Regularized Cox Regression

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Introduction

This vignette describes how one can use the `glmnet` package to fit regularized Cox models.

The Cox proportional hazards model is commonly used for the study of the relationship beteween predictor variables and survival time. In the usual survival analysis framework, we have data of the form $(y_1, x_1, \delta_1), \ldots, (y_n, x_n, \delta_n)$ where y_i, the observed time, is a time of failure if δ_i is 1 or a right-censored time if δ_i is 0. We also let $t_1 < t_2 < \ldots < t_m$ be the increasing list of unique failure times, and let $j(i)$ denote the index of the observation failing at time t_i.

The Cox model assumes a semi-parametric form for the hazard

$$h_i(t) = h_0(t)e^{x_i^T\beta},$$

where $h_i(t)$ is the hazard for patient i at time t, $h_0(t)$ is a shared baseline hazard, and β is a fixed, length p vector. In the classic setting $n \geq p$, inference is made via the partial likelihood

$$L(\beta) = \prod_{i=1}^{m} \frac{e^{x_{j(i)}^T\beta}}{\sum_{j \in R_i} e^{x_j^T\beta}},$$

where R_i is the set of indices j with $y_j \geq t_i$ (those at risk at time t_i).

Note there is no intercept in the Cox model as it is built into the baseline hazard, and like it, would cancel in the partial likelihood.

In `glmnet`, we penalize the negative log of the partial likelihood with an elastic net penalty.

(Credits: The original `"coxnet"` algorithm for right-censored data was developed by Noah Simon, Jerome Friedman, Trevor Hastie and Rob Tibshirani: see Simon et al. (2011) for details. The other features for Cox models, introduced in v4.1, were developed by Kenneth Tay, Trevor Hastie, Balasubramanian Narasimhan and Rob Tibshirani.)

Basic usage for right-censored data

We use a pre-generated set of sample data and response. `x` must be an $n \times p$ matrix of covariate values — each row corresponds to a patient and each column a covariate. `y` is an $n \times 2$ matrix, with a column `"time"` of failure/censoring times, and `"status"` a 0/1 indicator, with 1 meaning the time is a failure time, and 0 a censoring time. The `Surv` function in the `survival` package creates such a response matrix, and it is recommended that the user uses the output of a call to `Surv` for the response to `glmnet`. (For backward compatibility, `glmnet` can accept a two-column matrix with column names `"time"` and `"status"` for right-censored data.)

```
library(glmnet)
```

```
## Loading required package: Matrix
```

```
## Loaded glmnet 5.2
```

```
library(survival)
data(CoxExample)
x <- CoxExample$x
y <- CoxExample$y
y[1:5, ]
```

```
##            time status
## [1,] 1.76877757      1
## [2,] 0.54528404      1
## [3,] 0.04485918      0
## [4,] 0.85032298      0
## [5,] 0.61488426      1
```

We apply the `glmnet` function to compute the solution path under default settings:

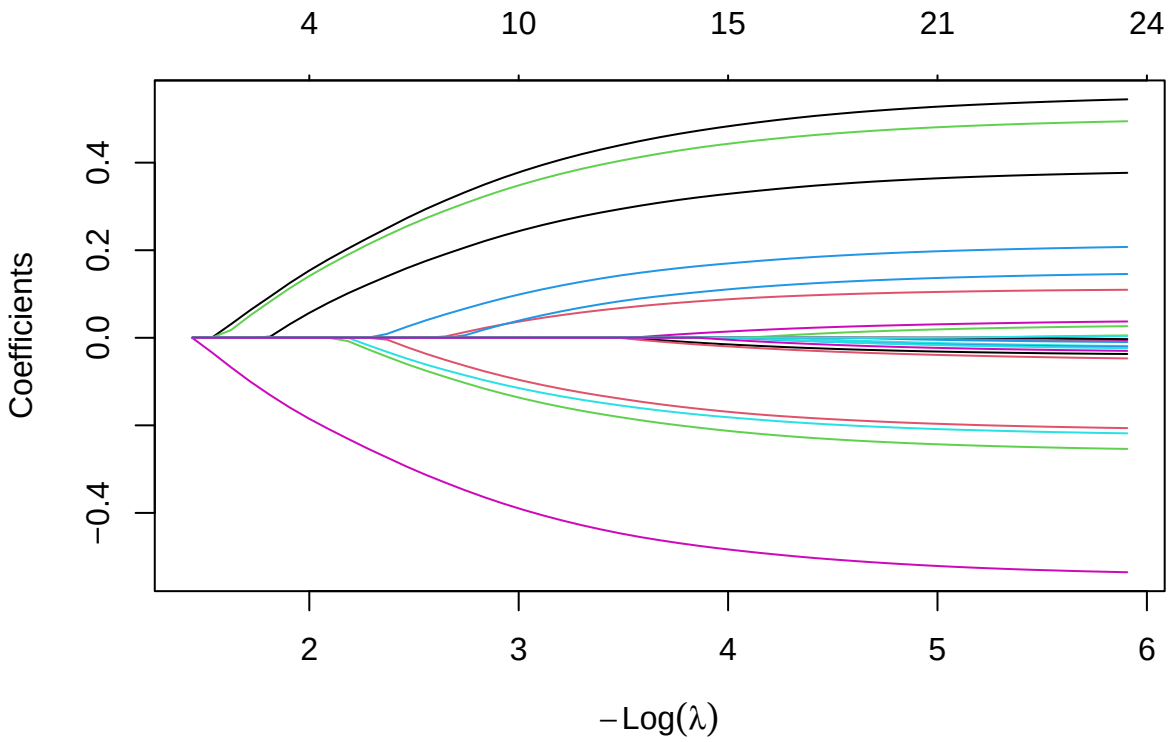
```
fit <- glmnet(x, y, family = "cox")
```

```
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
```

