordinate in pixels or mm).
duration	Duration in seconds.
frequency	Sampling frequency in Hz.

Value

Percentage of data loss.

Examples

```
data_loss_from_expected(c(1, NA, 3), c(1, 2, NA), duration = 1, frequency = 3)
```

---

data_loss_from_invalid

Compute Data Loss from number of invalid samples.

Description

Calculates percentage of missing gaze samples.

Usage

```
data_loss_from_invalid(a, b)
```

Arguments

a	Horizontal gaze values (e.g. azimuth or horizontal coordinate in pixels or mm).
b	Vertical gaze values (e.g. azimuth or horizontal coordinate in pixels or mm).

Value

Percentage of missing samples.

Examples

```
data_loss_from_invalid(c(1, NA, 3), c(1, 2, NA))
```

effective_frequency *Compute Effective Sampling Frequency*

Description

Calculates effective frequency based on valid samples.

Usage

```
effective_frequency(a, b, duration)
```

Arguments

a	Horizontal gaze values (e.g. azimuth or horizontal coordinate in pixels or mm).
b	Vertical gaze values (e.g. azimuth or horizontal coordinate in pixels or mm).
duration	Duration in seconds.

Value

Effective frequency in Hz.

Examples

```
effective_frequency(c(1, NA, 3), c(1, 2, NA), duration = 1)
```

ETDQ_version *Get ETDQualitizer Version*

Description

Returns the current version string of the ETDQualitizer tool.

Usage

```
ETDQ_version()
```

Value

A character string representing the version number.

Examples

```
ETDQ_version()
```

Fick_to_vector *Convert Fick Angles to 3D Vector*

Description

Converts azimuth and elevation angles (in degrees) to a 3D unit vector.

Usage

```
Fick_to_vector(azi, ele, rho = 1)
```

Arguments

azi	Azimuth angle in degrees.
ele	Elevation angle in degrees.
rho	Radius (default is 1.0).

Value

A list with components x, y, and z.

Examples

```
Fick_to_vector(30, 10)
```

frechet_median_on_sphere *Compute the Spherical Frechet Median*

Description

Finds the unit direction that minimizes the sum of angular distances to a collection of 3D direction vectors. Non-finite rows are ignored.

Usage

```
frechet_median_on_sphere(vectors, tol = 1e-12, max_iter = 128)
```

Arguments

vectors	Numeric matrix with three columns containing 3D direction vectors.
tol	Convergence tolerance (default: 1e-12).
max_iter	Maximum number of optimization iterations (default: 128).

Value

A numeric vector of length three containing the spherical Frechet median, or three NaNs if no finite vectors are provided.

Examples

```
frechet_median_on_sphere(rbind(c(0, 0, 1), c(0, 0, 1)))
```

---

precision_using_moving_window
Precision Using Moving Window

Description

Computes gaze precision using a moving window and selected metric.

Usage

```
precision_using_moving_window(
  azi,
  ele,
  window_length,
  metric,
  aggregation_fun = median,
  ...
)
```

Arguments

azi	Azimuth values.
ele	Elevation values.
window_length	Window size in samples.
metric	Precision metric: "RMS-S2S", "STD", or "BCEA".
aggregation_fun	Function to aggregate precision values across the windows (default: median).
...	Additional arguments passed to metric function.

Value

Aggregated precision value.

Examples

```
precision_using_moving_window(rnorm(100), rnorm(100), 10, "STD")
```

`report_data_quality_table` *Summarize and Report Data Quality Metrics*

Description

This function summarizes data quality metrics from a validation procedure by computing averages per participant and generating descriptive statistics across participants. It also returns a formatted textual summary suitable for reporting.

Usage

```
report_data_quality_table(dq_table)
```

Arguments

`dq_table`	A 'data.frame' containing data quality metrics. Must include columns 'file', 'eye', 'target_id', and relevant numeric metrics such as 'accuracy', 'rms_s2s', and 'std'. This would generally be created by concatenating the output of the compute_data_quality_from_validation() for multiple files.

Details

The summary text excludes BCEA and data loss metrics. BCEA is considered a niche metric and data loss is best reported across the full dataset rather than just the validation subset.

