

# Package ‘mexhaz’

January 20, 2022

**Type** Package

**Title** Mixed Effect Excess Hazard Models

**Version** 2.2

**Date** 2022-01-20

**Author** Hadrien Charvat, Aurelien Belot

**Maintainer** Hadrien Charvat <chadrien@ncc.go.jp>

**Description** Fit flexible (excess) hazard regression models with the possibility of including non-proportional effects of covariables and of adding a random effect at the cluster level (corresponding to a shared frailty). A detailed description of the package functionalities is provided in Charvat and Belot (2021) <[doi:10.18637/jss.v098.i14](https://doi.org/10.18637/jss.v098.i14)>.

**Depends** survival

**Imports** statmod, MASS, numDeriv, splines, lamW

**Suggests** utils, rstpm2

**License** GPL (>= 2)

**NeedsCompilation** yes

**Repository** CRAN

**Date/Publication** 2022-01-20 14:42:42 UTC

## R topics documented:

mexhaz-package	2
adjsurv	4
fixef	7
fixef.mexhaz	7
lines.predMexhaz	8
lines.resMexhaz	9
mexhaz	11
plot.predMexhaz	17
plot.resMexhaz	18
points.predMexhaz	19
predict.mexhaz	20

print.mexhaz . . . . .	24
print.predMexhaz . . . . .	25
print.summary.mexhaz . . . . .	26
ranef . . . . .	27
ranef.mexhaz . . . . .	27
riskfunc . . . . .	28
simdatn1 . . . . .	31
simdatn2 . . . . .	31
summary.mexhaz . . . . .	32
update.mexhaz . . . . .	32
vcov . . . . .	36
vcov.mexhaz . . . . .	37

**Index****38**

---

mexhaz-package*Mixed effect parametric excess hazard models*

---

**Description**

Fit an (excess) hazard regression model using different shapes for the baseline hazard (Weibull, piecewise constant, exponential of a B-spline of degree 1 to 3, exponential of a restricted cubic spline), with the possibility to include time-dependent effects of variable(s) and a random effect defined at the cluster level. Follow-up time can be entered in the right-censored or counting process input style. The latter allows the modelling of survival data with delayed entries. The time-dependent effect of a covariate is modelled by adding interaction terms between the covariate and a function of time of the same class as the one used for the baseline hazard (in particular, with the same knots for piecewise constant hazards; and with the same degree and the same knots for B-spline or restricted cubic spline functions). The random effect is assumed to be normally distributed with mean 0 and standard deviation sigma. The optimisation process uses adaptive Gaussian quadrature to calculate the cluster-specific marginal likelihoods. The logarithm of the full marginal likelihood, defined as the sum of the logarithms of the cluster-specific marginal likelihoods, is then maximised using an optimisation routine such as `nlm` (default) or `optim`. Functions to compute and plot the predicted (excess) hazard and (net) survival (possibly with marginal or cluster-specific predictions in the case of a random effect model) are provided.

**Details**

Package:	mexhaz
Type:	Package
Version:	2.2
Date:	2022-01-19
License:	GPL (>=2)

## Author(s)

Hadrien Charvat, Aurelien Belot

## References

Charvat H, Remontet L, Bossard N, Roche L, Dejardin O, Rachet B, Launoy G, Belot A; CENSUR Working Survival Group. A multilevel excess hazard model to estimate net survival on hierarchical data allowing for non-linear and non-proportional effects of covariates. *Stat Med* 2016;35(18):3066-3084 (doi: 10.1002/sim.6881)

Charvat H, Belot A. An R package for fitting flexible hazard-based regression models for overall and excess mortality with a random effect. *J Stat Softw* 2021;98(14):1-36 (doi: 10.18637/jss.v098.i14)

## Examples

```
data(simdatn1)

## Fit of a mixed-effect excess hazard model, with the baseline hazard
## described by a Weibull distribution (without covariates)

Mod_weib_mix <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~1, data=simdatn1, base="weibull",
expected="popmrate", verbose=0, random="clust")

## Examples of syntax for various models (not run)

## Fit of a fixed-effect excess hazard model, with the baseline hazard
## described by a Weibull distribution and with effects of age (agecr),
## deprivation index (depindex) and sex (IsexH) using the optim
## procedure and the BFGS method (see help of optim).

# Mod_weib <- mexhaz(formula=Surv(time=timesurv,
# event=vstat)~agecr+depindex+IsexH, data=simdatn1, base="weibull",
# expected="popmrate", verbose=1000, fnoptim="optim",
# method="BFGS")

## Fit of a mixed-effect excess hazard model, with the baseline hazard
## described by a cubic B-spline with two knots at 1 and 5 year and with
## effects of age (agecr), deprivation index (depindex) and sex (IsexH)

# Mod_bs3_2mix <- mexhaz(formula=Surv(time=timesurv,
# event=vstat)~agecr+depindex+IsexH, data=simdatn1, base="exp.bs",
# degree=3, knots=c(1,5), expected="popmrate", random="clust",
# verbose=1000)

## Fit of a fixed-effect overall hazard model, with the baseline hazard
## described by a piecewise constant function with the following vector
## of knots (defining the endpoints of the intervals on which the hazard
```

```

## is constant): (1,3,5,8), and with effects of age (agecr), deprivation
## index (depindex) and sex (IsexH)

# Mod_pw <- mexhaz(formula=Surv(time=timesurv, event=vstat)~
# agecr+depindex+IsexH, data= simdatn1, base="pw.cst", knots=c(1,3,5,8),
# verbose=1000)

## Fit of a fixed-effect excess hazard model, with the baseline hazard
## described by a cubic B-spline with two knots at 1 and 5 year and with
## effects of age (agecr), deprivation index (depindex) and sex (IsexH)

# Mod_bs3_2 <- mexhaz(formula=Surv(time=timesurv,
# event=vstat)~agecr+depindex+IsexH, data=simdatn1, base="exp.bs",
# degree=3, knots=c(1,5), expected="popmrate", verbose=1000)

## Fit of a mixed-effect excess hazard model, with the baseline hazard
## described by a cubic B-spline with two knots at 1 and 5 year and with
## effects of age (agecr), deprivation index (depindex) and sex (IsexH)

# Mod_bs3_2mix <- mexhaz(formula=Surv(time=timesurv,
# event=vstat)~agecr+depindex+IsexH, data=simdatn1, base="exp.bs",
# degree=3, knots=c(1,5), expected="popmrate", random="clust",
# verbose=1000)

## Fit of a mixed-effect excess hazard model, with the baseline hazard
## described by a cubic B-spline with two knots at 1 and 5 year, with
## effects of age (agecr), deprivation index (depindex) and sex (IsexH)
## and with a time-dependent effect for age (agecr) and sex (IsexH).

# Mod_bs3_2mixnph <- mexhaz(formula=Surv(time=timesurv,
# event=vstat)~agecr+depindex+IsexH + nph(agecr+IsexH), data=simdatn1,
# base="exp.bs", degree=3, knots=c(1,5), expected="popmrate",
# random="clust", verbose=1000)

```

adjsurv

*Computation of direct adjusted survival estimates based on a mexhaz model*

## Description

Function for computing direct adjusted survival estimates from a model fitted with the `mexhaz`. It can be used to obtain direct adjusted survival estimates for one or two populations. In the latter case, survival difference estimates are also computed. Corresponding variance estimates are based on the Delta Method (based on the assumption of multivariate normality of the model parameter estimates). When the model includes a random effect, two types of predictions can be made: (i) marginal predictions (obtained by integration over the random effect distribution) or (ii) conditional

predictions either for a particular cluster (using the corresponding shrinkage estimate) or for the value 0 of the random effect.

## Usage

```
adjsurv(object, time.pts, data, data.0 = NULL, weights = NULL,
clust.name = NULL, marginal = TRUE, level = 0.95)
```

## Arguments

object	an object of class <code>mexhaz</code> , corresponding to a hazard-based regression model fitted with the <code>mexhaz</code> function.
time.pts	a vector of numerical values representing the time points at which predictions are requested. Time values greater than the maximum follow-up time on which the model estimation was based are discarded.
data	a <code>data.frame</code> containing the values of the covariates of the population for which direct adjusted estimates are to be calculated.
data.0	an optional <code>data.frame</code> containing the values of the covariates of a second population for which direct adjusted estimates can also be calculated (and compared with those of the first population). The default value is set to <code>NULL</code> .
clust.name	name of the variable in <code>data</code> (and <code>data.0</code> ) containing information on cluster membership to be used to obtain conditional predictions from a mixed effect model. Standard errors of prediction are obtained with the approximation of the conditional mean squared error of prediction (without the second-order bias correction term) described in Booth and Hobert. This argument is not used if the model is a fixed effect model. The default value is <code>NULL</code> : this corresponds to marginal predictions (if <code>marginal</code> is set to <code>TRUE</code> , the preferred option), or to conditional predictions for the value 0 of the random effect (if <code>marginal</code> is set to <code>FALSE</code> ).
weights	optional argument specifying the weights to be associated with each row of <code>data</code> (and <code>data.0</code> ). the default value is set to <code>NULL</code> which corresponds to attributing to each row of the dataset(s) a weight equal to one over the total number of rows.
marginal	logical value controlling the type of predictions returned by the function when the model includes a random intercept. When <code>TRUE</code> , marginal predictions are computed. The marginal survival is obtained by integrating the predicted survival over the distribution of the random effect. When <code>FALSE</code> (default value), conditional predictions depending on the value of the <code>cluster</code> argument are calculated.
level	a number in (0,1) specifying the level of confidence for computing the confidence intervals of the hazard and the survival. By default, <code>level=0.95</code> .