All the standard options such as `alpha`, `weights`, `nlambda` and `standardize` package, and their usage is similar as in the Gaussian case. (See the vignette "An Introduction to `glmnet`" for details, or refer to the help file `help(glmnet)`.)

We can plot the coefficients with the `plot` method:

```
plot(fit)
```



As before, we can extract the coefficients at certain values of λ:

```
coef(fit, s = 0.05)
```

```
## 30 x 1 sparse Matrix of class "dgCMatrix"
##               1
## V1   0.37710773
## V2  -0.09554676
## V3  -0.13605156
## V4   0.09820157
## V5  -0.11442394
## V6  -0.38911885
## V7   0.24303014
## V8   0.03650661
....
```

Since the Cox Model is not commonly used for prediction, we do not give an illustrative example on prediction. If needed, users can refer to the help file by typing `help(predict.glmnet)`.

Cross-validation

The function `cv.glmnet` can be used to compute K-fold cross-validation (CV) for the Cox model. The usage is similar to that for other families except for two main differences.

First, `type.measure` only supports `"deviance"` (also default) which gives the partial-likelihood, and `"C"`, which gives the Harrell *C index*. This is like the area under the curve (AUC) measure of concordance for survival data, but only considers comparable pairs. Pure concordance would record the fraction of pairs for which the order of the death times agree with the order of the predicted risk. However, with survival data, if an observation is right censored at a time *before* another observation's death time, they are not comparable.

The code below illustrates how one can perform cross-validation using the Harell C index. Note that unlike most error measures, a higher C index means better prediction performance.

```r
set.seed(1)
cvfit <- cv.glmnet(x, y, family = "cox", type.measure = "C")
```

```
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
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## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
```
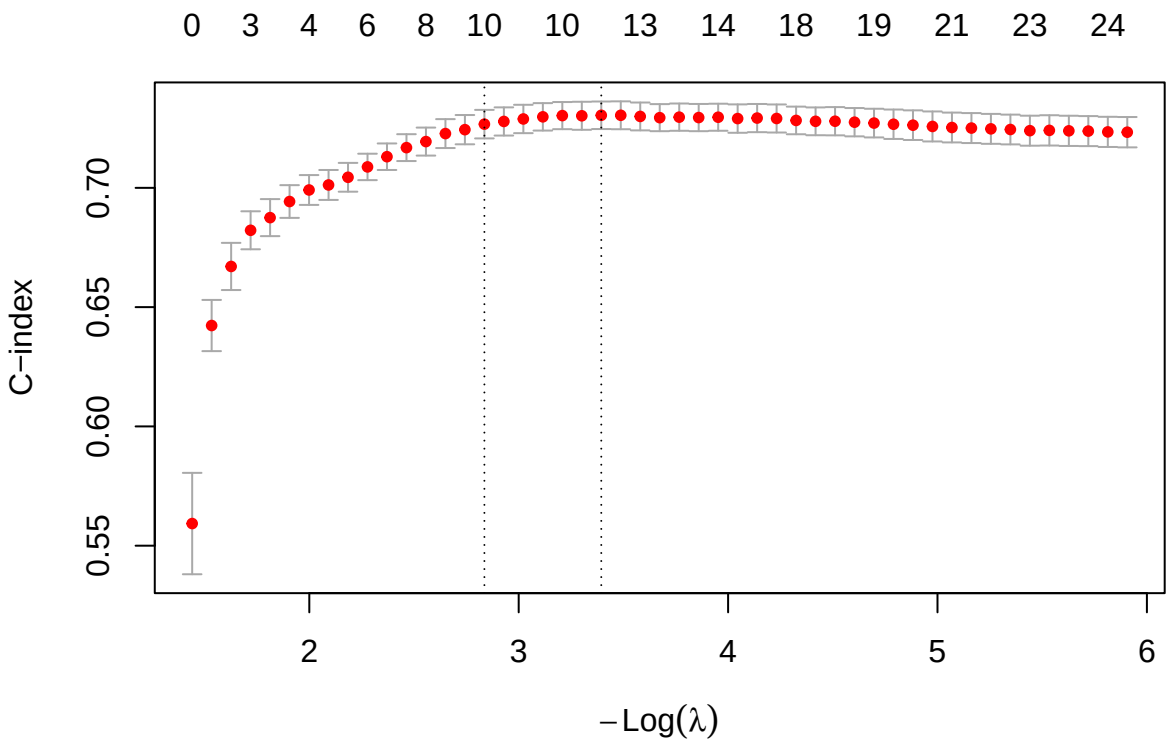

Once fit, we can view the optimal λ value and a cross validated error plot to help evaluate our model.

```r
plot(cvfit)
```



As with other families, the left vertical line in our plot shows us where the CV-error curve hits its minimum. The right vertical line shows us the most regularized model with CV-error within 1 standard deviation of the minimum. We also extract such optimal λ's:

```
cvfit$lambda.min
```

```
## [1] 0.03356003
```

```
cvfit$lambda.1se
```

```
## [1] 0.05864711
```

Second, the option `grouped = TRUE` (default) obtains the CV partial likelihood for the Kth fold by subtraction, i.e. by subtracting the log partial likelihood evaluated on the full dataset from that evaluated on the $(K-1)/K$ dataset. This makes more efficient use of risk sets. With `grouped = FALSE` the log partial likelihood is computed only on the Kth fold, which is only reasonable if each fold has a large number of observations.

