Package 'cotram'

November 19, 2025

Title Count Transformation Models

Version 0.6-0

Date 2025-11-19

Description Count transformation models featuring parameters interpretable as discrete hazard ratios, odds ratios, reverse-time discrete hazard ratios, or transformed expectations. An appropriate data transformation for a count outcome and regression coefficients are simultaneously estimated by maximising the exact discrete log-likelihood using the computational framework provided in package 'mlt', technical details are given in Siegfried & Hothorn (2020) <DOI:10.1111/2041-210X.13383>. The package also contains an experimental implementation of multivariate count transformation models with an application to multi-species distribution models <DOI:10.48550/arXiv.2201.13095>.

Depends R (>= 3.5.0), tram (>= 1.3-0), mlt (>= 1.7-0)

Imports variables (>= 1.0-2), basefun (>= 1.0-5), survival, utils, qrng

Suggests TH.data, knitr, lattice, colorspace, multcomp, mvtnorm, numDeriv, viridis, Hmsc

VignetteBuilder knitr

URL `http://ctm.R-forge.R-project.org`

Encoding UTF-8

License GPL-2

NeedsCompilation no

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Repository CRAN

Date/Publication 2025-11-19 15:20:02 UTC

Contents

`confband` *Confidence Bands*

Description

Confidence bands for transformation, distribution, survivor or cumulative hazard functions

Usage

```
## S3 method for class 'cotram'
confband(object, newdata,  level = 0.95,
       type = c("trafo", "distribution", "survivor", "cumhazard"),
       smooth = FALSE, q = NULL, K = 20, cheat = K, ...)
```

Arguments

`object`	an object of class `cotram`.
`newdata`	a data frame of observations.
`level`	the confidence level.
`type`	the function to compute the confidence band for.
`smooth`	logical; if `TRUE` a smoothed function of `type` is returned.
`q`	quantiles at which to evaluate the model.
`K`	number of grid points the function is evaluated at (in the absence of `q` and `smooth = TRUE`).
`cheat`	number of grid points the function is evaluated at when using the quantile obtained for `K` grid points (in the absence of `q` and `smooth = TRUE`).
`...`	additional arguments to `confint.glht`.

Details

The function is evaluated at the count response or at `K` grid points and simultaneous confidence intervals are then interpolated in order to construct the band.

Value

For each row in `newdata` the function and corresponding confidence band evaluated at the count response (or `K` or `cheat` grid points) is returned.

Examples

```
op <- options(digits = 4)

data("birds", package = "TH.data")

### fit count transformation model with cloglog link
m_birds <- cotram(SG5 ~ AOT + AFS + GST + DBH + DWC + LOG, data = birds,
                  method = "cloglog")

### compute asymptotic confidence bands for the distribution function
### for the first oberservation
confband(m_birds, newdata = birds[1, ], type = "distribution")

options(op)
```

`cotram` *Count Transformation Models*

Description

Likelihood-based count transformation models for fully parameterised discrete conditional distribution functions. The link function governing the interpretation of the predictor can be chosen and results in discrete hazard ratios, odds ratios, reverse time hazard ratios or conditional expectation of transformed counts.

Usage

```
cotram(formula, data, method = c("logit", "cloglog", "loglog", "probit"),
       log_first = TRUE, prob = 0.9, subset, weights, offset, cluster,
       na.action = na.omit, ...)
```

Arguments

`formula`	an object of class `"formula"`: a symbolic description of the model structure to be fitted. The details of model specification are given under `tram` and in the package vignette.
`data`	an optional data frame, list or environment (or object coercible by `as.data.frame` to a data frame) containing the variables in the model. If not found in `data`, the variables are taken from `environment(formula)`.
`method`	character specifying the choice of the link function, mapping the transformation function into probabilities. Available choices include the logit, complementary log-log, log-log or probit link. The different link functions govern the interpretation of the linear predictor. Details of the interpretation can be found in the package vignette.

