# CoDa R Package

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## Description

The CoDa R package contains the implementation of the Compositional Data Mortality Model (CoDa). This is a Lee-Carter (1992) type method that is used to modelling and forecasting the life table distribution of deaths (dx) using Principal Component Analysis. In the context of mortality forecasting the CoDa method was fist used in Bergeron-Boucher et al. (2017). The package includes functions for fitting the model, analysing it's goodness-of-fit and performing mortality projections.

## Installation

1. Make sure you have the most recent version of R
2. Run the following code in your R console

```r
install.packages("CoDa")
```

## Updating to the latest version of the package

You can track and contribute to the development of `CoDa` on GitHub. To install it:

1. Install the release version of `devtools` from CRAN with `install.packages("devtools")`.

2. Make sure you have a working development environment.

    - **Windows**: Install Rtools.
    - **Mac**: Install `Xcode` from the Mac App Store.
    - **Linux**: Install a compiler and various development libraries (details vary across different flavors of Linux).

3. Install the development version of `CoDa`.

```r
devtools::install_github("mpascariu/CoDa")
```

## Help

All functions are documented in the standard way, which means that once you load the package using `library(CoDa)` you can just type `?coda` to see the help file.

# Examples

```r
library(CoDa)
```

## Fit CoDa model

The model can be fitted using function `coda` and using a dataset containing mortality data (dx distributions) in for of a matrix or data.frame with ages as row and time as column. `CoDa.data` is an example of such a data set.

```r
CoDa.data[1:5, 1:5]
```

```
##          1960        1961        1962        1963        1964
## 0 0.063768765 0.062408776 0.058475531 0.055569918 0.054402102
## 1 0.004484745 0.004205882 0.004092247 0.003889991 0.003846039
## 2 0.002571836 0.002508007 0.002415691 0.002317961 0.002175572
## 3 0.001976766 0.001851735 0.001814390 0.001787156 0.001714041
## 4 0.001615381 0.001571251 0.001416598 0.001463843 0.001364048
```

`CoDa.data` is containing distribution of deaths for US female population between 1960 and 2014. The data is provided in the package for testing purposes only. By the time you are using it, it may be outdated. Download actual demographic data free of charge from Human Mortality Database. Once a username and a password is created on the website the MortalityLaws R package can be used to extract data directly into your R console.

```r
M <- coda(dx = CoDa.data, x = 0:110, y = 1960:2014)
M
```

```
##
## Fit  : Compositional-Data Lee-Carter Mortality Model
## Model: clr d[x] = a[x] + b[x]k[t]
## Call : coda(dx = CoDa.data, x = 0:110, y = 1960:2014)
## Ages  in fit:  0 - 110
## Years in fit:  1960 - 2014
```

## Output objects

The output is an object of class `coda` with the components:

- `input` – List with arguments provided in input. Saved for convenience;
- `call` – The unevaluated expression of the defined coda function.
- `coefficients` – Estimated coefficients;
- `fitted` – Fitted values of the estimated CoDa model;
- `residuals` – Deviance residuals;
- `x` – Vector of ages used in the fitting;
- `y` – Vector of years used in the fitting;

```r
ls(M)
```

```
## [1] "call"          "coefficients"  "fitted.values" "input"
## [5] "residuals"     "x"             "y"
```