Value

A named list with two elements:

txt A character string summarizing key metrics (accuracy, RMS-S2S precision, STD precision).

measures A list containing:

- `all`: A data frame with per-participant averages (grouped by 'file').
- `mean`, `std`, `min`, `max`: Named numeric vectors with summary statistics across participants.

Examples

```
## Not run:
# NB: this example requires a gaze data table to run. See the complete example at
# https://github.com/dcnieho/ETDQualitizer/blob/master/example/R.R for how to prepare
# the input data for this function
result <- report_data_quality_table(dq_table)
cat(result$txt)
head(result$measures$all)

## End(Not run)
```

rms_s2s *RMS of Sample-to-Sample Differences*

Description

Computes root mean square of differences between successive gaze samples.

Usage

```
rms_s2s(azi, ele, central_tendency_fun = mean)
```

Arguments

azi	Azimuth values in degrees.
ele	Elevation values in degrees.
central_tendency_fun	Function to compute central tendency (default: mean).

Value

A list with rms, rms_azi, and rms_ele, the total RMS of sample-to-sample distances and that of the azimuthal and elevation components (all in degrees).

Examples

```
rms_s2s(c(1, 2, 3), c(1, 2, 3))
```

ScreenConfiguration *R6 Screen Configuration Class*

Description

Provides methods for converting between pixel, millimeter, and degree units.

Public fields

screen_size_x_mm	Screen width in mm.
screen_size_y_mm	Screen height in mm.
screen_res_x_pix	Horizontal screen resolution in pixels.
screen_res_y_pix	Vertical screen resolution in pixels.
viewing_distance_mm	Viewing distance in mm.

Methods

Public methods:

- ScreenConfiguration$new()
- ScreenConfiguration$pix_to_mm()
- ScreenConfiguration$pix_to_deg()
- ScreenConfiguration$mm_to_deg()
- ScreenConfiguration$mm_to_pix()
- ScreenConfiguration$deg_to_mm()
- ScreenConfiguration$deg_to_pix()
- ScreenConfiguration$screen_extents()
- ScreenConfiguration$clone()

Method `new()`**:** Creates a new ScreenConfiguration object with screen and viewing distance parameters.

Usage:

```
ScreenConfiguration$new(
  screen_size_x_mm,
  screen_size_y_mm,
  screen_res_x_pix,
  screen_res_y_pix,
  viewing_distance_mm
)
```

Arguments:

`screen_size_x_mm` Screen width in millimeters.

`screen_size_y_mm` Screen height in millimeters.

`screen_res_x_pix` Horizontal screen resolution in pixels.

`screen_res_y_pix` Vertical screen resolution in pixels.

`viewing_distance_mm` Viewing distance in millimeters.

Returns: A new ScreenConfiguration object.

Examples:

```
sc <- ScreenConfiguration$new(500, 300, 1920, 1080, 600)
```

Method `pix_to_mm()`**:** Converts pixel coordinates to millimeter coordinates on the screen.

Usage:

```
ScreenConfiguration$pix_to_mm(x, y)
```

Arguments:

`x` Horizontal pixel coordinate.

`y` Vertical pixel coordinate.

Returns: A list with x and y in millimeters.

Examples:

```
sc$pix_to_mm(960, 540)
```

Method `pix_to_deg()`**:** Converts pixel coordinates to an angular gaze direction in degrees.

Usage:

```
ScreenConfiguration$pix_to_deg(x, y)
```

Arguments:

`x` Horizontal pixel coordinate.

`y` Vertical pixel coordinate.

Returns: A list with azimuth (`"azi"`) and elevation (`"ele"`) in degrees.

Examples:

```
sc$pix_to_deg(960, 540)
```

Method `mm_to_deg()`**:** Converts millimeter coordinates to an angular gaze direction in degrees.

Usage:

```
ScreenConfiguration$mm_to_deg(x, y)
```

Arguments:

`x` Horizontal position in millimeters.

`y` Vertical position in millimeters.

Returns: A list with azimuth (`"azi"`) and elevation (`"ele"`) in degrees.

Examples:

```
sc$mm_to_deg(100, 50)
```

Method `mm_to_pix()`**:** Converts millimeter coordinates on the screen to pixel coordinates.