`prob`	probability giving the quantile of the response defining the upper limit of the support of a smooth Bernstein polynomial (with the lower limit being set to 0). If a vector of two probabilites is specified, the corresponding quantiles of the response define the lower and upper limit of the support, respectively. Note, that the support is rounded to integer values.
`log_first`	logical; if `TRUE`, a Bernstein polynomial is defined on the log-scale for (y + 1).
`subset`	an optional vector specifying a subset of observations to be used in the fitting process.
`weights`	an optional vector of weights to be used in the fitting process. Should be `NULL` or a numeric vector. If present, the weighted log-likelihood is maximised.
`offset`	this can be used to specify an _a priori_ known component to be included in the linear predictor during fitting. This should be `NULL` or a numeric vector of length equal to the number of cases.
`cluster`	optional factor with a cluster ID employed for computing clustered covariances.
`na.action`	a function which indicates what should happen when the data contain `NA`s. The default is set to `na.omit`.
`...`	additional arguments to `tram`.

Details

Likelihood-based estimation of a fully parameterised conditional discrete distribution function for count data, while ensuring interpretability of the linear predictors. The models are defined with a negative shift term relating positive predictors to larger values of the conditional mean. For the model with logistic or cloglog link `exp(-coef())` is the multiplicative change of discrete odds-ratios or hazard ratios. For the model with loglog link `exp(coef())` is the multiplicative change of the reverse time hazard ratios. Applying a transformation model with probit link `coef()` gives the conditional expectation of the transformed counts, with transformation function estimated from data.

Value

An object of class `cotram` and `tram`, with corresponding `coef`, `vcov`, `logLik`, `summary`, `print`, `plot` and `predict` methods.

References

Sandra Siegfried, Torsten Hothorn (2020), Count Transformation Models, *Methods in Ecology and Evolution*, **11**(7), 818–827, doi:10.1111/2041210X.13383.

Torsten Hothorn, Lisa Möst, Peter Bühlmann (2018), Most Likely Transformations, *Scandinavian Journal of Statistics*, **45**(1), 110–134, doi:10.1111/sjos.12291.

Torsten Hothorn (2020), Most Likely Transformations: The mlt Package, *Journal of Statistical Software*, **92**(1), 1–68, doi:10.18637/jss.v092.i01.

Examples

```
op <- options(digits = 2)

data("birds", package = "TH.data")
cotram(SG5 ~ AOT + AFS + GST + DBH + DWC + LOG, data = birds)

options(op)
```

`cotram-methods` *Methods for Count Transformation Models*

Description

Methods for objects inheriting from class cotram

Usage

```
## S3 method for class 'cotram'
predict(object, newdata = model.frame(object),
        type = c("lp", "trafo", "distribution", "survivor", "density",
                 "logdensity", "hazard", "loghazard", "cumhazard",
                 "logcumhazard", "odds", "logodds", "quantile"),
        smooth = FALSE, q = NULL, K = 20, prob = 1:(10-1)/10, ...)
## S3 method for class 'cotram'
plot(x, newdata, type = c("distribution", "survivor","density",
                          "logdensity", "cumhazard", "quantile", "trafo"),
        confidence = c("none", "band"), level = 0.95,
        smooth = FALSE, q = NULL, K = 20, cheat = K, prob = 1:(10-1)/10,
        col = "black", fill = "lightgrey",
        lty = 1, lwd = 1, add = FALSE, ...)
## S3 method for class 'cotram'
as.mlt(object)
## S3 method for class 'cotram'
logLik(object, parm = coef(as.mlt(object), fixed = FALSE), newdata, ...)
```

Arguments

`object, x`	a fitted linear count transformation model inheriting from class `cotram`.
`newdata`	an optional data frame of observations.
`parm`	model parameters.
`type`	type of prediction, current options include linear predictors (`"lp"`, of `x` variables in the formula `y ~ x`), transformation functions (`"trafo"`) or distribution functions on the scale of the cdf (`"distribution"`), survivor function, density function, log-density function, cumulative hazard function or quantile function.
`confidence`	whether to plot a confidence band (see `confband`).