## Summary

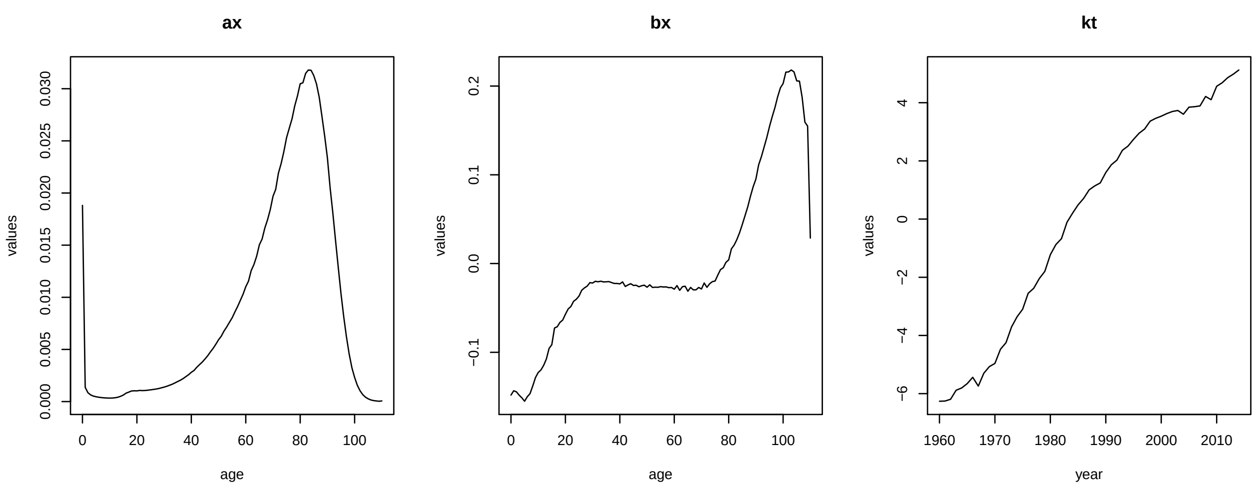
```r
summary(M)
```

```
##
## Fit   : Compositional-Data Lee-Carter Mortality Model
## Model: clr d[x] = a[x] + b[x]k[t]
## Coefficients:
##          ax       bx    .    y       kt
## 0   0.01882 -0.14822    | 1960  -6.2615
## 1   0.00136 -0.14334    | 1961 -6.25469
## 2   0.00085 -0.14457    | 1962 -6.19413
## 3   0.00064 -0.14831    | 1963 -5.88283
## 4   0.00053 -0.15134    | 1964 -5.80534
## 5   0.00046 -0.15515    | 1965 -5.65574
## ...     ...      ... <NA>  ...      ...
## 105 0.00026  0.20582    | 2009  4.10337
## 106 0.00015  0.20556    | 2010  4.56493
## 107   9e-05  0.18714    | 2011  4.68676
## 108   6e-05  0.15935    | 2012  4.86257
## 109   3e-05   0.1549    | 2013  4.98146
## 110   6e-05   0.0287    | 2014  5.12442
```

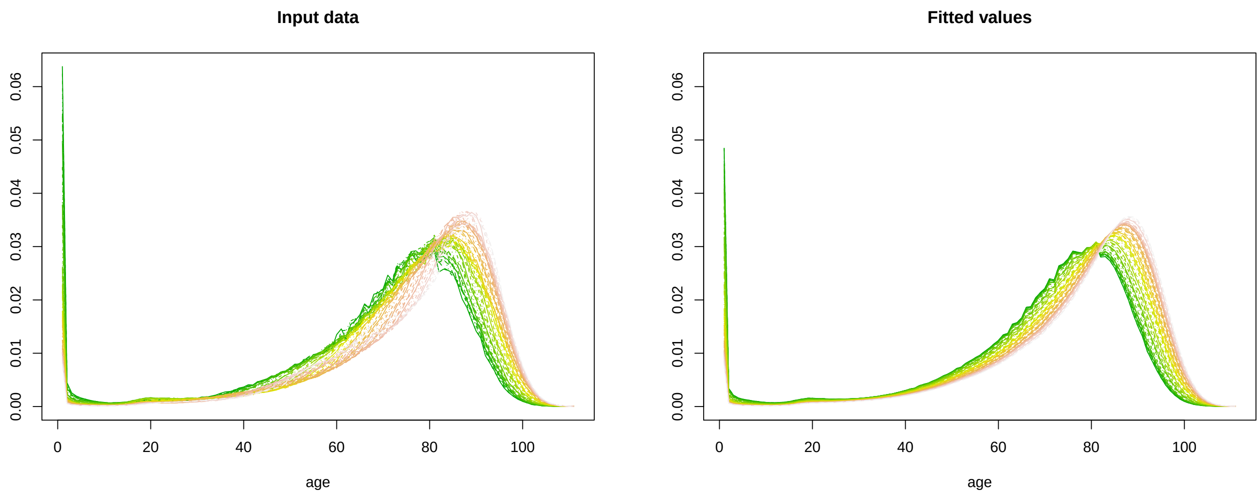
## How to plot fitted parameters and fitted values of a `CoDa` mortality model