## Value

An object of class `resMexhaz` that can be used by the function `plot.resMexhaz` to produce graphics of the direct adjusted survival curve. It contains the following elements:

results	a data.frame consisting of: the time points at which the direct adjusted survival values have been calculated; the direct adjusted survival values with their confidence limits for population data; the direct adjusted survival values with their confidence limits for population data.0; the direct adjusted survival difference estimates with their confidence limits.
type	type of results returned by the function. The value is used by <code>plot.resMexhaz</code> and <code>lines.resMexhaz</code> , and set to "as" (adjusted survival).
multiobs	value used by <code>plot.resMexhaz</code> and <code>lines.resMexhaz</code> , and set to FALSE (computation of the adjusted survival at several time points for one vector of covariates).
ci.method	method used to compute confidence limits. Currently set to "delta" as only the Delta Method is implemented.
level	level of confidence used to compute confidence limits.

### Author(s)

Hadrien Charvat, Aurelien Belot

### References

Charvat H, Remontet L, Bossard N, Roche L, Dejardin O, Rachet B, Launoy G, Belot A; CENSUR Working Survival Group. A multilevel excess hazard model to estimate net survival on hierarchical data allowing for non-linear and non-proportional effects of covariates. *Stat Med* 2016;35:3066-3084 (doi: 10.1002/sim.6881)

Booth JG, Hobert JP. Standard errors of prediction in generalized linear mixed models. *J Am Stat Assoc* 1998;93:262-272 (doi: 10.2307/2669622).

### See Also

[plot.resMexhaz](#), [lines.resMexhaz](#)

### Examples

```
data(simdatn1)

## Fit of a fixed-effect hazard model, with the baseline hazard
## described by a linear B-spline with two knots at 1 and 5 year and with
## effects of age (agecr), deprivation index (depindex) and sex (IsexH)

Mod_bs1_2 <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~agecr+depindex+IsexH, data=simdatn1, base="exp.bs",
degree=1, knots=c(1,5), verbose=0)

## Direct adjusted survival for the simdatn1 population
DAS_Modbs1_2 <- adjsurv(Mod_bs1_2, time pts=seq(1,10),
data=simdatn1)
```

---

**fixef***Method for extracting fixed effects*

---

## Description

This is a generic function.

## Usage

```
fixef(x, ...)
```

## Arguments

`x` a fitted object from which fixed effects can be extracted.  
`...` may be required by some methods using this generic function.

## Value

see the documentation for the specific class.

## See Also

[ranef](#)

## Examples

```
## See the specific class documentation.
```

---

**fixef.mexhaz***Method for extracting fixed effects from a mexhaz object*

---

## Description

Display a vector containing the fixed effects of a mexhaz model.

## Usage

```
## S3 method for class 'mexhaz'  
fixef(x, ...)
```

## Arguments

`x` an object of class `mexhaz`.  
`...` not used.

**Value**

A vector containing the fixed effect estimates.

**See Also**

[mexhaz](#)

**Examples**

```
data(simdatn1)

## Fit of a mixed-effect excess hazard model, with the baseline hazard
## described by a Weibull distribution (without covariables)

Mod_weib_mix <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~1, data=simdatn1, base="weibull",
expected="popmrate", verbose=0, random="clust")

fixef(Mod_weib_mix)
```

**lines.predMexhaz** *Lines method for a predMexhaz object*

**Description**

Function for adding to an already existing graphical window the predicted (excess) hazard or (net) survival based on a predMexhaz object.

**Usage**

```
## S3 method for class 'predMexhaz'
lines(x, which = c("surv", "hazard"), conf.int =
TRUE, lty.pe = "solid", lty.ci = "dashed", ...)
```

**Arguments**

- x** an object of class predMexhaz, corresponding to (excess) hazard and (net) survival predictions based on a survival model fitted with the mexhaz function. Predictions can be obtained for multiple times for one vector of covariables ("multitime") or for several vectors of covariables at one time point ("multiobs"). The lines() function only applies to the "multitime" type of predictions.
- which** type of curve to be plotted. Selection can be made between "surv" (default value) for the (net) survival curve and "hazard" for the (excess) hazard.
- conf.int** logical values allowing the user to decide whether to plot the confidence limits of the survival (or hazard).
- lty.pe** type of line used for drawing the hazard/survival estimate.

lty.ci type of line used for drawing the confidence limits.

... additional parameters that are directly passed to the `lines` function. These parameters, if not already used internally by the `lines.predMexhaz` function, will apply simultaneously to the point estimate and confidence limit curves.

## See Also

[predict.mexhaz](#), [plot.predMexhaz](#)

## Examples

```
data(simdatn1)

## Fit of a fixed-effect hazard model, with the baseline hazard
## described by a linear B-spline with two knots at 1 and 5 year and with
## effects of age (agecr), deprivation index (depindex) and sex (IsexH)

Mod_bs2_2 <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~agecr+depindex+IsexH, data=simdatn1, base="exp.bs",
degree=2, knots=c(1,5), verbose=0)

## Prediction at several time points for one vector of covariates
Pred_Modbs2_2A <- predict(Mod_bs2_2, time.pts=seq(0,10,by=0.1),
data.val=data.frame(agecr=0,depindex=0.5,IsexH=1))

plot(Pred_Modbs2_2A, which="hazard", col="red")
lines(Pred_Modbs2_2A, which="hazard", conf.int=FALSE)
```

---

`lines.resMexhaz` *Lines method for a `resMexhaz` object*

---

## Description

Function for adding to an already existing graphical window various quantities calculated from a `mexhaz` model.

## Usage

```
## S3 method for class 'resMexhaz'
lines(x, conf.int = TRUE, lty.pe = "solid", lty.ci =
"blank", col.ci = "blue", alpha.col.ci = 0.25, ...)
```

## Arguments

x	an object of class <code>resMexhaz</code> , corresponding to various predictions based on a survival model fitted with the <code>mexhaz</code> function. Predictions can be obtained for multiple times for one vector of covariates ("multitime") or for several vectors of covariates at one time point ("multiobs"). The <code>plot()</code> function only applies to the "multitime" type of predictions.
conf.int	logical value allowing the user to decide whether to plot the confidence limits of the survival (or hazard).
lty.pe	type of line used for drawing the hazard/survival estimate.
lty.ci	type of line used for drawing the confidence limits.
col.ci	color used to fill in the polygon defined by the confidence limits.
alpha.col.ci	parameter used internally by the <code>rgb()</code> function to set the color transparency.
...	additional parameters that are directly passed to the <code>lines</code> function. These parameters will apply simultaneously to the point estimate and confidence limit curves.

## See Also

[adjsurv](#), [riskfunc](#), [plot.resMexhaz](#)

## Examples

```
data(simdatn1)

## Fit of a fixed-effect hazard model, with the baseline hazard
## described by a linear B-spline with two knots at 1 and 5 year and with
## effects of age (agecr), deprivation index (depindex) and sex (IsexH)

Mod_bs2 <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~agecr+depindex+IsexH, data=simdatn1, base="exp.bs",
degree=2, knots=c(1,5), verbose=0)

## Relative risk (ratio of cumulative incidence curves) for men versus
## women for two different values of age

RR_Modbs2a <- riskfunc(Mod_bs2, time.pts=seq(0,10, by=0.1),
data=data.frame(agecr=0.1, IsexH=1, depindex=0),
data.0=data.frame(agecr=0.1, IsexH=0, depindex=0), conf.int="delta",
type="rr")

RR_Modbs2b <- riskfunc(Mod_bs2, time.pts=seq(0,10, by=0.1),
data=data.frame(agecr=-0.1, IsexH=1, depindex=0),
data.0=data.frame(agecr=-0.1, IsexH=0, depindex=0), conf.int="delta",
type="rr")

plot(RR_Modbs2a)
lines(RR_Modbs2a, col.ci="green")
```

---

```
abline(h=1, lty="dashed")
```

---

mexhaz

*mexhaz function*

## Description

Fit an (excess) hazard regression model using different shapes for the baseline hazard (Weibull, piecewise constant, exponential of a B-spline of degree 1 to 3, exponential of a restricted cubic spline), with the possibility to include time-dependent effects of variable(s) and a random effect defined at the cluster level. The function accepts right-censored and counting process input styles for the follow-up time. The latter allows the modelling of survival data with delayed entries. The time-dependent effect of a covariate is modelled by adding interaction terms between the covariate and a function of time of the same class as the one used for the baseline hazard (in particular, with the same knots for piecewise constant hazards; and with the same degree and the same knots for B-spline or restricted cubic spline functions). The random effect is assumed to be normally distributed with mean 0 and standard deviation sigma. The optimisation process uses adaptive Gaussian quadrature to calculate the cluster-specific marginal likelihoods. The logarithm of the full marginal likelihood, defined as the sum of the logarithms of the cluster-specific marginal likelihoods, is then maximised using an optimisation routine such as `nlm` (default) or `optim`.