`level`	the confidence level.
`smooth`	logical; if `TRUE` a smoothed function of `type` is returned.
`q`	quantiles at which to evaluate the model.
`prob`	probabilities for the evaluation of the quantile function (`type = "quantile"`).
`K`	number of grid points the function is evaluated at (for `smooth = TRUE` and in absence of `q`).
`cheat`	number of grid points the function is evaluated at when using the quantile obtained for `K` grid points (in the absence of `q` and `smooth = TRUE`).
`col`	color for the lines to plot.
`fill`	color for the confidence band.
`lty`	line type for the lines to plot.
`lwd`	line width.
`add`	logical; indicating if a new plot shall be generated (the default).
`...`	additional arguments to the underlying methods for `predict`.

Details

`predict` and `plot` can be used to inspect the model on different scales.

See Also

`predict.cotram`, `confband.cotram`, `tram-methods`, `mlt-methods`, `plot.ctm`

Examples

```
op <- options(digits = 4)

data("birds", package = "TH.data")

### fit count transformation model with cloglog link
m_birds <- cotram(SG5 ~ AOT + AFS + GST + DBH + DWC + LOG, data = birds,
                  method = "cloglog")
logLik(m_birds)

### classical likelihood inference
summary(m_birds)

### coefficients of the linear predictor (discrete hazard ratios)
exp(-coef(m_birds))

### compute predicted median along with 10% and 90% quantile for the first
### three observations
nd <- birds[1:3,]
round(predict(m_birds, newdata = nd, type = "quantile", prob = c(.1, .5, .9),
              smooth = TRUE), 3)

### plot the predicted distribution for these observations
plot(m_birds, newdata = nd, type = "distribution",
```

```
      col = c("skyblue", "grey", "seagreen"))

options(op)
```

---

mcotram *Multivariate Count Conditional Transformation Models*

Description

A proof-of-concept implementation of multivariate conditional transformation models for count data.

Usage

```
mcotram(..., formula = ~ 1, data, conditional = FALSE, theta = NULL,
        fixed = NULL, scale = FALSE, optim = mltoptim(hessian = TRUE),
        M = 1000, dofit = TRUE, domargins = TRUE)
```

Arguments

`...`	marginal count transformation models, one for each response
`formula`	a model formula describing a model for the dependency structure via the lambda parameters. The default is set to `~ 1` for constant lambdas.
`data`	a data.frame.
`conditional`	logical; parameters are defined conditionally (only possible when all models are probit models). This is the default as described by Klein et al. (2022). If `FALSE`, parameters can be directly interpreted marginally, this is explained in Section 2.6 by Klein et al. (2022). Using `conditional = FALSE` with probit-only models gives the same likelihood but different parameter estimates.
`theta`	an optional vector of starting values.
`fixed`	an optional named numeric vector of predefined parameter values.
`scale`	a logical indicating if (internal) scaling shall be applied to the model coefficients.
`optim`	a list of optimisers as returned by `mltoptim`
`M`	number of Halton sequences used to approximate the log-likelihood in `lpmvnorm`.
`dofit`	logical; parameters are fitted by default, otherwise a list with log-likelihood and score function is returned.
`domargins`	logical; all model parameters are fitted by default, including the parameters of marginal models.

Details

The function implements multivariate count conditional transformation models. The response is assumed to be a vector of counts.

Value

An object of class `mmlt` with `coef` and `predict` methods.

References

Luisa Barbani, Roland Brandl, Torsten Hothorn (2022), Multi-species Count Transformation Models, doi:10.48550/arXiv.2201.13095.

Nadja Klein, Torsten Hothorn, Luisa Barbanti, Thomas Kneib (2020), Multivariate Conditional Transformation Models. *Scandinavian Journal of Statistics*, doi:10.1111/sjos.12501.