Handling of ties

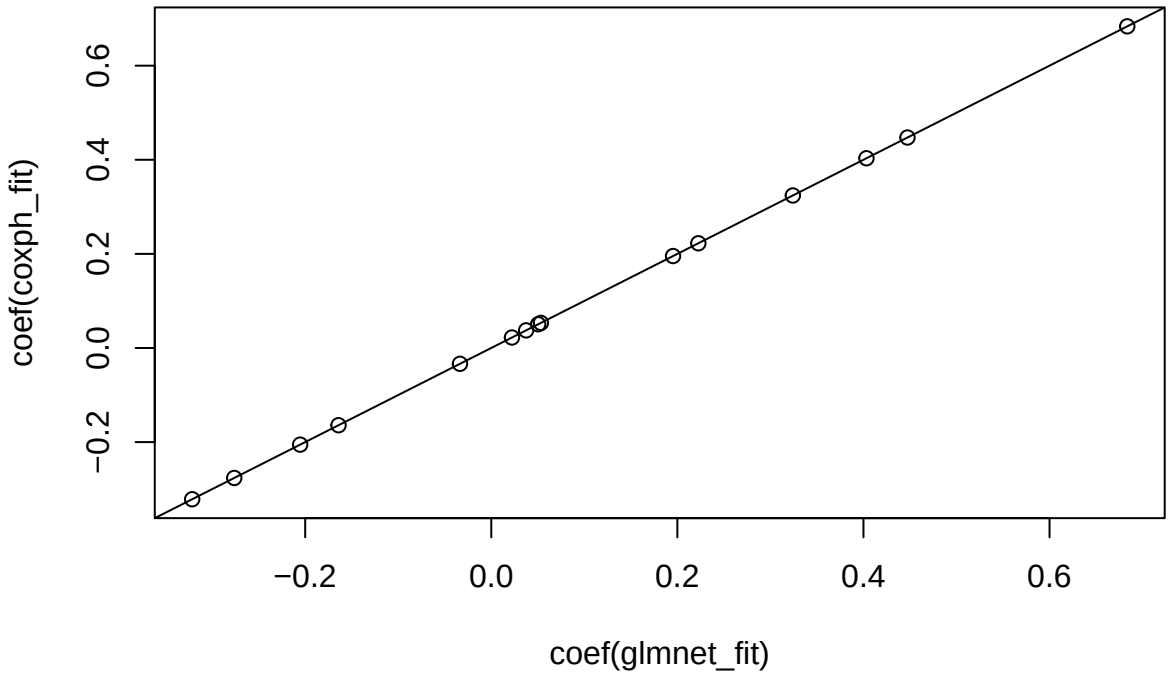
`glmnet` supports both the Breslow and Efron approximations for handling ties in survival times. The `cox.ties` argument selects between them.

In the current release (v5.0) the default is `cox.ties = "breslow"`, which matches the pre-v5.0 behavior of `glmnet`. **In v5.1 this default will change to `cox.ties = "efron"` to match the default of `survival::coxph`.** Calls to `glmnet()` with `family = "cox"` that do not set `cox.ties` explicitly will emit a transition warning until the switch occurs. To silence the warning, pass `cox.ties` explicitly:

- `cox.ties = "breslow"` locks in the v5.0 default.
- `cox.ties = "efron"` previews the v5.1 default.