## Usage

```
mexhaz(formula, data, expected = NULL, base = c("weibull",
"exp.bs", "exp.ns", "pw.cst"), degree = 3, knots = NULL,
bound = NULL, n.gleg = 20, init = NULL, random = NULL,
n.aghq = 10, fnoptim = c("nlm", "optim"), verbose = 0,
method = "Nelder-Mead", iterlim = 10000, numHess = FALSE,
print.level = 1, exactGradHess = TRUE, gradtol =
ifelse(exactGradHess, 1e-8, 1e-6), ...)
```

## Arguments

**formula** a formula object, with the response on the left of the `~` operator, and the linear predictor on the right. The response must be of the form `Surv(time, event)` for right censored data or `Surv(time, time2, event)` for counting process style data. The linear predictor accepts a special instruction `nph()` for specifying variables for which a time-dependent effect should be modelled (if several variables are modelled with time-dependent effects, separate these variables inside the `nph()` instruction with a `+` sign).

In case `time` takes the value 0 for some observations when data are entered in the right censored style, it is assumed that these observations refer to events (or censoring) that occurred on the first day of follow-up. Consequently, a value of 1/730.5 (half a day) is substituted in order to make computations possible. However, it should be stressed that this is just a convention and that it does not make much sense if the time scale is not expressed in years. We therefore advise the analyst to deal with 0 time values during the dataset preparation stage.

data	a <code>data.frame</code> containing the variables referred to in the formula, as well as in the <code>expected</code> and <code>random</code> arguments if these arguments are used.
expected	name of the variable (must be given in quotes) representing the population (i.e., expected) hazard. By default, <code>expected=NULL</code> , which means that the function estimates the overall hazard (and not the excess hazard).
base	functional form that should be used to model the baseline hazard. Selection can be made between the following options: "weibull" for a Weibull hazard, "exp.bs" for a hazard described by the exponential of a B-spline (only B-splines of degree 1, 2 or 3 are accepted), "exp.ns" for a hazard described by the exponential of a restricted cubic spline (also called 'natural spline'), "pw.cst" for a piecewise constant hazard. By default, <code>base="weibull"</code> .  For the Weibull hazard model, the cumulative hazard is given by the following relationship: $H(t,x,z) = \lambda * \exp(x'b) * t^{(\rho * \exp(z'g))}$ where <code>lambda</code> and <code>rho</code> are the parameters of the Weibull baseline hazard, <code>x</code> represent variables with proportional effect (with corresponding regression coefficients <code>'b'</code> ) and <code>z</code> represent variables with time-dependent effects (with corresponding regression coefficients <code>'g'</code> ). The <code>mexhaz()</code> function does not estimate directly <code>lambda</code> and <code>rho</code> but their logarithms (in the output of the function, these are named respectively <code>'logLambda'</code> and <code>'logRho'</code> ).  For the spline-based hazards, it should be noted that the B-spline and restricted cubic spline bases created internally in the <code>mexhaz()</code> function are identical to those obtained by the use of, respectively, the <code>bs()</code> and <code>ns()</code> functions from the <code>splines</code> package.
degree	if <code>base="exp.bs"</code> , <code>degree</code> represents the degree of the B-spline used. Only integer values between 1 and 3 are accepted, and 3 is the default.
knots	if <code>base="exp.bs"</code> or <code>"exp.ns"</code> , <code>knots</code> is the vector of interior knots of the spline. If <code>base="pw.cst"</code> , <code>knots</code> is the vector defining the endpoints of the time intervals on which the hazard is assumed to be constant. By default, <code>knots=NULL</code> (that is, it produces a B-spline with no interior knots if <code>base="exp.bs"</code> , a linear B-spline with no interior knots if <code>base="exp.ns"</code> , or a constant hazard over the whole follow-up period if <code>base="pw.cst"</code> ).
bound	a vector of two numerical values corresponding to the boundary knots of the spline functions. If <code>base="exp.bs"</code> or <code>base="exp.ns"</code> , computation of the B-spline basis requires that boundary knots be given. The <code>bound</code> argument allows the user to specify these boundary knots. If <code>base="exp.bs"</code> , the interval defined by the boundary knots must at least include the interval <code>c(0,max(time))</code> (otherwise, there could be problems with ill-conditioned bases). If <code>base="exp.ns"</code> , the boundary knots correspond to the knots beyond which the spline is constrained to be linear (in that case, the boundary knots can be values contained in <code>c(0,max(time))</code> ). By default, the boundary knots are set to <code>c(0,max(time))</code> .
n.gleg	if <code>base="exp.bs"</code> and <code>degree</code> is equal to 2 or 3, or if <code>base="exp.ns"</code> , the cumulative hazard is computed via Gauss-Legendre quadrature and <code>n.gleg</code> is the number of quadrature nodes to be used to compute the cumulative hazard. By default, <code>n.gleg=20</code> .

init	<p>vector of initial values. By default <code>init=NULL</code> and the initial values are internally set to the following values:</p> <p>for the baseline hazard:</p> <p>if <code>exactGradHess=TRUE</code> (except for the excess hazard random effect model for which this argument is ignored), the intercept is set to <math>0.5 * \log(\text{Number of events}/\text{Person-years of observation})</math> and all other parameters set to 0. In case of failed convergence, several trials are run with an adaptation of the value of the intercept.</p> <p>if <code>exactGradHess=FALSE</code>, the following values are used:</p> <ul style="list-style-type: none"> <li>- if <code>base="weibull"</code>, the logarithm of the scale and shape parameters is set to 0.1;</li> <li>- if <code>base="exp.bs"</code>, the parameters of the B-spline are all set to -1;</li> <li>- if <code>base="exp.ns"</code>, the parameters of the restricted cubic spline are all set to -1;</li> <li>- if <code>base="pw.cst"</code>, the logarithm of the piecewise-constant hazards are set to -1;</li> </ul> <p>the parameters describing the effects of the covariables are all set to 0;</p> <p>the parameter representing the standard deviation of the random effect is set to 0.1 (if <code>exactGradHess=TRUE</code>, several trials are run with an adaptation of the value in case of failed convergence).</p>
random	<p>name of the variable to be entered as a random effect (must be given between quotes), representing the cluster membership. By default, <code>random=NULL</code> which means that the function fits a fixed effects model.</p>
n.aghq	<p>number of quadrature points used for estimating the cluster-specific marginal likelihoods by adaptive Gauss-Hermite quadrature. By default, <code>n.aghq=10</code>.</p>
fnoptim	<p>name of the R optimisation procedure used to maximise the likelihood. Selection can be made between "<code>nlm</code>" (by default) and "<code>optim</code>". Note: if <code>exactGradHess=TRUE</code>, this argument will be ignored (<code>fnoptim</code> will be set automatically to "<code>nlm</code>").</p>
verbose	<p>integer parameter representing the frequency at which the current state of the optimisation process is displayed. Internally, an 'evaluation' is defined as an estimation of the log-likelihood for a given vector of parameters. This means that the number of evaluations is increased each time the optimisation procedure updates the value of any of the parameters to be estimated. If <code>verbose=n</code> (with <code>n</code> an integer), the function will display the current values of the parameters, the log-likelihood and the time elapsed every <code>n</code> evaluations. If <code>verbose=0</code> (default), nothing is displayed.</p>
method	<p>if <code>fnoptim="optim"</code>, <code>method</code> represents the optimisation method to be used by <code>optim</code>. By default, <code>method="Nelder-Mead"</code>. This parameter is not used if <code>fnoptim="nlm"</code>.</p>
iterlim	<p>if <code>fnoptim="nlm"</code>, <code>iterlim</code> represents the maximum number of iterations before the <code>nlm</code> optimisation procedure is terminated. By default, <code>iterlim</code> is set to 10000. This parameter is not used if <code>fnoptim="optim"</code> (in this case, the maximum number of iterations must be given as part of a list of control parameters via the <code>control</code> argument: see the help page of <code>optim</code> for further details).</p>

numHess	logical value allowing the user to choose between the Hessian returned by the optimization algorithm (default) or the Hessian estimated by the <code>hessian</code> function from the <code>numDeriv</code> package. The latter might be more accurate but its estimation is more time-consuming. We suggest to use the default Hessian estimation procedure during model building and estimate the <code>numDeriv</code> -based Hessian only on the final model. Note: if <code>exactGradHess=TRUE</code> , this argument is ignored.
print.level	this argument is only used if <code>fnoptim="nlm"</code> . It determines the level of printing during the optimisation process. The default value (for the <code>mexhaz</code> function) is set to '1' which means that details on the initial and final step of the optimisation procedure are printed (see the help page of <code>nlm</code> for further details).
exactGradHess	logical value allowing the user to decide whether maximisation of the likelihood should be based on the analytic gradient and Hessian computed internally (default, corresponding to <code>exactGradHess=TRUE</code> ). In that case, optimisation is performed with the <code>nlm</code> function. Note: even if set to <code>TRUE</code> , this argument is ignored when the user wants to fit an excess hazard model including a random effect because in that case, there is no simple way to obtain the analytic gradient and Hessian.
gradtol	this argument is only used if <code>fnoptim="nlm"</code> . It corresponds to the tolerance at which the scaled gradient is considered close enough to zero to terminate the algorithm. The default value depends on the value of the argument <code>exactGradHess</code> .
...	represents additional parameters directly passed to <code>nlm</code> or <code>optim</code> to control the optimisation process.

