

# Package ‘landpred’

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**Type** Package

**Title** Landmark Prediction of a Survival Outcome

**Version** 2.0

**Description** Nonparametric methods for landmark prediction of long-term survival outcomes, incorporating covariate and short-term event information. The package supports the construction of flexible varying-coefficient models that use discrete covariates, as well as multiple continuous covariates. The goal is to improve prediction accuracy when censored short-term events are available as predictors, using robust nonparametric procedures that do not require correct model specification and avoid restrictive parametric assumptions found in alternative methods. More information on these methods can be found in Parast et al. 2012 <[doi:10.1080/01621459.2012.721281](https://doi.org/10.1080/01621459.2012.721281)>, Parast et al. 2011 <[doi:10.1002/bimj.201000150](https://doi.org/10.1002/bimj.201000150)>, and Parast and Cai 2013 <[doi:10.1002/sim.5776](https://doi.org/10.1002/sim.5776)>. A tutorial for this package is available here: <<https://www.laylaparast.com/landpred>>.

**License** GPL

**Imports** survival, stats, quantreg, splines, sm, quantreg

**NeedsCompilation** no

**Suggests** testthat (>= 3.0.0)

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## Contents

AUC.landmark . . . . .	2
BS.landmark . . . . .	3
coef.landpred_model_continuous . . . . .	4
coefficient_se . . . . .	4
cumsum2 . . . . .	5
data_example_landpred . . . . .	5
fit_glm_normal . . . . .	6
fit_short_glm . . . . .	6
get_model . . . . .	7
Ghat.FUN . . . . .	7
helper.si . . . . .	8
Kern.FUN . . . . .	8
landpred . . . . .	9

mse_cv . . . . .	10
optimize_bandwidth . . . . .	11
predict.landpred_model_continuous . . . . .	12
predict.landpred_model_discrete . . . . .	12
print.landpred_model_continuous . . . . .	13
print.landpred_model_discrete . . . . .	13
print.landpred_object . . . . .	14
Prob.Covariate . . . . .	14
Prob.Covariate.ShortEvent . . . . .	15
Prob.Null . . . . .	15
summary.landpred_model_continuous . . . . .	16
summary.landpred_object . . . . .	16
VTM . . . . .	17
Wi.FUN . . . . .	17

**Index****19****AUC.landmark***Estimates the area under the ROC curve (AUC).***Description**

This function calculates the AUC given the data (truth) and corresponding estimated probabilities; uses a continuity correction.

**Usage**

```
AUC.landmark(t0, tau, data, weight=NULL)
```

**Arguments**

t0	The landmark time.
tau	The prediction window.
data	A data matrix where the first column is XL = min(TL, C) where TL is the time of the long term event, C is the censoring time; the second column is DL = 1*(TL < C); the third column is the estimated probability P(TL < t0 + tau   TL > t0).
weight	an optional weight to be incorporated in all estimation.

**Value**

AUC.est	Estimated AUC
---------	---------------

**References**

Parast, Layla, Su-Chun Cheng, and Tianxi Cai. Incorporating short-term outcome information to predict long-term survival with discrete markers. Biometrical Journal 53.2 (2011): 294-307.

## Examples

```

data(data_example_landpred)
t0=2
tau = 8

out = Prob.Null(t0=t0,tau=tau,data=data_example_landpred)

#get data with predictions
data_pred = out$data

#calculate training AUC
AUC.landmark(t0=t0,tau=tau, data = data_pred[,c("XL","DL","prob_est")])

```

---

**BS.landmark**

*Estimates the Brier score.*

---

## Description

This function calculates the Brier score given the data (truth) and corresponding estimated probabilities.

## Usage

```
BS.landmark(t0, tau, data, weight=NULL)
```

## Arguments

t0	The landmark time.
tau	The prediction window.
data	A data matrix where the first column is XL = min(TL, C) where TL is the time of the long term event, C is the censoring time; the second column is DL = 1*(TL < C); the third column is the estimated probability P(TL < t0 + tau   TL > t0).
weight	an optional weight to be incorporated in all estimation.

## Value

Brier.score	Estimated Brier score
-------------	-----------------------

## References

Parast, Layla, Su-Chun Cheng, and Tianxi Cai. Incorporating short-term outcome information to predict long-term survival with discrete markers. Biometrical Journal 53.2 (2011): 294-307.

## Examples

```

data(data_example_landpred)
t0=2
tau = 8

out = Prob.Null(t0=t0,tau=tau,data=data_example_landpred)

```

```
#get data with predictions
data_pred = out$data

#calculate training BS
BS.landmark(t0=t0,tau=tau, data = data_pred[,c("XL","DL","prob_est")])
```

---

**coef.landpred\_model\_continuous***Extract Coefficients from Landpred Continuous Model***Description**

Extracts coefficients. If `t_s` is provided, it fits the short-term GLM and returns its coefficients.