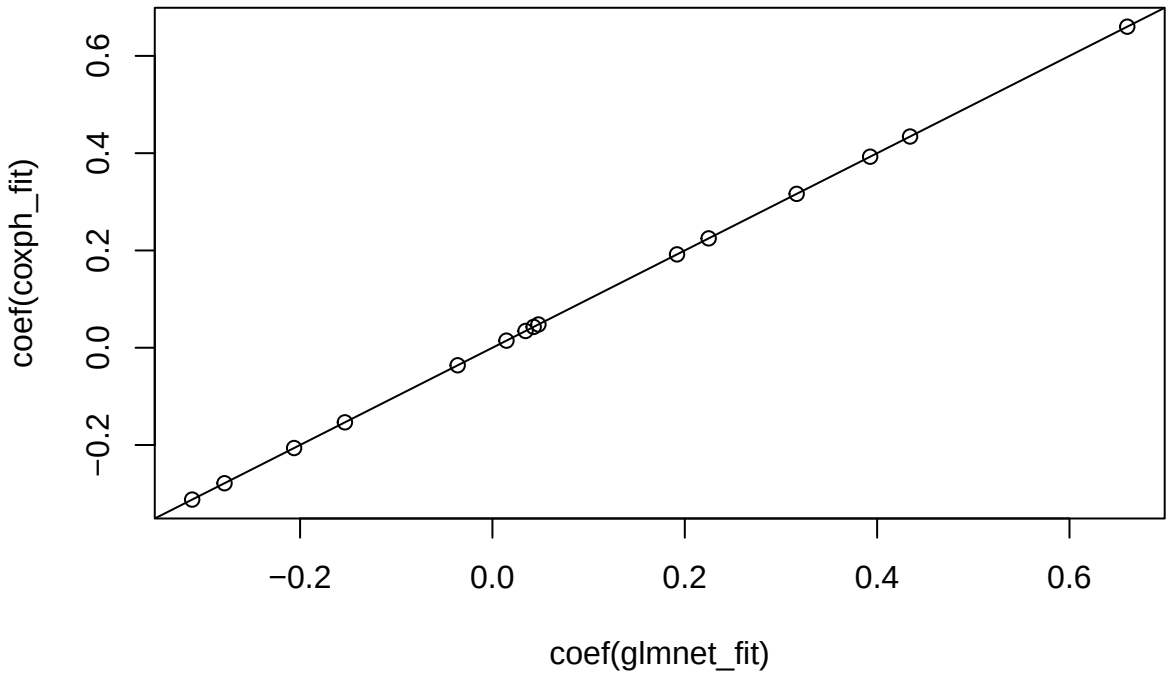
```
# create x matrix
set.seed(1)
nobs <- 100; nvars <- 15
x <- matrix(rnorm(nobs * nvars), nrow = nobs)
```

```r
# create response with many ties
ty <- rep(rexp(nobs / 5), each = 5)
tcens <- rbinom(n = nobs, prob = 0.3, size = 1)
y <- Surv(ty, tcens)

# Efron: set cox.ties = "efron" in glmnet (matches coxph's default)
glmnet_fit <- glmnet(x, y, family = "cox", lambda = 0, cox.ties = "efron")
coxph_fit <- coxph(y ~ x)
plot(coef(glmnet_fit), coef(coxph_fit))
abline(0, 1)
```



The Breslow approximation (current `glmnet` default):

```r
# Breslow: set cox.ties = "breslow" in glmnet, ties = "breslow" in coxph
glmnet_fit <- glmnet(x, y, family = "cox", lambda = 0, cox.ties = "breslow")
coxph_fit <- coxph(y ~ x, ties = "breslow")
plot(coef(glmnet_fit), coef(coxph_fit))
abline(0, 1)
```



Cox models for start-stop data

Since version 4.1 `glmnet` can fit models where the response is a (start, stop] time interval. As explained in Therneau and Grambsch (2000), the ability to work with start-stop responses opens the door to fitting regularized Cox models with

- time-dependent covariates,
- time-dependent strata,
- left truncation,
- multiple time scales,
- multiple events per subject,
- independent increment, marginal, and conditional models for correlated data, and
- various forms of case-cohort models.

The code below shows how to create a response of this type (using `survival` package's `Surv` function) and how to fit such a model with `glmnet`.

```
# create x matrix
set.seed(2)
nobs <- 100; nvars <- 15
xvec <- rnorm(nobs * nvars)
xvec[sample.int(nobs * nvars, size = 0.4 * nobs * nvars)] <- 0
x <- matrix(xvec, nrow = nobs)  # non-sparse x
x_sparse <- Matrix::Matrix(xvec, nrow = nobs, sparse = TRUE)  # sparse x

# create start-stop data response
beta <- rnorm(5)
fx <- x_sparse[, 1:5] %*% beta / 3
ty <- rexp(nobs, drop(exp(fx)))
tcens <- rbinom(n = nobs, prob = 0.3, size = 1)
starty <- runif(nobs)
yss <- Surv(starty, starty + ty, tcens)
```

```
# fit regularized Cox model with start-stop data
fit <- glmnet(x, yss, family = "cox")
```