### Value

An object of class `mexhaz` containing the following elements:

dataset	name of the dataset used to fit the model.
call	function call on which the model is based.
formula	formula part of the call.
expected	name of the variable corresponding to the expected hazard (takes the value <code>NA</code> for standard, i.e., 'non-excess' hazard models).
xlevels	information concerning the levels of the categorical variables used in the model (used by <code>predict.mexhaz</code> ).
n.obs.tot	total number of observations in the dataset.
n.obs	number of observations used to fit the model (after exclusion of missing values).
n.events	number of events (after exclusion of missing values).
n.clust	number of clusters.
n.time.0	number of observations for which the observed follow-up time was equal to 0 (only for right censored type data).
base	function used to model the baseline hazard.
max.time	maximal observed time in the dataset.
boundary.knots	vector of boundary values used to define the B-spline (or natural spline) bases.

degree	degree of the B-spline used to model the logarithm of the baseline hazard.
knots	vector of interior knots used to define the B-spline (or natural spline) bases.
names.ph	names of the covariables with a proportional effect.
random	name of the variable defining cluster membership (set to NA in the case of a purely fixed effects model).
init	a vector containing the initial values of the parameters.
coefficients	a vector containing the parameter estimates.
std.errors	a vector containing the standard errors of the parameter estimates.
vcov	the variance-covariance matrix of the estimated parameters.
gradient	the gradient of the log-likelihood function evaluated at the estimated parameters.
hessian	the Hessian of the log-likelihood function evaluated at the estimated parameters.
mu.hat	a <code>data.frame</code> containing the estimated cluster-specific random effects (shrinkage estimators).
var.mu.hat	the covariance matrix of the cluster-specific shrinkage estimators.
vcov.fix.mu.hat	a matrix containing the covariances between the fixed effect and the cluster-specific shrinkage estimators. More specifically, the i-th line of the matrix represents the covariances between the shrinkage estimator of the i-th cluster and the fixed effect estimates. This matrix is used by the function <code>predict.mexhaz</code> to make cluster-specific predictions.
n.par	number of estimated parameters.
n.gleg	number of Gauss-Legendre quadrature points used to calculate the cumulative (excess) hazard (only relevant if a B-spline of degree 2 or 3 or a cubic restricted spline was used to model the logarithm of the baseline hazard).
n.aghq	number of adaptive Gauss-Hermite quadrature points used to calculate the cluster-specific marginal likelihoods (only relevant if a multi-level model is fitted).
fnoptim	name of the R optimisation procedure used to maximise the likelihood.
method	optimisation method used by <code>optim</code> .
code	code (integer) indicating the status of the optimisation process (this code has a different meaning for <code>nlm</code> and for <code>optim</code> : see their respective help page for details).
loglik	value of the log-likelihood at the end of the optimisation procedure.
iter	number of iterations used in the optimisation process.
eval	number of evaluations used in the optimisation process.
time.elapsed	total time required to reach convergence.

## Author(s)

Hadrien Charvat, Aurelien Belot

## References

Charvat H, Remontet L, Bossard N, Roche L, Dejardin O, Rachet B, Launoy G, Belot A; CENSUR Working Survival Group. A multilevel excess hazard model to estimate net survival on hierarchical data allowing for non-linear and non-proportional effects of covariates. *Stat Med* 2016;35(18):3066-3084 (doi: 10.1002/sim.6881)

Charvat H, Belot A. An R package for fitting flexible hazard-based regression models for overall and excess mortality with a random effect. *J Stat Softw* 2021;98(14):1-36 (doi: 10.18637/jss.v098.i14)

## See Also

[fixef.mexhaz](#), [predict.mexhaz](#), [print.mexhaz](#), [ranef.mexhaz](#), [summary.mexhaz](#), [update.mexhaz](#), [vcov.mexhaz](#)

## Examples

```
data(simdatn1)

## Fit of a mixed-effect excess hazard model, with the baseline hazard
## described by a Weibull distribution (without covariates)

Mod_weib_mix <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~1, data=simdatn1, base="weibull",
expected="popmrate", verbose=0, random="clust")

## More complex examples (not run)

## Fit of a mixed-effect excess hazard model, with the baseline hazard
## described by a cubic B-spline with two knots at 1 and 5 year and with
## effects of age (agecr), deprivation index (depindex) and sex (IsexH)

# Mod_bs3_2mix_nph <- mexhaz(formula=Surv(time=timesurv,
# event=vstat)~agecr+depindex+IsexH+nph(agecr), data=simdatn1,
# base="exp.bs", degree=3, knots=c(1,5), expected="popmrate",
# random="clust", verbose=1000)

## Fit of a mixed-effect excess hazard model, with the baseline hazard
## described by a restricted cubic spline with two knots at the
## tertiles of the distribution of follow-up times for individuals who
## presented the event and with effects of age (agecr) and sex (IsexH)

# Mod_ns3_2mix_nph <- mexhaz(formula=Surv(time=timesurv,
# event=vstat)~agecr+nph(agecr), data=simdatn1, base="exp.ns", degree=3,
# knots=quantile(simdatn1[simdatn1$vstat==1,]$timesurv, probs=c(1:2/3)),
# expected="popmrate", random="clust", verbose=1000)
```

---

plot.predMexhaz	<i>Plot method for a predMexhaz object</i>
-----------------	--

---

## Description

Function for plotting the predicted (excess) hazard or (net) survival based on a predMexhaz object.

## Usage

```
## S3 method for class 'predMexhaz'
plot(x, which = c("surv", "hazard"), conf.int =
TRUE, lty.pe = "solid", lty.ci = "dashed", ...)
```

## Arguments

x	an object of class predMexhaz, corresponding to (excess) hazard and (net) survival predictions based on a survival model fitted with the mexhaz function. Predictions can be obtained for multiple times for one vector of covariates ("multitime") or for several vectors of covariates at one time point ("multiobs"). The plot() function only applies to the "multitime" type of predictions.
which	type of curve to be plotted. Selection can be made between "surv" (default value) for the (net) survival curve and "hazard" for the (excess) hazard.
conf.int	logical value allowing the user to decide whether to plot the confidence limits of the survival (or hazard).
lty.pe	type of line used for drawing the hazard/survival estimate.
lty.ci	type of line used for drawing the confidence limits.
...	additional parameters that are directly passed to the plot function. These parameters will apply simultaneously to the point estimate and confidence limit curves.

## See Also

[predict.mexhaz](#), [points.predMexhaz](#), [lines.predMexhaz](#)

## Examples

```
data(simdatn1)

## Fit of a fixed-effect hazard model, with the baseline hazard
## described by a linear B-spline with two knots at 1 and 5 year and with
## effects of age (agecr), deprivation index (depindex) and sex (IsexH)

Mod_bs2_2 <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~agecr+depindex+IsexH, data=simdatn1, base="exp.bs",
degree=2, knots=c(1,5), verbose=0)
```

```
## Prediction at several time points for one vector of covariates
Pred_Modbs2_2A <- predict(Mod_bs2_2, time pts=seq(0,10,by=0.1),
data.val=data.frame(agecr=0,depindex=0.5,IsexH=1))

plot(Pred_Modbs2_2A, which="hazard")
```

---

plot.resMexhaz

*Plot method for a resMexhaz object*

---

## Description

Function for plotting various quantities calculated from a `mexhaz` model.

## Usage

```
## S3 method for class 'resMexhaz'
plot(x, conf.int = TRUE, lty.pe = "solid", lty.ci =
"blank", col.ci = "blue", alpha.col.ci = 0.25, ylim = NULL, ...)
```

## Arguments

<code>x</code>	an object of class <code>resMexhaz</code> , corresponding to various predictions based on a survival model fitted with the <code>mexhaz</code> function. Predictions can be obtained for multiple times for one vector of covariates ("multitime") or for several vectors of covariates at one time point ("multiobs"). The <code>plot()</code> function only applies to the "multitime" type of predictions.
<code>conf.int</code>	logical value allowing the user to decide whether to plot the confidence limits of the survival (or hazard).
<code>lty.pe</code>	type of line used for drawing the hazard/survival estimate.
<code>lty.ci</code>	type of line used for drawing the confidence limits.
<code>col.ci</code>	color used to fill in the polygon defined by the confidence limits.
<code>alpha.col.ci</code>	parameter used internally by the <code>rgb()</code> function to set the color transparency.
<code>ylim</code>	when set to <code>NULL</code> (default value), the range of the y-axis is based on the range of the confidence limits of the quantity to be plotted.
<code>...</code>	additional parameters that are directly passed to the <code>plot</code> function. These parameters will apply simultaneously to the point estimate and confidence limit curves.