Usage:

```
ScreenConfiguration$mm_to_pix(x, y)
```

Arguments:

`x` Horizontal position in millimeters.

`y` Vertical position in millimeters.

Returns: A list with x and y in pixels.

Examples:

```
sc$mm_to_pix(100, 50)
```

Method `deg_to_mm()`**:** Converts an angular gaze direction in degrees to millimeter coordinates on the screen.

Usage:

```
ScreenConfiguration$deg_to_mm(azi, ele)
```

Arguments:

`azi` Azimuth in degrees (Fick angles).

`ele` Elevation in degrees (Fick angles).

Returns: A list with x and y in millimeters.

Examples:

```
sc$deg_to_mm(2, 1)
```

Method `deg_to_pix()`**:** Converts an angular gaze direction in degrees to pixel coordinates.

Usage:

```
ScreenConfiguration$deg_to_pix(azi, ele)
```

Arguments:

`azi` Azimuth in degrees (Fick angles).

`ele` Elevation in degrees (Fick angles).

Returns: A list with x and y in pixels.

Examples:

```
sc$deg_to_pix(2, 1)
```

Method `screen_extents()`**:** Computes the horizontal and vertical extents of the screen (in degrees).

Usage:

```
ScreenConfiguration$screen_extents()
```

Returns: A list with width and height in degrees.

Examples:

```
sc$screen_extents()
```

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

Usage:

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

Arguments:

`deep` Whether to make a deep clone.

Examples

```
sc <- ScreenConfiguration$new(500, 300, 1920, 1080, 600)
sc$pix_to_deg(960, 540)

## ------------------------------------------------
## Method `ScreenConfiguration$new`
## ------------------------------------------------

sc <- ScreenConfiguration$new(500, 300, 1920, 1080, 600)

## ------------------------------------------------
## Method `ScreenConfiguration$pix_to_mm`
## ------------------------------------------------

sc$pix_to_mm(960, 540)

## ------------------------------------------------
## Method `ScreenConfiguration$pix_to_deg`
## ------------------------------------------------

sc$pix_to_deg(960, 540)
```

```
## ------------------------------------------------
## Method `ScreenConfiguration$mm_to_deg`
## ------------------------------------------------

sc$mm_to_deg(100, 50)

## ------------------------------------------------
## Method `ScreenConfiguration$mm_to_pix`
## ------------------------------------------------

sc$mm_to_pix(100, 50)

## ------------------------------------------------
## Method `ScreenConfiguration$deg_to_mm`
## ------------------------------------------------

sc$deg_to_mm(2, 1)

## ------------------------------------------------
## Method `ScreenConfiguration$deg_to_pix`
## ------------------------------------------------

sc$deg_to_pix(2, 1)

## ------------------------------------------------
## Method `ScreenConfiguration$screen_extents`
## ------------------------------------------------

sc$screen_extents()
```

`std` *Standard Deviation of Gaze Samples*

Description

Computes standard deviation of azimuth and elevation.

Usage

```
std(azi, ele)
```

Arguments

`azi`	Azimuth values in degrees.
`ele`	Elevation values in degrees.

Value

A list with `std`, `std_azi`, and `std_ele`, the total STD of sample-to-sample distances and that of the azimuthal and elevation components (all in degrees).

Examples

```
std(c(1, 2, 3), c(1, 2, 3))
```

`vector_to_Fick` *Convert 3D Vector to Fick Angles*

Description

Converts a 3D vector to azimuth and elevation angles (in degrees).

Usage

```
vector_to_Fick(x, y, z)
```

Arguments

`x`	X component of the vector.
`y`	Y component of the vector.
`z`	Z component of the vector.

Value

A list with components `azi` and `ele`.

Examples

```
vector_to_Fick(0.5, 0.2, 0.8)
```

Index

accuracy, 2

bcea, 3

compute_data_quality_from_validation, 3

data_loss_from_expected, 9
data_loss_from_invalid, 10
DataQuality, 5

effective_frequency, 11
ETDQ_version, 11

Fick_to_vector, 12
frechet_median_on_sphere, 12

precision_using_moving_window, 13

report_data_quality_table, 14
rms_s2s, 15

ScreenConfiguration, 15
std, 19

vector_to_Fick, 20