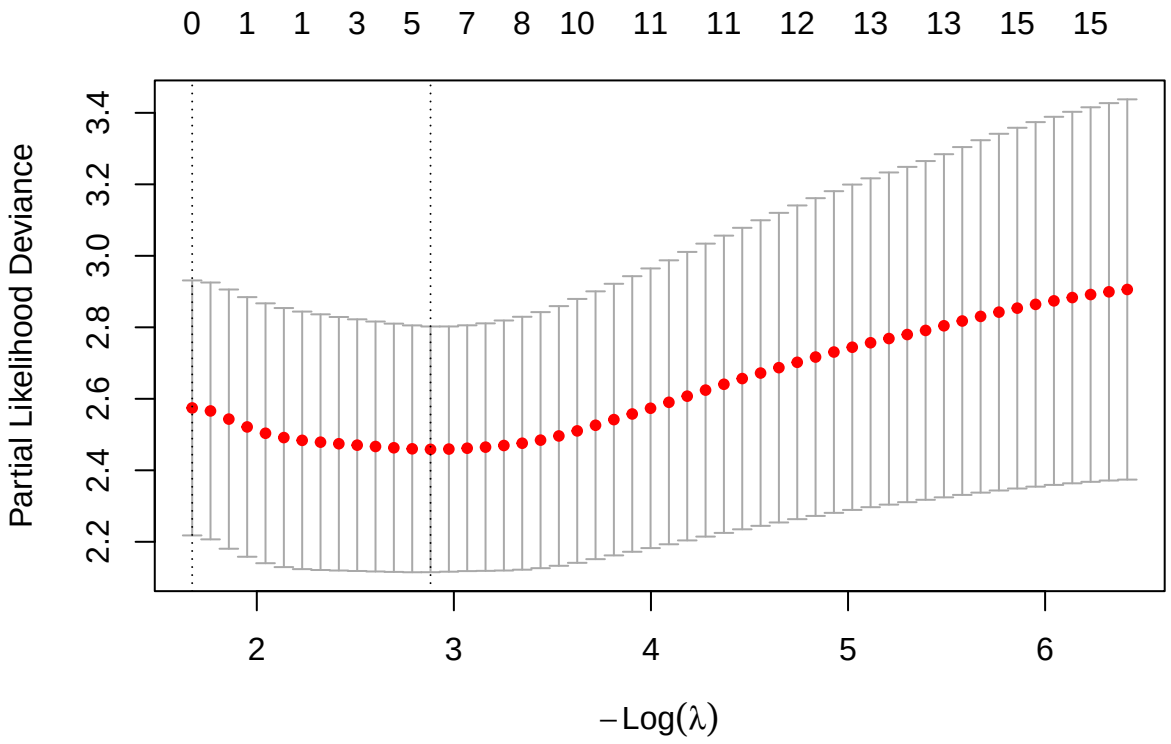
```
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
```

(Note that the call above would have worked as well if `x` was replaced by `x_sparse`.) `cv.glmnet` works with start-stop data too:

```
cv.fit <- cv.glmnet(x, yss, family = "cox", nfolds = 5)
```

```
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
```

```
plot(cv.fit)
```

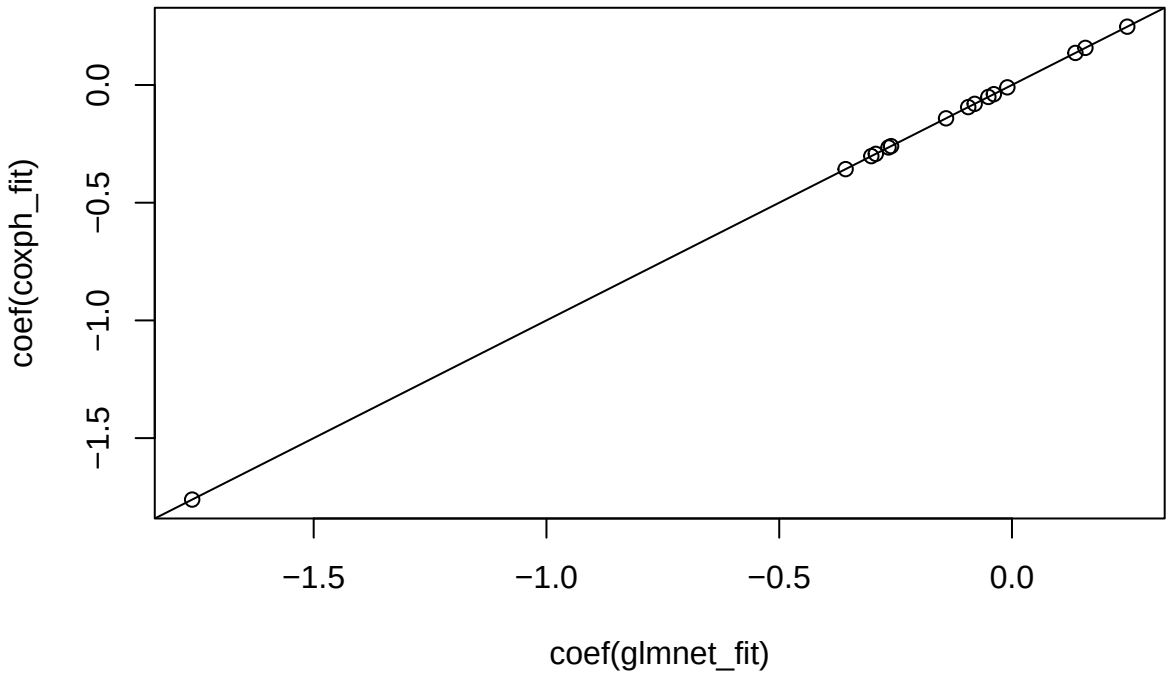


As a sanity check, the code below shows that fitting start-stop responses using `glmnet` with `lambda = 0` matches up with `coxph`'s result:

```
glmnet_fit <- glmnet(x, yss, family = "cox", lambda = 0)
```

```
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
```

```
coxph_fit <- coxph(yss ~ x)
plot(coef(glmnet_fit), coef(coxph_fit))
abline(0, 1)
```



Stratified Cox models

One extension of the Cox regression model is to allow for strata that divide the observations into disjoint groups. Each group has its own baseline hazard function, but the groups share the same coefficient vector for the covariates provided by the design matrix `x`.