Two types of plots are available: `"coef"` to obtain representations of the three estimated series of parameters and `"data"` for visualising the input and fitted values.

```r
plot(M, plotType = "coef", ylab = "values")
```



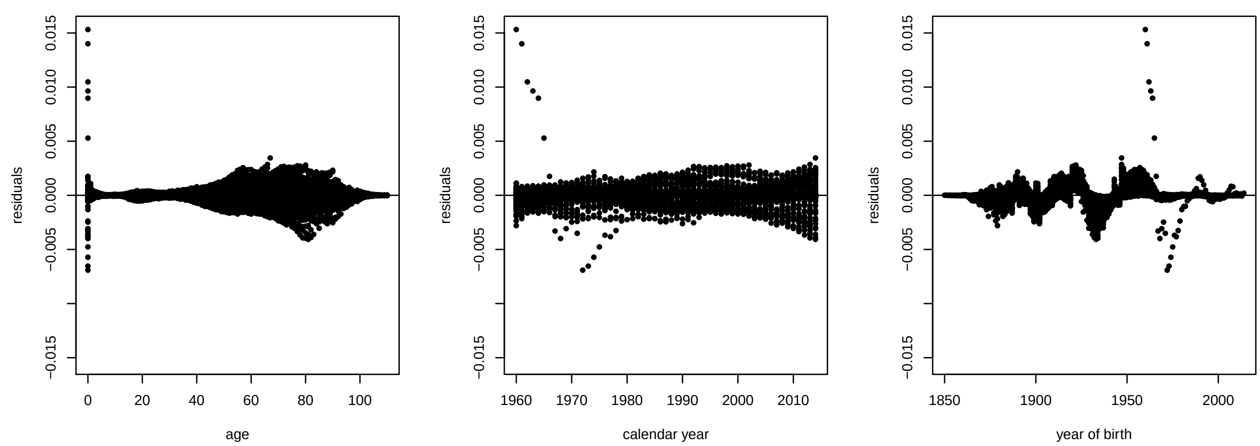

```r
plot(M, plotType = "data")
```




## Plot Residuals

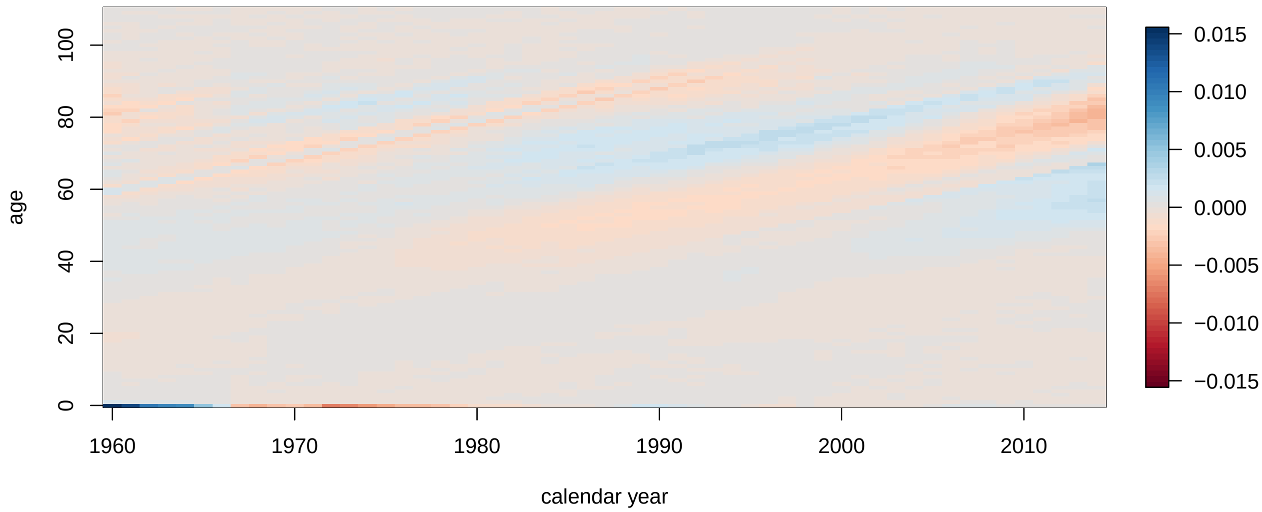
Form the resulted deviance residuals, `resid(M)`, three types of figures can be obtained. When `plotType = "scatter"` scatter plots of the residuals against age, calendar year and cohort (year of birth) are produced.

```
plot(resid(M), plotType = "scatter")
```



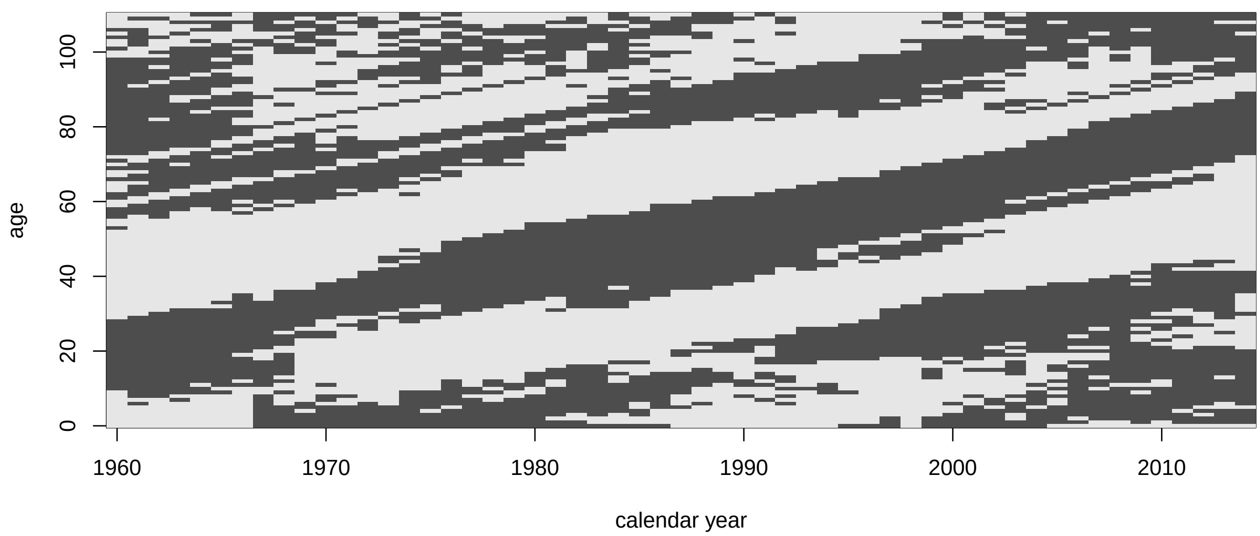

When `plotType = "colourmap"` a two dimensional colour map of the residuals is plotted. This is produced using function `image.plot`. See `image.plot` for further parameters that can be passed to this type of plots.

```
plot(resid(M), plotType = "colourmap")
```