**Usage**

```
## S3 method for class 'landpred_model_continuous'
coef(object, t_s = NULL, ...)
```

**Arguments**

- `object` A `landpred_model_continuous` object.
- `t_s` Optional short-term event time.
- `...` Additional arguments.

**Value**

A named vector of coefficients.

**coefficient\_se***Calculate Standard Errors for Coefficients***Description**

Calculates standard errors for the coefficients of the `landpred` model. If `t_s` is provided, it uses the bootstrap. Otherwise, it returns the standard errors from the GLM.

**Usage**

```
coefficient_se(model_c, t_s = NULL, samples = 300)
```

**Arguments**

- `model_c` A `landpred_model_continuous` object.
- `t_s` The time of the short-term event.
- `samples` The number of resampling iterations.

**Value**

A named vector of standard errors.

---

cumsum2	<i>Helper function</i>
---------	------------------------

---

**Description**

Helper function; should not be called directly by user.

**Usage**

```
cumsum2(mydat)
```

**Arguments**

mydat	mydat
-------	-------

**Value**

out	matrix
-----	--------

**Author(s)**

Layla Parast

---

data\_example\_landpred *Hypothetical data to be used in examples.*

---

**Description**

Hypothetical data to be used in examples.

**Usage**

```
data(data_example_landpred)
```

**Format**

A data frame with 4868 observations on the following 5 variables.

XL a numeric vector. XL = min(TL, C) where TL is the time of the long term event, C is the censoring time.

DL a 0/1 vector. DL = 1\*(TL < C) where TL is the time of the long term event, C is the censoring time.

XS a numeric vector. XS = min(TS, C) where TS is the time of the long term event, C is the censoring time.

DS a 0/1 vector. DS = 1\*(TS < C) where TS is the time of the long term event, C is the censoring time.

Z a 0/1 vector of discrete covariate values.

**Examples**

```
data(data_example_landpred)
```

**fit\_glm\_normal***Fit GLM with Normal Weights (No Short-term Event Info)***Description**

Fits a GLM for the probability of the event occurring before  $t_0 + \tau$ , given survival up to  $t_0$ , using only baseline covariates.

**Usage**

```
fit_glm_normal(landpred_obj, t0, tau)
```

**Arguments**

- `landpred_obj` A landpred object containing the data.
- `t0` The landmark time.
- `tau` The prediction window.

**Value**

A fitted glm object.

**fit\_short\_glm***Fit GLM with Kernel Weights (Short-Term Event Info)***Description**

Fits a GLM for the probability of the event occurring before  $t_0 + \tau$ , given survival up to  $t_0$  and information on a short-term event. Uses kernel weighting based on the short-term event time.

**Usage**

```
fit_short_glm(landpred_obj, t0, tau, t_s, bw, transform, indices = NULL)
```

**Arguments**

- `landpred_obj` A landpred object containing the data.
- `t0` The landmark time.
- `tau` The prediction window.
- `t_s` The time of the short-term event.
- `bw` The bandwidth for kernel weighting.
- `transform` A transformation function for the time variable (e.g., log).
- `indices` Optional indices to subset the data.

**Value**

A fitted glm object.

---

`get_model`*Get Landpred Model*

---

**Description**

Creates a landpred model object for a specific landmark time and prediction window. Dispatches to continuous or discrete model creation based on the landpred object type.

**Usage**

```
get_model(landpred_obj, t0, tau, bw = NULL, transform = identity)
```

**Arguments**

<code>landpred_obj</code>	A landpred object.
<code>t0</code>	The landmark time.
<code>tau</code>	The prediction window.
<code>bw</code>	The bandwidth.
<code>transform</code>	Transformation function.

**Value**

A landpred\_model object (continuous or discrete).

---

`Ghat.FUN`*Estimate Survival Function*

---

**Description**

Estimate Survival Function

**Usage**

```
Ghat.FUN(tt, data, type = "f1", weight.given)
```

**Arguments**

<code>tt</code>	Time points.
<code>data</code>	Data frame.
<code>type</code>	Type of estimator.
<code>weight.given</code>	Optional weights.

`helper.si`      *Helper function for AUC.landmark*

### Description

Helper function for AUC.landmark; should not be called directly by user.