`glmnet` can fit stratified Cox models with the elastic net penalty. With `coxph` one can specify strata in the model formula. Since `glmnet` does not use a model formula, we achieve this by adding a strata attribute to the `Surv` response object. We achieve this via the function `stratifySurv`:

```
strata <- rep(1:5, length.out = nobs)
y2 <- stratifySurv(y, strata)
str(y2[1:6])
```

```
##  'stratifySurv' num [1:6, 1:2] 0.605+ 0.605+ 0.605+ 0.605+ 0.605+ 0.816
##  - attr(*, "dimnames")=List of 2
##   ..$ : NULL
##   ..$ : chr [1:2] "time" "status"
##  - attr(*, "type")= chr "right"
##  - attr(*, "strata")= int [1:6] 1 2 3 4 5 1
```

`stratifySurv` returns an object of class `stratifySurv`. We can then pass this `stratifySurv` object as the response to a `glmnet` call. `glmnet` will fit a stratified Cox model if it detects that the response has class `stratifySurv`.

```
fit <- glmnet(x, y2, family = "cox")
```

```
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
```

This `stratifySurv` object can also be passed to `cv.glmnet` to fit stratified Cox models with cross-validation:

```
cv.fit <- cv.glmnet(x, y2, family = "cox", nfolds = 5)
```

```
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
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## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
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## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
```
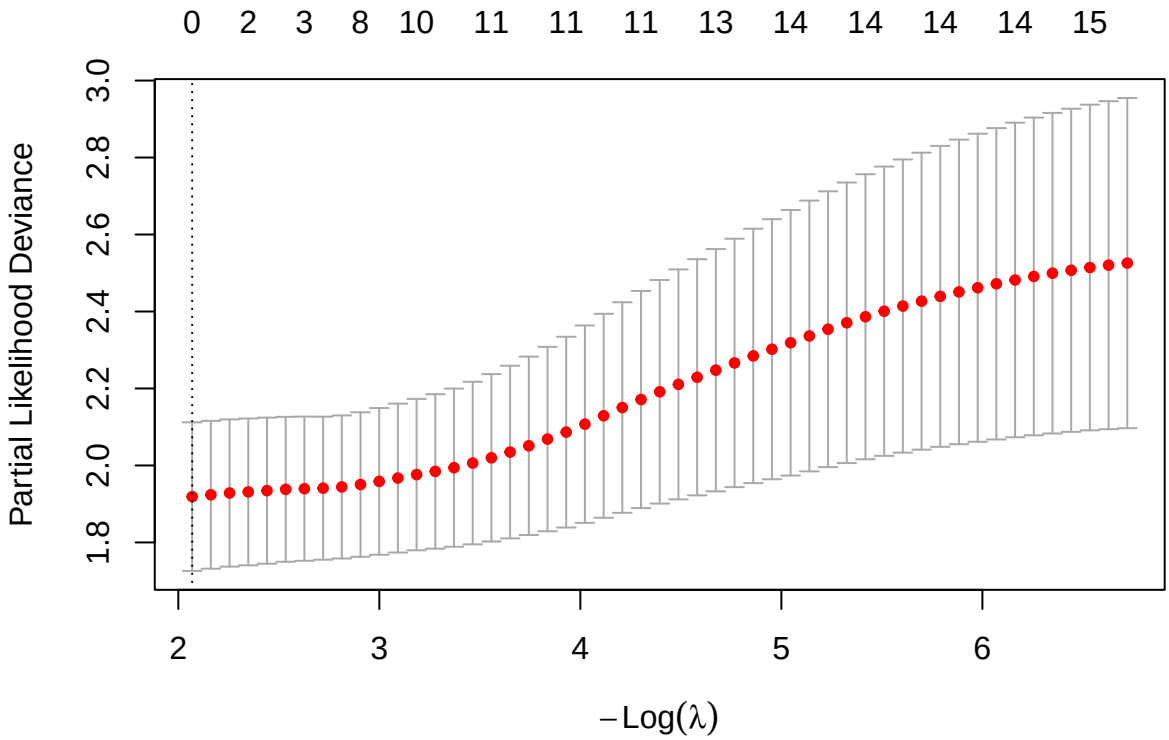

```
plot(cv.fit)
```



Note that simply giving the response a `"strata"` attribute is not enough! The response needs to be of class `stratifySurv` in order for subsetting to work correctly. To protect against this, an error will be thrown if

the response has a "strata" attribute but is not of class stratifySurv. Add strata via the stratifySurv function.

```
y3 <- y
attr(y3, "strata") <- strata
str(y3[1:6])  # note that the strata attribute is no longer there
```

```
##  'Surv' num [1:6, 1:2] 0.605+ 0.605+ 0.605+ 0.605+ 0.605+ 0.816
##  - attr(*, "dimnames")=List of 2
##   ..$ : NULL
##   ..$ : chr [1:2] "time" "status"
##  - attr(*, "type")= chr "right"
```

```
fit <- glmnet(x, y3, family = "cox")
```

```
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
```

Plotting survival curves

Fitting a regularized Cox model using glmnet with family = "cox" returns an object of class "coxnet". Class "coxnet" objects have a survfit method which allows the user to visualize the survival curves from the model. In addition to the "coxnet" object, the user must pass the x and y objects used to fit the model (for computation of the baseline hazard), as well as the lambda value for which the survival curve is desired:

```
fit <- glmnet(x, y, family = "cox")
```