When `plotType = "signplot"` a two dimensional black and white map of the residuals is plotted with dark grey representing negative residuals and light grey representing positive residuals. This is produced using function `image.default`.

```
plot(resid(M), plotType = "signplot")
```




## Mortality projections

Mortality projections can be obtained using function `predict`. The example below shows how a 30 year mortality forcast is realised using the fitted `coda` model. For the computation of the `jumpchoice` there are two alternatives: `actual` (uses actual rates from final year) and `fit` (uses fitted rates).

```
P <- predict(M, h = 30, jumpchoice = 'actual')
P
```

```
##
## Forecast: Compositional-Data Lee-Carter Mortality Model
## Call    : predict.coda(object = M, h = 30, jumpchoice = "actual")
## Time series model (kt): ARIMA(2,2,2)
## Ages  in forecast   :  0 - 110
## Years in forecast   :  2015 - 2044
```

```r
# list of objects in predict
ls(P)
```

```
## [1] "call"              "conf.intervals"   "deep"
## [4] "kt"                "predicted.values" "x"
## [7] "y"
```

```r
# Predicted distribution of death
head(P$predicted.values, 3)
```

```
##           2015         2016         2017         2018         2019
## 0 0.0075851408 0.0075122888 0.0071610721 0.0070100479 0.0067843320
## 1 0.0004882349 0.0004836694 0.0004616400 0.0004521574 0.0004379734
## 2 0.0003116650 0.0003087307 0.0002945754 0.0002884838 0.0002793739
##           2020         2021         2022         2023         2024
## 0 0.0065498611 0.0063901695 0.0061528080 0.0059875747 0.0057904885
## 1 0.0004232242 0.0004131699 0.0003982116 0.0003877887 0.0003753454
## 2 0.0002699034 0.0002634490 0.0002538487 0.0002471609 0.0002391785
##           2025         2026         2027         2028         2029
## 0 0.0056057935 0.0054392728 0.0052553604 0.0050972852 0.0049295726
## 1 0.0003636732 0.0003531400 0.0003414958 0.0003314780 0.0003208397
## 2 0.0002316926 0.0002249387 0.0002174742 0.0002110538 0.0002042374
##           2030         2031         2032         2033         2034
## 0 0.0047720332 0.0046201851 0.0044673466 0.0043248650 0.0041815764
## 1 0.0003108373 0.0003011874 0.0002914654 0.0002823939 0.0002732625
## 2 0.0001978299 0.0001916496 0.0001854247 0.0001796176 0.0001737735
##           2035         2036         2037         2038         2039
## 0 0.0040449341 0.0039117279 0.0037813077 0.0036562608 0.0035333042
## 1 0.0002645465 0.0002560419 0.0002477074 0.0002397089 0.0002318368
## 2 0.0001681966 0.0001627563 0.0001574260 0.0001523117 0.0001472795
##           2040         2041         2042         2043         2044
## 0 0.0034149202 0.0032996082 0.0031875662 0.0030792190 0.0029736429
## 1 0.0002242505 0.0002168542 0.0002096610 0.0002026986 0.0001959080
## 2 0.0001424311 0.0001377052 0.0001331102 0.0001286637 0.0001243278
```

# References


1. Bergeron-Boucher, M-P., Canudas-Romo, V., Oeppen, J. and Vaupel, W.J. 2017. Coherent forecasts of mortality with compositional data analysis. Demographic Research, Volume 17, Article 17, Pages 527–566.

2. Oeppen, J. 2008. Coherent forecasting of multiple-decrement life tables: A test using Japanese cause of death data. Paper presented at the European Population Conference 2008, Barcelona, Spain, July 9-12, 2008.

3. Aitchison, J. 1986. The Statistical Analysis of Compositional Data. London: Chapman and Hall. 2015.

4. Ronald D. Lee and Lawrence R. Carter. 1992. Modeling and Forecasting U.S. Mortality, Journal of the American Statistical Association, 87:419, 659–671.

5. Wikipedia. Compositional data