### Usage

```
helper.si(yy,FUN,Yi,Vi=NULL)
```

### Arguments

<code>yy</code>	<code>yy</code>
<code>FUN</code>	<code>FUN</code>
<code>Yi</code>	<code>Yi</code>
<code>Vi</code>	<code>Vi</code>

### Value

<code>out</code>	matrix
------------------	--------

### Author(s)

Layla Parast

`Kern.FUN`      *Calculates kernel matrix*

### Description

Calculates the kernel matrix

### Usage

```
Kern.FUN(zz, zi, bw)
```

### Arguments

<code>zz</code>	<code>zz</code>
<code>zi</code>	<code>zi</code>
<code>bw</code>	bandwidth

### Value

the kernel matrix

### Author(s)

Layla Parast

---

<b>landpred</b>	<i>Create a Landpred Object</i>
-----------------	---------------------------------

---

### Description

Parses the formula and data to create a landpred object used for landmark prediction. Call ‘?landpred.pacakge‘ for more information on the legacy API.

### Usage

```
landpred(formula, data, discrete = FALSE, no.covariates = FALSE)
```

### Arguments

formula	A formula object with a Surv object on the LHS and covariates on the RHS.
data	The data frame.
discrete	Logical, whether to use the discrete method (legacy).
no.covariates	Logical, whether there are covariates or not.

### Value

A landpred\_object.

### Examples

```
library(landpred)
library(survival)

# Load example data
data(data_example_landpred)

# Define landmark time and prediction window
t0 <- 2
tau <- 8

# Create a landpred object using the formula interface
# The formula specifies: Long-term survival ~ Short-term survival + Covariates
# Note: The short-term event must be a Surv object
obj <- landpred(
  Surv(XL, DL) ~ Surv(XS, DS) + Z,
  data = data_example_landpred,
  discrete = FALSE
)

# 1. Optimize bandwidth (Optional but recommended)
# This uses cross-validation to find the optimal bandwidth for the short-term event
# We use log transformation for the time variable as it's often more appropriate
bw <- optimize_bandwidth(
  landpred_obj = obj,
  t0 = t0,
  tau = tau,
  lower = 0.5,
  upper = 5,
```

```

    transform = log
  )

  print(paste("Optimal bandwidth:", bw))

  # 2. Fit the model
  # We pass the optimized bandwidth and the transformation used
  model <- get_model(
    landpred_obj = obj,
    t0 = t0,
    tau = tau,
    bw = bw,
    transform = log
  )

  print(model)
  summary(model, t_s = 1)

  # 3. Predict on new data
  # For demonstration, we use the first 10 rows of the original data as "new data"
  new_data <- data_example_landpred[1:10, ]

  # The predict function expects a data frame with the same column names as used in the formula
  probs <- predict(model, newdata = new_data)

  print("Predicted probabilities:")
  print(probs)

```

***mse\_cv****Calculate MSE for Bandwidth Selection using Cross-Validation***Description**

Calculate MSE for Bandwidth Selection using Cross-Validation

**Usage**

```

mse_cv(
  bw,
  landpred_obj,
  t0,
  tau,
  transform = identity,
  reps = 50,
  train_prop = 0.66
)

```

**Arguments**

- |                           |                        |
|---------------------------|------------------------|
| <code>bw</code>           | The bandwidth to test. |
| <code>landpred_obj</code> | The landpred object.   |
| <code>t0</code>           | The landmark time.     |

<code>tau</code>	The prediction window.
<code>transform</code>	Transformation function for short-term event.
<code>reps</code>	Number of repetitions.
<code>train_prop</code>	Proportion of data to use for training.

**Value**

The Mean Squared Error.

`optimize_bandwidth`

*Optimize Bandwidth for Continuous Landpred Models*

**Description**

Selects the optimal bandwidth by minimizing the Mean Squared Error (MSE) using cross-validation.

**Usage**

```
optimize_bandwidth(
  landpred_obj,
  t0,
  tau,
  lower = 0.05,
  upper = 5,
  transform = identity,
  reps = 50,
  train_prop = 0.66
)
```

**Arguments**

<code>landpred_obj</code>	A landpred object.
<code>t0</code>	The landmark time.
<code>tau</code>	The prediction window.
<code>lower</code>	Lower bound for bandwidth search.
<code>upper</code>	Upper bound for bandwidth search.
<code>transform</code>	Transformation function for the short-term event (e.g., log). Default is identity.
<code>reps</code>	Number of cross-validation repetitions. Default is 50.
<code>train_prop</code>	Proportion of data used for training in each fold. Default is 0.66.

**Value**

The optimal bandwidth.

---

**predict.landpred\_model\_continuous**

*Predict Method for Landpred Continuous Model*

---

### Description

Predicts the probability of the event occurring given new data.

### Usage

```
## S3 method for class 'landpred_model_continuous'
predict(object, newdata = NULL, type = "response", ...)
```

### Arguments

object	A landpred_model_continuous object.
newdata	New data frame containing covariates and short-term event info.
type	Type of prediction (default "response").
...	Additional arguments

### Value

A vector of predicted probabilities.