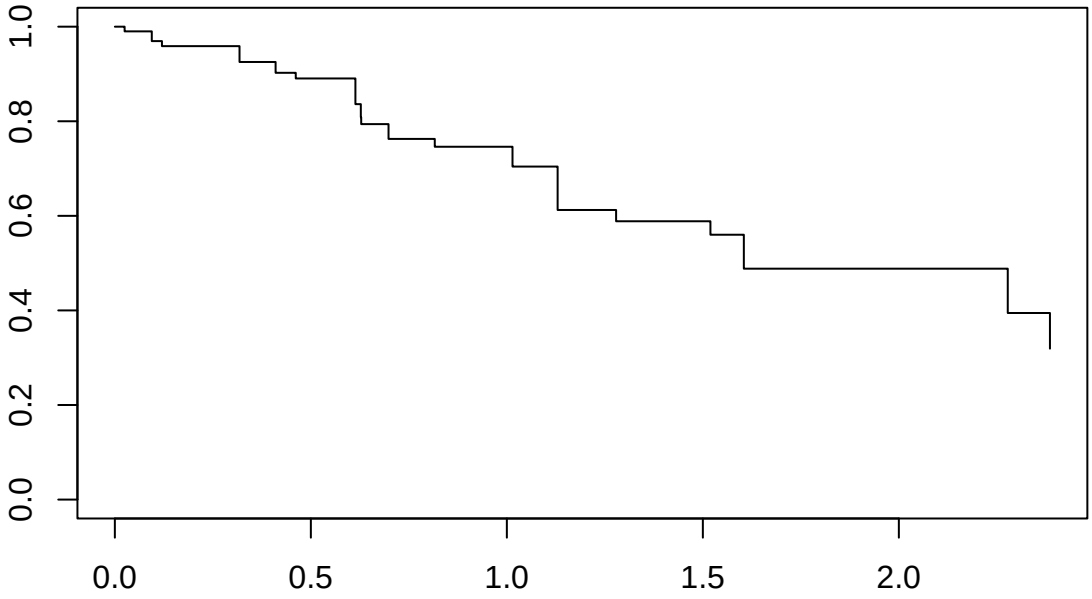
```
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
```

```
survival::survfit(fit, s = 0.05, x = x, y = y)
```

```
## Call: survfit.coxnet(formula = fit, s = 0.05, x = x, y = y)
##
##        n events median
## [1,] 100     33    1.6
```

We are unable to provide standard errors for these survival curves, so we do not present the confidence bounds for them. To plot the survival curve, pass the result of the survfit call to plot:

```
plot(survival::survfit(fit, s = 0.05, x = x, y = y))
```

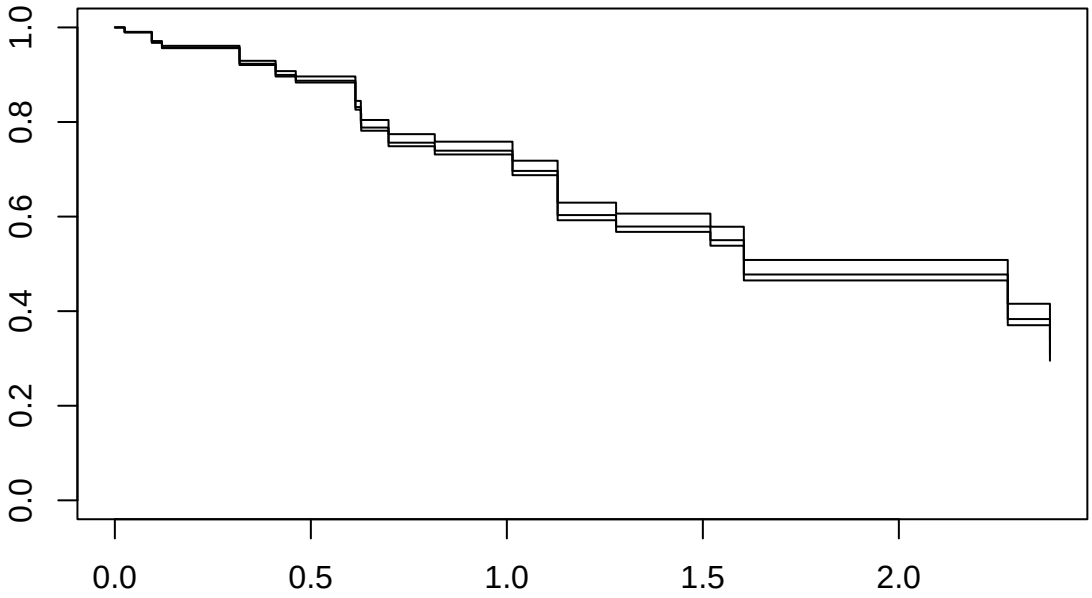


As noted in the documentation for `survival::survfit.coxph`, without new data, a curve is produced for a single "pseudo" subject with covariate values equal to the means of the data set, and this resulting curve(s) almost never make sense. We can get survival curves for individual observations by passing a `newx` argument:

```
survival::survfit(fit, s = 0.05, x = x, y = y, newx = x[1:3, ])
```

```
## Call: survfit.coxnet(formula = fit, s = 0.05, x = x, y = y, newx = x[1:3,
##     ])
##
##     n events median
## 1 100     33   1.60
## 2 100     33   1.60
## 3 100     33   2.28
```

```
plot(survival::survfit(fit, s = 0.05, x = x, y = y, newx = x[1:3, ]))
```



If the original model was fit with strata, then the `strata` option needs to be specified as well. If `newx` is

being passed for such a model, the strata for these new observations need to be passed via `newstrata`.