## See Also

[adjsurv](#), [riskfunc](#), [lines.resMexhaz](#)

## Examples

```

data(simdatn1)

## Fit of a fixed-effect hazard model, with the baseline hazard
## described by a linear B-spline with two knots at 1 and 5 year and with
## effects of age (agecr), deprivation index (depindex) and sex (IsexH)

Mod_bs2 <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~agecr+depindex+IsexH, data=simdatn1, base="exp.bs",
degree=2, knots=c(1,5), verbose=0)

## Relative risk (ratio of cumulative incidence curves) for men versus
## women

RR_Modbs2 <- riskfunc(Mod_bs2, time.pts=seq(0,10, by=0.1),
data=data.frame(agecr=0.1, IsexH=1, depindex=0),
data.0=data.frame(agecr=0.1, IsexH=0, depindex=0), conf.int="delta",
type="rr")

plot(RR_Modbs2)
abline(h=1, lty="dashed")

```

---

points.predMexhaz *Points method for a predMexhaz object*

---

## Description

Function for adding to an already existing graphical window the predicted (excess) hazard or (net) survival based on a predMexhaz object.

## Usage

```

## S3 method for class 'predMexhaz'
points(x, which = c("surv", "hazard"), conf.int =
TRUE, lty.pe = "solid", lty.ci = "dashed", ...)

```

## Arguments

- x an object of class predMexhaz, corresponding to (excess) hazard and (net) survival predictions based on a survival model fitted with the mexhaz function. Predictions can be obtained for multiple times for one vector of covariates ("multitime") or for several vectors of covariates at one time point ("multiobs"). The points() function only applies to the "multitime" type of predictions.
- which type of curve to be plotted. Selection can be made between "surv" (default value) for the (net) survival curve and "hazard" for the (excess) hazard.

conf.int	logical values allowing the user to decide whether to plot the confidence limits of the survival (or hazard).
lty.pe	type of line used for drawing the hazard/survival estimate (used when 'type="l"').
lty.ci	type of line used for drawing the confidence limits (used when 'type="l"').
...	additional parameters that are directly passed to the points function. These parameters, if not already used internally by the points.predMexhaz function, will apply simultaneously to the point estimate and confidence limit curves.

## See Also

[predict.mexhaz](#), [plot.predMexhaz](#)

## Examples

```
data(simdatn1)

## Fit of a fixed-effect hazard model, with the baseline hazard
## described by a linear B-spline with two knots at 1 and 5 year and with
## effects of age (agecr), deprivation index (depindex) and sex (IsexH)

Mod_bs2_2 <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~agecr+depindex+IsexH, data=simdatn1, base="exp.bs",
degree=2, knots=c(1,5), verbose=0)

## Prediction at several time points for one vector of covariates
Pred_Modbs2_2A <- predict(Mod_bs2_2, time pts=seq(0,10,by=0.1),
data.val=data.frame(agecr=0, depindex=0.5, IsexH=1))

plot(Pred_Modbs2_2A, which="hazard", col="red")
points(Pred_Modbs2_2A, which="hazard", type="l", conf.int=FALSE)
```

---

## Description

Function for predicting the (excess) hazard and the corresponding (net) survival from a model fitted with the `mexhaz` function for a particular vector of covariates. If the survival model was fitted with an expected hazard (excess hazard model), the estimates obtained are excess hazard and net survival estimates. Corresponding variance estimates are based on the Delta Method or Monte Carlo simulation (based on the assumption of multivariate normality of the model parameter estimates). This function allows the computation of the hazard and the survival at one time point for several vectors of covariates or for one vector of covariates at several time points. When the model includes a random effect, two types of predictions can be made: (i) marginal predictions (obtained by integration over the random effect distribution) or (ii) conditional predictions either for a particular cluster (using the corresponding shrinkage estimate) or for the value 0 of the random effect.

## Usage

```
## S3 method for class 'mexhaz'
predict(object, time.pts, data.val = data.frame(.NotUsed = NA),
cluster = NULL, marginal = FALSE, conf.int = c("delta", "simul", "none"),
level = 0.95, delta.type.h = c("log", "plain"), delta.type.s = c("log-log",
"log", "plain"), nb.sim = 10000, keep.sim = FALSE, include.gradient = FALSE, ...)
```

## Arguments

object	an object of class <code>mexhaz</code> , corresponding to a hazard-based regression model fitted with the <code>mexhaz</code> function.
time.pts	a vector of numerical values representing the time points at which predictions are requested. Time values greater than the maximum follow-up time on which the model estimation was based are discarded.
data.val	a <code>data.frame</code> containing the values of the covariates at which predictions should be calculated.
cluster	a vector of size either one or the number of observations in <code>data.val</code> corresponding to the cluster(s) for which conditional predictions should be calculated. In the first case, conditional predictions for all observations are obtained for the same cluster, while in the second case, conditional predictions can be made for a different cluster for each observation in <code>data.val</code> . Standard errors of prediction are obtained with the approximation of the conditional mean squared error of prediction (without the second-order bias correction term) described in Booth and Hobert. This argument is not used if the model is a fixed effect model. The default value is <code>NULL</code> : this corresponds to marginal predictions (if <code>marginal</code> is set to <code>TRUE</code> , the preferred option), or to conditional predictions for the value 0 of the random effect (if <code>marginal</code> is set to <code>FALSE</code> ).
marginal	logical value controlling the type of predictions returned by the function when the model includes a random intercept. When <code>TRUE</code> , marginal predictions are computed. The marginal survival is obtained by integrating the predicted survival over the distribution of the random effect. The marginal hazard rate is obtained as the opposite of the marginal time derivative of the survival divided by the marginal survival. When <code>FALSE</code> (default value), conditional predictions depending on the value of the <code>cluster</code> argument are calculated.
conf.int	method to be used to compute confidence limits. Selection can be made between the following options: <code>"delta"</code> for the Delta Method (default value); <code>"simul"</code> for Monte Carlo simulations (can be time-consuming, especially for models using B-splines for the logarithm of the baseline hazard); <code>"none"</code> indicates absence of confidence limits estimation.
level	a number in (0,1) specifying the level of confidence for computing the confidence intervals of the hazard and the survival. The default value is set to 0.95.
delta.type.h	type of confidence limits for the hazard when using the Delta Method. With the default value ("log"), the confidence limits are based on a Wald-type confidence interval for the logarithm of the hazard, otherwise they are based directly on a Wald-type CI for the hazard.

delta.type.s	type of confidence limits for the survival when using the Delta Method. With the default value ("log-log"), the confidence limits are based on a Wald-type confidence interval for the logarithm of the cumulative hazard; when the argument is set to "log", they are based on a Wald-type CI for the cumulative hazard; otherwise they are based directly on a Wald-type CI for the survival.
include.gradient	logical value allowing the function to return the components of the gradient of the logarithm of the hazard and of the logarithm of the cumulative hazard for each prediction. This argument is used only if conf.int is set to "delta". The default value is FALSE.
nb.sim	integer value representing the number of simulations used to estimate the confidence limits for the (excess) hazard and the (net) survival. This argument is used only if conf.int is set to "simul".
keep.sim	logical value determining if the simulated hazard and survival values should be returned (only used when conf.int is set to "simul"). These simulated values can be used by the riskfunc function to compute simulation-based confidence intervals for hazard ratios / risk ratios. The default value is set to FALSE.
...	for potential additional parameters.

### Value

An object of class predMexhaz that can be used by the function plot.predMexhaz to produce graphics of the (excess) hazard and the (net) survival. It contains the following elements:

call	the mexhaz function call on which the model is based.
results	a data.frame consisting of: the time points at which the (excess) hazard and the (net) survival have been calculated; the values of the covariates used to estimate the (excess) hazard and the (net) survival; the (excess) hazard values with their confidence limits; and the (net) survival values with their confidence limits.
variances	a data.frame consisting of two columns: the variance of the logarithm of the (excess) hazard and the variance of the (excess) cumulative hazard for each time points or each vector of covariates. The object variances is produced only when conf.int is set to "delta".
grad.loghaz	a data.frame consisting of the components of the gradient of the logarithm of the (excess) hazard for each time points or each vector of covariates. The number of columns corresponds to the number of model parameters. This object is produced only when conf.int is set to "delta" and include.gradient to TRUE.
grad.logcum	a data.frame consisting of the components of the gradient of the logarithm of the (excess) cumulative hazard for each time points or each vector of covariates. The number of columns corresponds to the number of model parameters. This object is produced only when conf.int is set to "delta" and include.gradient to TRUE.
vcov	a matrix corresponding to the covariance matrix used to compute the confidence intervals.

type	this item can take the value <code>multitime</code> (computation of the hazard and the survival at several time points for one vector of covariates) or <code>multiobs</code> (computation of the hazard and the survival at one time point for several vectors of covariates). It is used by <code>plot.predMexhaz</code> and <code>points.predMexhaz</code> .
type.me	the type of predictions produced in case of a model including a random intercept. Can take the values <code>conditional</code> or <code>marginal</code> .
ci.method	the method used to compute confidence limits.
level	level of confidence used to compute confidence limits.
delta.type	type of confidence limits for the hazard and the survival when using the Delta Method.
nb.sim	number of simulations used to estimate the confidence limits when <code>ci.method</code> is set to "simul".
sim.haz	matrix containing the simulated hazards (each column representing a simulated vector of values); only returned when <code>keep.sim</code> is set to TRUE.
sim.surv	matrix containing the simulated survival probabilities (each column representing a simulated vector of values); only returned when <code>keep.sim</code> is set to TRUE.