Examples

```
library("cotram")
data("spiders", package = "cotram")

### for illustration only
OR <- 1      ### order of transformation function
             ### OR = 1 means log-linear, use OR ~ 6
M <- 100     ### number of Halton sequences, seem sufficient here
fastopt <- mltoptim(abstol = 1e-3, reltol = 1e-3)
             ### faster convergence

## fit conditional marginal count transformation models
## one for each species
m_PF <- cotram(Pardosa_ferruginea ~ Elevation + Canopy_openess,
               data = spiders, method = "probit", order = OR)
m_HL <- cotram(Harpactea_lepida ~ Elevation + Canopy_openess,
               data = spiders, method = "probit", order = OR)
m_CC <- cotram(Callobius_claustrarius ~ Elevation + Canopy_openess,
               data = spiders, method = "probit", order = OR)
m_CT <- cotram(Coelotes_terrestris ~ Elevation + Canopy_openess,
               data = spiders, method = "probit", order = OR)
m_PL <- cotram(Pardosa_lugubris ~ Elevation + Canopy_openess,
               data = spiders, method = "probit", order = OR)
m_PR <- cotram(Pardosa_riparia ~ Elevation + Canopy_openess,
               data = spiders, method = "probit", order = OR)

### fit dependence parameters
mm <- mcotram(m_PF, m_HL, m_CC, m_CT, m_PL, m_PR, data = spiders,
              M = M, scale = TRUE, optim = fastopt)
logLik(mm)

### Kendall's tau: Dependence of species after accounting
### for elevation and canopy openess in marginal models
coef(mm, type = "Kendall")



### regress dependencies on elevation and canopy openess
mmc <- mcotram(m_PF, m_HL, m_CC, m_CT, m_PL, m_PR, data = spiders,
               formula = ~ Elevation + Canopy_openess, M = M,
```

```
               scale = TRUE, optim = fastopt)
logLik(mmc)

### weak evidence for such effects
pchisq(2 * (logLik(mmc) - logLik(mm)), df = 30, lower.tail = FALSE)

### plot Kendall's tau for different elevations / openess levels
nd <- expand.grid(Elevation = 80:120 * 10, Canopy_openess = 1:10 * 10)
KD <- Lower_tri(coef(mmc, newdata = nd, type = "Kendall"))
f <- factor(rownames(KD))
nd <- cbind(f = rep(f, nrow(nd)), nd[rep(1:nrow(nd), each = nlevels(f)),])
nd$KD <- c(KD)

if (require("lattice"))
contourplot(KD ~ Elevation + Canopy_openess | f, data = nd,
            cuts = 18, xlab = "Elevation", ylab = "Canopy openess")

### for example:
### => constant negative dependence of Pardosa_lugubris and Coelotes_terrestris
### => weak dependence of Harpactea_lepida and Pardosa_ferruginea
###    for low elevations, negative dependence increasing with elevation
```

`spiders` *Bavarian Forest Spider Data*

Description

Abundance of six spider species on 190 plots in the Bavarian Forest National Park

Usage

```
data("spiders")
```

Format

A data frame with 190 observations on the following 9 variables.

`Plot`	experimental plot id
`Elevation`	elevation of the plot
`Canopy_openess`	openess of canopy at plot
`Pardosa_ferruginea`	number of Pardosa ferruginea observed
`Harpactea_lepida`	number of Harpactea lepida observed
`Callobius_claustrarius`	number of Callobius claustrarius observed
`Coelotes_terrestris`	number of Coelotes terrestris observed
`Pardosa_lugubris`	number of Pardosa lugubris observed
`Pardosa_riparia`	number of Pardosa riparia observed

Details

To untangle effects of dead-wood addition and canopy openness on non-saproxylic epigeal arthropods, Seibold et al (2016) exposed different amounts of logs and branches on 190 0.1-ha plots located in sunny or shady mixed montane forests and sampled epigeal arthropods over three years. The data contain abundances of six spider species for all 190 plots, along with plot elevation and canopy openess.

Source

Sebastian Seibold, Claus Bässler, Petr Baldrian, Lena Reinhard, Simon Thorn, Michael D. Ulyshen, Ingmar Weiß and Jörg Müller (2016). Dead-wood addition promotes non-saproxylic epigeal arthropods but effects are mediated by canopy openness. *Biological Conservation*, **204**, 181–188, doi:10.1016/j.biocon.2016.09.031.

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