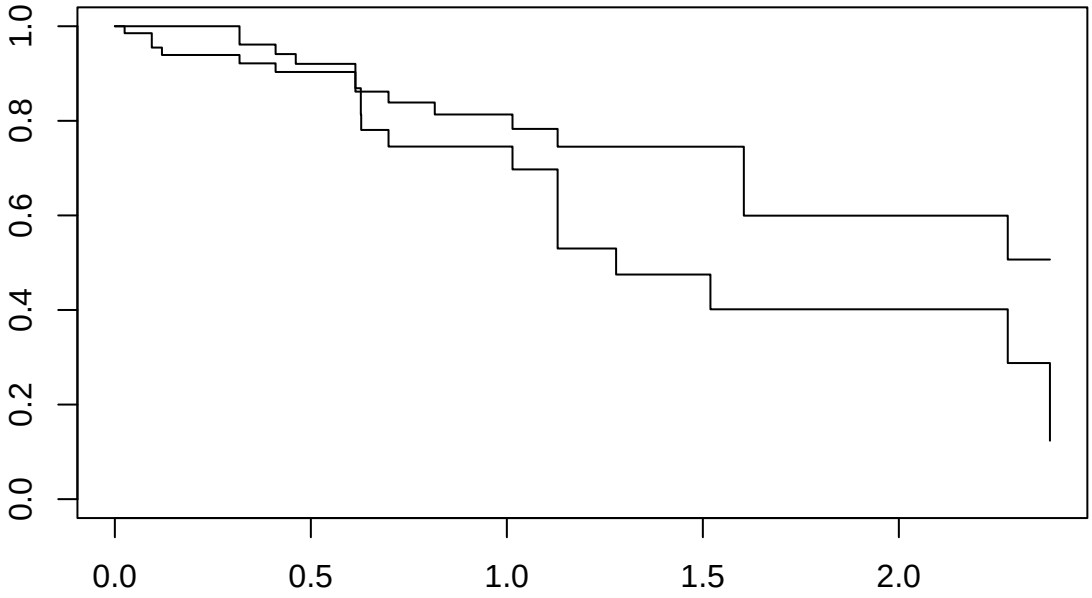
```
y2 <- stratifySurv(y, rep(1:2, length.out = nobs))
fit <- glmnet(x, y2, family = "cox")
```

```
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
```

```
survival::survfit(fit, s = 0.01, x = x, y = y2)
```

```
## Call: survfit.coxnet(formula = fit, s = 0.01, x = x, y = y2)
##
##           n events median
## strata=1 50     18   1.52
## strata=2 50     15   2.28
```

```
# survival curve plot for first two individuals in dataset
plot(survival::survfit(fit, s = 0.01, x = x, y = y2,
                       newx = x[1:2, ], newstrata = strata[1:2]))
```



To be consistent with other methods in `glmnet`, if the `s` parameter is not specified, survival curves are returned for the entire `lambda` sequence. The survival curves are returned as a list, one element for each `lambda` value.

```
sf <- survival::survfit(fit, x = x, y = y2)
length(sf)
```

```
## [1] 48
```

```
length(fit$lambda)
```

```
## [1] 48
```

The `survfit` method is available for `cv.glmnet` objects as well. By default, the `s` value chosen is the "lambda.1se" value stored in the CV object. The `s` value can also be set to the `"lambda.min"` value stored in the CV object.

```
cv.fit <- cv.glmnet(x, y2, family = "cox", nfolds = 5)
```

```
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
## Warning: Starting in glmnet 5.1, the default Cox tie-handling method will
## change from 'breslow' to 'efron' (matching survival::coxph). To silence this
## message and lock in the v5.0 default, pass cox.ties = 'breslow' explicitly. To
## preview the v5.1 behavior, pass cox.ties = 'efron'.
```

```
survival::survfit(cv.fit, x = x, y = y2)
```

```
## Call: survfit.cv.glmnet(formula = cv.fit, x = x, y = y2)
##
##           n events median
## strata=1 50     18   1.52
## strata=2 50     15   2.28
```

```
survival::survfit(cv.fit, s = "lambda.min", x = x, y = y2)
```

```
## Call: survfit.cv.glmnet(formula = cv.fit, s = "lambda.min", x = x,
##     y = y2)
##
##           n events median
## strata=1 50     18   1.52
## strata=2 50     15   2.28
```

References

Simon, Noah, Jerome Friedman, Trevor Hastie, and Robert Tibshirani. 2011. "Regularization Paths for Cox's Proportional Hazards Model via Coordinate Descent." *Journal of Statistical Software, Articles* 39 (5): 1–13. https://doi.org/10.18637/jss.v039.i05.

Therneau, Terry M., and Patricia M. Grambsch. 2000. *Modeling survival data: extending the Cox model*. Springer.