### Author(s)

Hadrien Charvat, Aurelien Belot

### References

Charvat H, Remontet L, Bossard N, Roche L, Dejardin O, Rachet B, Launoy G, Belot A; CENSUR Working Survival Group. A multilevel excess hazard model to estimate net survival on hierarchical data allowing for non-linear and non-proportional effects of covariates. *Stat Med* 2016;35:3066-3084 (doi: 10.1002/sim.6881)

Booth JG, Hobert JP. Standard errors of prediction in generalized linear mixed models. *J Am Stat Assoc* 1998;93:262-272 (doi: 10.2307/2669622).

### See Also

[print.predMexhaz](#), [plot.predMexhaz](#), [points.predMexhaz](#), [lines.predMexhaz](#)

### Examples

```
data(simdatn1)

## Fit of a fixed-effect hazard model, with the baseline hazard
## described by a linear B-spline with two knots at 1 and 5 year and
## with effects of age (agecr), deprivation index (depindex) and sex
## (IsexH)

Mod_bs1_2 <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~agecr+depindex+IsexH, data=simdatn1, base="exp.bs",
degree=1, knots=c(1,5), verbose=0)
```

```

## Prediction at several time points for one vector of covariates
Pred_Modbs1_2A <- predict(Mod_bs1_2, time.pts=seq(0.1,10,by=0.1),
data.val=data.frame(agecr=0,depindex=0.5,IsexH=1))

## Prediction for several vectors of covariates at one time point
Pred_Modbs1_2B <- predict(Mod_bs1_2, time.pts=10,
data.val=data.frame(agecr=c(-0.2,-0.1,0), depindex=c(0.5,0.5,0.5),
IsexH=c(1,1,1)))

## Prediction for all individuals of the study population
## at one time point

Pred_Modbs1_2C <- predict(Mod_bs1_2, time.pts=10,
data.val=simdatn1)

# Example of cluster-specific prediction (not run)

## Fit of a mixed-effect excess hazard model, with the baseline hazard
## described by a cubic B-spline with two knots at 1 and 5 year

# Mod_bs3_2mix <- mexhaz(formula=Surv(time=timesurv,
# event=vstat)~agecr+IsexH, data=simdatn1, base="exp.bs", degree=3,
# knots=c(1,5), expected="popmrate", random="clust", verbose=1000)

## Prediction at several time points for an individual in cluster 15
## with a specific vector of covariates
# Pred_Modbs3_2A <- predict(Mod_bs3_2mix,
# time.pts=seq(0.1,10,by=0.1), data.val=data.frame(agecr=0.2, IsexH=1),
# cluster=15)

```

---

print.mexhaz

*Print method for a mexhaz object*

---

## Description

Display the model call as well as the values of the estimated model parameters.

## Usage

```

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

```

## Arguments

x	an object of class <code>mexhaz</code> .
...	represents additional parameters directly passed to <code>print</code> .

**See Also**[mexhaz](#), [summary.mexhaz](#)**Examples**

```
data(simdatn1)

## Fit of a mixed-effect excess hazard model, with the baseline hazard
## described by a Weibull distribution (without covariates)

Mod_weib_mix <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~1, data=simdatn1, base="weibull",
expected="popmrate", verbose=0, random="clust")

print(Mod_weib_mix)
```

**print.predMexhaz***Print method for a predMexhaz object***Description**

Display the first lines of the `data.frame` containing the predictions provided by the `predMexhaz` function.

**Usage**

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

**Arguments**

<code>x</code>	an object of class <code>predMexhaz</code> .
<code>...</code>	represents additional parameters directly passed to <code>print</code> .

**See Also**[predict.mexhaz](#)**Examples**

```
data(simdatn1)

## Fit of a fixed-effect hazard model, with the baseline hazard
## described by a linear B-spline with two knots at 1 and 5 year and with
## effects of age (agecr), deprivation index (depindex) and sex (IsexH)
```

```

Mod_bs1_2 <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~agecr+depindex+IsexH, data=simdatn1, base="exp.bs",
degree=1, knots=c(1,5), verbose=0)

## Prediction at several time points for one vector of covariates
Pred_Modbs1_2A <- predict(Mod_bs1_2, time.pnts=seq(0.1,10,by=0.1),
data.val=data.frame(agecr=0,depindex=0.5,IsexH=1), conf.int="delta")

print(Pred_Modbs1_2A)

```

---

**print.summary.mexhaz** *Printing method for a summary.mexhaz object*

---

## Description

Display the model call, the values of the estimated model parameters, as well as the corresponding hazard ratios (only for proportional effects).

## Usage

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

## Arguments

<code>x</code>	an object of class <code>summary.mexhaz</code> .
<code>...</code>	represents additional parameters directly passed to <code>print</code> .

## See Also

[mexhaz](#), [print.mexhaz](#), [summary.mexhaz](#)

## Examples

```

data(simdatn1)

## Fit of a mixed-effect excess hazard model, with the baseline hazard
## described by a Weibull distribution (without covariates)

Mod_weib <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~1, data=simdatn1, base="weibull", verbose=0)

summary(Mod_weib)

```

---

**ranef***Method for extracting random effects*

---

**Description**

This is a generic function.

**Usage**

```
ranef(x, ...)
```

**Arguments**

`x` a fitted object from which random effects can be extracted.  
`...` might be used by some methods using this generic function.

**Value**

see the documentation for the specific class.

**See Also**

[fixef](#)

**Examples**

```
## See the specific class documentation.
```

---

**ranef.mexhaz***Method for extracting random effects from a mexhaz object*

---

**Description**

Display a data frame containing the cluster-specific random effects with their standard errors.

**Usage**

```
## S3 method for class 'mexhaz'  
ranef(x, ...)
```

**Arguments**

`x` an object of class `mexhaz`.  
`...` not used.

**Value**

A data frame with three columns containing the cluster names, the random effect estimates, and their standard errors.

**See Also**

[mexhaz](#)

**Examples**

```
data(simdatn1)

## Fit of a mixed-effect excess hazard model, with the baseline hazard
## described by a Weibull distribution (without covariables)

Mod_weib_mix <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~1, data=simdatn1, base="weibull",
expected="popmrate", verbose=0, random="clust")

ranef(Mod_weib_mix)
```

---

riskfunc

*Computation of hazard ratio and risk ratio estimates based on a mexhaz model*

---

**Description**

Function for computing hazard ratio and risk ratio (ratio of cumulative probabilities of failure) estimates from a model fitted with the `mexhaz` function. Corresponding confidence intervals are based on the Delta Method or Monte Carlo simulation (based on the assumption of multivariate normality of the model parameter estimates). This function allows the computation of estimates at one time point for several vectors of covariates or for one vector of covariates at several time points. When the model includes a random effect, two types of predictions can be made: (i) marginal predictions (obtained by integration over the random effect distribution) or (ii) conditional predictions either for a particular cluster (using the corresponding shrinkage estimate) or for the value 0 of the random effect.

**Usage**

```
riskfunc(object, time.pts, data, data.0, clust.name = NULL,
marginal = TRUE, type = c("hr", "rr"), conf.int = c("delta",
"simul"), level = 0.95, nb.sim = 10000, seed = NULL)
```

## Arguments

object	an object of class <code>mexhaz</code> , corresponding to a hazard-based regression model fitted with the <code>mexhaz</code> function.
time.pts	a vector of numerical values representing the time points at which predictions are requested. Time values greater than the maximum follow-up time on which the model estimation was based are discarded.
data	a <code>data.frame</code> containing the values of the covariates of the population for which hazard ratios or risk ratios are to be calculated.
data.0	a <code>data.frame</code> containing the values of the covariates of the reference population. Each row of <code>data.0</code> is used as the reference for the corresponding row of <code>data</code> .
clust.name	name of the variable in <code>data</code> (and <code>data.0</code> ) containing information on cluster membership to be used to obtain conditional predictions from a mixed effect model. Standard errors of prediction are obtained with the approximation of the conditional mean squared error of prediction (without the second-order bias correction term) described in Booth and Hobert. This argument is not used if the model is a fixed effect model. The default value is <code>NULL</code> : this corresponds to marginal predictions (if <code>marginal</code> is set to <code>TRUE</code> , the preferred option), or to conditional predictions for the value 0 of the random effect (if <code>marginal</code> is set to <code>FALSE</code> ).
marginal	logical value controlling the type of predictions returned by the function when the model includes a random intercept. When <code>TRUE</code> , marginal predictions are computed. The marginal survival is obtained by integrating the predicted survival over the distribution of the random effect. When <code>FALSE</code> (default value), conditional predictions depending on the value of the <code>cluster</code> argument are calculated.
type	argument specifying the type of predictions to be calculated. Selection can be made between " <code>hr</code> " (hazard ratio) and " <code>rr</code> " (risk ratio, i.e., ratio of cumulative failure probabilities).
conf.int	method to be used to compute confidence limits. Selection can be made between the following options: " <code>delta</code> " for the Delta Method (default value); " <code>simul</code> " for Monte Carlo simulations (can be time-consuming, especially for models using B-splines for the logarithm of the baseline hazard).
level	a number in (0,1) specifying the level of confidence for computing the confidence intervals of the hazard and the survival. By default, this argument is set to 0.95.
nb.sim	integer value representing the number of simulations used to estimate the confidence limits for the (excess) hazard and the (net) survival. This argument is used only if <code>conf.int</code> is set to " <code>simul</code> ".
seed	argument allowing the user to set a random seed for simulations (only relevant when <code>conf.int</code> is set to " <code>simul</code> "). The default value is set to <code>NULL</code> in which case a random seed is automatically generated inside the function.

### Value

An object of class `resMexhaz` that can be used by the function `plot.resMexhaz` to produce graphics of the hazard ratio or risk ratio curve. It contains the following elements:

<code>results</code>	a <code>data.frame</code> consisting of: the time points at which values have been calculated; the hazard ratio / risk ratio values with their confidence limits.
<code>type</code>	type of results returned by the function. The value is used by <code>plot.resMexhaz</code> and <code>lines.resMexhaz</code> , and can take the values "hr" (hazard ratio) or "rr" (risk ratio).
<code>multiobs</code>	value used by <code>plot.resMexhaz</code> and <code>lines.resMexhaz</code> , and set to FALSE when estimates are computed at several time points for one vector of covariates.
<code>ci.method</code>	method used to compute confidence limits.
<code>level</code>	level of confidence used to compute confidence limits.

### Author(s)

Hadrien Charvat, Aurelien Belot

### References

Charvat H, Remontet L, Bossard N, Roche L, Dejardin O, Rachet B, Launoy G, Belot A; CENSUR Working Survival Group. A multilevel excess hazard model to estimate net survival on hierarchical data allowing for non-linear and non-proportional effects of covariates. *Stat Med* 2016;35:3066-3084 (doi: 10.1002/sim.6881)

Booth JG, Hobert JP. Standard errors of prediction in generalized linear mixed models. *J Am Stat Assoc* 1998;93:262-272 (doi: 10.2307/2669622).

### See Also

[plot.resMexhaz](#), [lines.resMexhaz](#)

### Examples

```
data(simdatn1)

## Fit of a fixed-effect hazard model, with the baseline hazard
## described by a linear B-spline with two knots at 1 and 5 year and with
## effects of age (agecr), deprivation index (depindex) and sex (IsexH)

Mod_bs1_2 <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~agecr+depindex+IsexH, data=simdatn1, base="exp.bs",
degree=1, knots=c(1,5), verbose=0)

## Risk ratio along time for agecr=0.2 compared to agecr=0.1

RR_Modbs1_2 <- riskfunc(Mod_bs1_2, time.pnts=seq(0,10,le=101),
data=data.frame(agecr=0.2,depindex=0,IsexH=1),
data.0=data.frame(agecr=0.1,depindex=0,IsexH=1),type="rr",
```

```
conf.int="delta")
plot(RR_Modbs1_2)
```

---

simdatn1

*Simulated dataset*

---

### Description

The simdatn1 dataset has 4000 rows and 8 columns.

### Format

This dataset contains the following columns:

**age** Age at diagnosis (continuous).  
**agecr** Centred and rescaled age variable (age-70)/100.  
**depindex** Deprivation index (continuous).  
**IsexH** Sex (0 = Female, 1 = Male).  
**clust** ID number of the cluster.  
**vstat** Vital status (0 = Alive, 1 = Dead).  
**timesurv** Follow-up time (years).  
**popmrate** Population (expected) mortality rate at the time of censoring.

---

simdatn2

*Simulated dataset*

---

### Description

The simdatn2 dataset has 4000 rows and 8 columns. The IsexH variable is simulated with a non-proportional effect.

### Format

This dataset contains the following columns:

**age** Age at diagnosis (continuous).  
**agecr** Centred and rescaled age variable (age-70)/100.  
**depindex** Deprivation index (continuous).  
**IsexH** Sex (0 = Female, 1 = Male).  
**clust** ID number of the cluster.  
**vstat** Vital status (0 = Alive, 1 = Dead).  
**timesurv** Follow-up time (years).  
**popmrate** Population (expected) mortality rate at the time of censoring.

---

summary.mexhaz	<i>Summary method for a mexhaz object</i>
----------------	---

---

## Description

Produces a summary of a mexhaz object.

## Usage

```
## S3 method for class 'mexhaz'
summary(object, ...)
```

## Arguments

object	an object of class mexhaz.
...	represents additional parameters directly passed to summary.

## See Also

[mexhaz](#), [print.mexhaz](#), [print.summary.mexhaz](#)

## Examples

```
data(simdatn1)

## Fit of a mixed-effect excess hazard model, with the baseline hazard
## described by a Weibull distribution (without covariates)

Mod_weib <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~1, data=simdatn1, base="weibull", verbose=0)

summary(Mod_weib)
```

---

update.mexhaz	<i>Update of a mexhaz model</i>
---------------	---------------------------------

---

## Description

Function allowing the user to update an existing mexhaz model. All the arguments of the model can be updated. If the argument 'init' is not provided, the function uses the estimated values of the existing model as starting values for the corresponding parameters of the new model.

## Usage

```
## S3 method for class 'mexhaz'
update(object, formula, data, expected = NULL, base = NULL,
degree = 3, knots = NULL, bound = NULL, n.gleg = 20, init = NULL,
random = NULL, n.aghq = 10, fnoptim = c("nlm", "optim"),
verbose = 0, method = "Nelder-Mead", iterlim = 10000, numHess = FALSE,
print.level = 1, exactGradHess = TRUE, gradtol =
ifelse(exactGradHess, 1e-8, 1e-6), envir = parent.frame(), ...)
```

## Arguments

object	an object of class <code>mexhaz</code> , corresponding to a survival model fitted with the <code>mexhaz</code> function.
formula	a formula object, with the response on the left of the <code>~</code> operator, and the linear predictor on the right. The response must be of the form <code>Surv(time, event)</code> for right censored data or <code>Surv(time, time2, event)</code> for counting process style data. The linear predictor accepts a special instruction <code>nph()</code> for specifying variables for which a time-dependent effect should be modelled (if several variables are modelled with time-dependent effects, separate these variables inside the <code>nph()</code> instruction with a <code>+</code> sign).  In case <code>time</code> takes the value 0 for some observations when data are entered in the right censored style, it is assumed that these observations refer to events (or censoring) that occurred on the first day of follow-up. Consequently, a value of 1/730.5 (half a day) is substituted in order to make computations possible. However, it should be stressed that this is just a convention and that it does not make much sense if the time scale is not expressed in years. We therefore advise the analyst to deal with 0 time values during the dataset preparation stage. See <a href="#">update.formula</a> for more details.
data	a <code>data.frame</code> containing the variables referred to in the <code>formula</code> , as well as in the <code>expected</code> and <code>random</code> arguments if these arguments are used.
expected	name of the variable (must be given in quotes) representing the population (i.e., expected) hazard. By default, <code>expected=NULL</code> , which means that the function estimates the overall hazard (and not the excess hazard).
base	functional form that should be used to model the baseline hazard. Selection can be made between the following options: "weibull" for a Weibull hazard, "exp.bs" for a hazard described by the exponential of a B-spline (only B-splines of degree 1, 2 or 3 are accepted), "exp.ns" for a hazard described by the exponential of a restricted cubic B-spline (also called 'natural spline'), "pw.cst" for a piecewise constant hazard. By default, <code>base=NULL</code> .
degree	if <code>base="exp.bs"</code> , <code>degree</code> represents the degree of the B-spline used. Only integer values between 1 and 3 are accepted, and 3 is the default.
knots	if <code>base="exp.bs"</code> or "exp.ns", <code>knots</code> is the vector of interior knots of the spline. If <code>base="pw.cst"</code> , <code>knots</code> is the vector defining the endpoints of the time intervals on which the hazard is assumed to be constant. By default, <code>knots=NULL</code> (that is, it produces a B-spline with no interior knots if <code>base="exp.bs"</code> , a linear B-spline with no interior knots if <code>base="exp.ns"</code> , or a constant hazard over the whole follow-up period if <code>base="pw.cst"</code> ).

bound	If <code>base="exp.bs"</code> or <code>base="exp.ns"</code> , computation of the B-spline basis requires that boundary knots be given. The <code>bound</code> argument allows the user to specify these boundary knots. If <code>base="exp.bs"</code> , the interval defined by the boundary knots must at least include the interval <code>c(0,max(time))</code> (otherwise, there could be problems with ill-conditioned bases). If <code>base="exp.ns"</code> , the boundary knots correspond to the knots beyond which the spline is constrained to be linear (in that case, the boundary knots can be values contained in <code>c(0,max(time))</code> ). By default, the boundary knots are set to <code>c(0,max(time))</code> .
<code>n.gleg</code>	if <code>base="exp.bs"</code> and <code>degree</code> is equal to 2 or 3, or if <code>base="exp.ns"</code> , the cumulative hazard is computed via Gauss-Legendre quadrature and <code>n.gleg</code> is the number of quadrature nodes to be used to compute the cumulative hazard. By default, <code>n.gleg=20</code> .
<code>init</code>	<p>vector of initial values. By default <code>init=NULL</code> and the initial values are internally set to the following values:</p> <p>for the baseline hazard:</p> <p>if <code>exactGradHess=TRUE</code> (except for the excess hazard random effect model for which this argument is ignored), the intercept is set to <code>0.5*log(Number of events/Person-years of observation)</code> and all other parameters set to 0. In case of failed convergence, several trials are run with an adaptation of the value of the intercept.</p> <p>if <code>exactGradHess=FALSE</code>, the following values are used:</p> <ul style="list-style-type: none"> <li>- if <code>base="weibull"</code>, the scale and shape parameters are set to 0.1;</li> <li>- if <code>base="exp.bs"</code>, the parameters of the B-spline are all set to -1;</li> <li>- if <code>base="exp.ns"</code>, the parameters of the restricted cubic B-spline are all set to -1;</li> <li>- if <code>base="pw.cst"</code>, the logarithm of the piecewise-constant hazards are set to -1;</li> </ul> <p>the parameters describing the effects of the covariates are all set to 0;</p> <p>the parameter representing the standard deviation of the random effect is set to 0.1. (if <code>exactGradHess=TRUE</code>, several trials are run with an adaptation of the value in case of failed convergence).</p>
<code>random</code>	name of the variable to be entered as a random effect (must be given between quotes), representing the cluster membership. By default, <code>random=NULL</code> which means that the function fits a fixed effects model.
<code>n.aghq</code>	number of quadrature points used for estimating the cluster-specific marginal likelihoods by adaptive Gauss-Hermite quadrature. By default, <code>n.aghq=10</code> .
<code>fnoptim</code>	name of the R optimisation procedure used to maximise the likelihood. Selection can be made between " <code>nlm</code> " (by default) and " <code>optim</code> ". Note: if <code>exactGradHess=TRUE</code> , this argument will be ignored ( <code>fnoptim</code> will be set automatically to " <code>nlm</code> ").
<code>verbose</code>	integer parameter representing the frequency at which the current state of the optimisation process is displayed. Internally, an 'evaluation' is defined as an estimation of the log-likelihood for a given vector of parameters. This means that the number of evaluations is increased each time the optimisation procedure updates the value of any of the parameters to be estimated. If <code>verbose=n</code> (with <code>n</code> an integer), the function will display the current values of the parameters, the

	log-likelihood and the time elapsed every <code>n</code> evaluations. If <code>verbose=0</code> , nothing is displayed.
<code>method</code>	if <code>fnoptim="optim"</code> , <code>method</code> represents the optimisation method to be used by <code>optim</code> . By default, <code>method="Nelder-Mead"</code> . This parameter is not used if <code>fnoptim="nlm"</code> .
<code>iterlim</code>	if <code>fnoptim="nlm"</code> , <code>iterlim</code> represents the maximum number of iterations before the <code>nlm</code> optimisation procedure is terminated. By default, <code>iterlim</code> is set to 10000. This parameter is not used if <code>fnoptim="optim"</code> (in this case, the maximum number of iterations must be given as part of a list of control parameters via the <code>control</code> argument: see the help page of <code>optim</code> for further details).
<code>numHess</code>	logical value allowing the user to choose between the Hessian returned by the optimization algorithm (default) or the Hessian estimated by the <code>hessian</code> function from the <code>numDeriv</code> package. The latter might be more accurate but its estimation is more time-consuming. We suggest to use the default Hessian estimation procedure during model building and estimate the <code>numDeriv</code> -based Hessian only on the final model. Note: if <code>exactGradHess=TRUE</code> , this argument is ignored.
<code>print.level</code>	this argument is only used if <code>fnoptim="nlm"</code> . It determines the level of printing during the optimisation process. The default value (for the <code>mexhaz</code> function) is set to '1' which means that details on the initial and final step of the optimisation procedure are printed (see the help page of <code>nlm</code> for further details).
<code>exactGradHess</code>	logical value allowing the user to decide whether maximisation of the likelihood should be based on the analytic gradient and Hessian computed internally (default, corresponding to <code>exactGradHess=TRUE</code> ). In that case, optimisation is performed with the <code>nlm</code> function. Note: even if set to <code>TRUE</code> , this argument is ignored when the user wants to fit an excess hazard model including a random effect because in that case, there is no simple way to obtain the analytic gradient and Hessian.
<code>gradtol</code>	this argument is only used if <code>fnoptim="nlm"</code> . It corresponds to the tolerance at which the scaled gradient is considered close enough to zero to terminate the algorithm. The default value depends on the value of the argument <code>exactGradHess</code> .
<code>envir</code>	environment in which the objects' names given as arguments to the updated model are to be found.
<code>...</code>	represents additional parameters directly passed to <code>nlm</code> or <code>optim</code> to control the optimisation process.

## Value

An object of class `mexhaz`. See [mexhaz](#) for more details.

## Author(s)

Hadrien Charvat, Aurelien Belot

## References

Charvat H, Remontet L, Bossard N, Roche L, Dejardin O, Rachet B, Launoy G, Belot A; CENSUR Working Survival Group. A multilevel excess hazard model to estimate net survival on hierarchical data allowing for non-linear and non-proportional effects of covariates. *Stat Med* 2016;35:3066-3084 (doi: 10.1002/sim.6881)

## See Also

[mexhaz](#)

## Examples

```
data(simdatn1)

## Fit of a mixed-effect excess hazard model, with the baseline hazard
## described by a Weibull distribution (without covariables)

Mod_weib <- mexhaz(formula=Surv(time=timesurv,
event=vstat)~1, data=simdatn1, base="weibull", verbose=0)

## Add an effect of gender
Mod_weib_2 <- update(Mod_weib, formula=~.+IsexH)
```

vcov

*Method for extracting the covariance matrix*

## Description

This is a generic function.

## Usage

`vcov(object, ...)`

## Arguments

<code>object</code>	a fitted object from which the covariance matrix can be extracted.
<code>...</code>	may be required by some methods using this generic function.

## Value

see the documentation for the specific class.

## Examples

```
## See the specific class documentation.
```

---

**vcov.mexhaz***Method for extracting the covariance matrix of the fixed effects*

---

## Description

Display a the covariance matrix of the fixed effects of a mexhaz model.

## Usage

```
## S3 method for class 'mexhaz'  
vcov(object, ...)
```

## Arguments

object	an object of class <code>mexhaz</code> .
...	not used.

## Value

The estimated covariance matrix of the fixed effects.

## See Also

[mexhaz](#)

## Examples

```
data(simdatn1)  
  
## Fit of a mixed-effect excess hazard model, with the baseline hazard  
## described by a Weibull distribution (without covariables)  
  
Mod_weib_mix <- mexhaz(formula=Surv(time=timesurv,  
event=vstat)~1, data=simdatn1, base="weibull",  
expected="popmrate", verbose=0, random="clust")  
  
vcov(Mod_weib_mix)
```

# Index

## \* package

`mexhaz`, 2

`adjsurv`, 4, 10, 18

`fixef`, 7, 27

`fixef.mexhaz`, 7, 16

`lines.predMexhaz`, 8, 17, 23

`lines.resMexhaz`, 6, 9, 18, 30

`mexhaz`, 8, 11, 25, 26, 28, 32, 35–37

`mexhaz`-package, 2

`plot.predMexhaz`, 9, 17, 20, 23

`plot.resMexhaz`, 6, 10, 18, 30

`points.predMexhaz`, 17, 19, 23

`predict.mexhaz`, 9, 16, 17, 20, 20, 25

`print.mexhaz`, 16, 24, 26, 32

`print.predMexhaz`, 23, 25

`print.summary.mexhaz`, 26, 32

`ranef`, 7, 27

`ranef.mexhaz`, 16, 27

`riskfunc`, 10, 18, 28

`simdatn1`, 31

`simdatn2`, 31

`summary.mexhaz`, 16, 25, 26, 32

`update.formula`, 33

`update.mexhaz`, 16, 32

`vcov`, 36

`vcov.mexhaz`, 16, 37