---

**predict.landpred\_model\_discrete**

*Predict Method for Discrete Landpred Model*

---

### Description

Predicts probabilities using the discrete landpred model.

### Usage

```
## S3 method for class 'landpred_model_discrete'
predict(object, newdata = NULL, ...)
```

### Arguments

object	A landpred_model_discrete object.
newdata	Optional new data.
...	Additional arguments.

### Value

Predicted probabilities.

---

```
print.landpred_model_continuous
```

*Print Method for Landpred Continuous Model*

---

## Description

Prints the continuous landpred model results.

## Usage

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

## Arguments

x           A landpred\_model\_continuous object.  
...          Additional arguments.

---

```
print.landpred_model_discrete
```

*Print Method for Discrete Landpred Model*

---

## Description

Prints the discrete landpred model results.

## Usage

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

## Arguments

x           A landpred\_model\_discrete object.  
...          Additional arguments.

`print.landpred_object` *Print Method for Landpred Object*

### Description

Prints a summary of the landpred object.

### Usage

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

### Arguments

<code>x</code>	A landpred_object.
<code>...</code>	Additional arguments.

Prob.Covariate

*Calculate Probability with Covariate Information*

### Description

Calculates the probability of the event occurring before  $t_0 + \tau$ , given survival up to  $t_0$ , using a single covariate.

### Usage

```
Prob.Covariate(t0, tau, data, weight = NULL, short = TRUE, newdata = NULL)
```

### Arguments

<code>t0</code>	The landmark time.
<code>tau</code>	The prediction window.
<code>data</code>	The data frame for training.
<code>weight</code>	Optional weights.
<code>short</code>	Logical, whether the covariate is short-term.
<code>newdata</code>	Dataframe of new data for prediction.

### Value

A landpred\_result object.

---

Prob.Covariate.ShortEvent*Calculate Probability with Short Event Information*

---

**Description**

Calculates the probability of the event occurring before  $t_0 + \tau$ , given survival up to  $t_0$ , using information on a short-term event.

**Usage**

```
Prob.Covariate.ShortEvent(
  t0,
  tau,
  data,
  weight = NULL,
  bandwidth = NULL,
  newdata = NULL
)
```

**Arguments**

t0	The landmark time.
tau	The prediction window.
data	The data frame.
weight	Optional weights.
bandwidth	Bandwidth for kernel smoothing.
newdata	Optional new data for prediction.

**Value**

A landpred\_result object.

---

Prob.Null*Calculate Probability with No Information*

---

**Description**

Calculates the probability of the event occurring before  $t_0 + \tau$ , given survival up to  $t_0$ , without using any covariate information.

**Usage**

```
Prob.Null(t0, tau, data, weight = NULL, newdata = NULL)
```

**Arguments**

t0	The landmark time.
tau	The prediction window.
data	The data frame.
weight	Optional weights.
newdata	Optional new data for prediction.

**Value**

A landpred\_result object.

**summary.landpred\_model\_continuous**

*Summary Method for Landpred Continuous Model*

**Description**

Prints a summary of the model, including coefficients and standard errors.

**Usage**

```
## S3 method for class 'landpred_model_continuous'
summary(object, t_s = NULL, ...)
```

**Arguments**

object	A landpred_model_continuous object.
t_s	Optional short-term event time.
...	Additional arguments.

**summary.landpred\_object**

*Summary Method for Landpred Object*

**Description**

Prints a detailed summary of the landpred object.

**Usage**

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

**Arguments**

object	A landpred_object.
...	Additional arguments.

VTM

*Helper function, repeats a row.***Description**

This function creates a matrix that repeats vc, dm times where each row is equal to the vc vector.

**Usage**

```
VTM(vc, dm)
```

**Arguments**

- |    |                       |
|----|-----------------------|
| vc | the vector to repeat. |
| dm | number of rows.       |

**Value**

a matrix that repeats vc, dm times where each row is equal to the vc vector

Wi.FUN

*Computes the inverse probability of censoring weights for a specific t0 and tau***Description**

Computes the inverse probability of censoring weights for a specific t0 and tau i.e. this computes  $I(t0 < XL < t0+tau)*DL/G(XL) + I(XL>t0+tau)/G(t0+tau)$  where XL = min(TL, C), TL is the time of the long term event, C is the censoring time, DL = 1\*(TL < C) and G() is the estimate survival probability for censoring estimated using the Kaplan Meier estimator

**Usage**

```
Wi.FUN(data, t0, tau, weight.given = NULL)
```

**Arguments**

- |              |  |
|--------------|--|
| data         | n by k matrix, where k>= 2. A data matrix where the first column is XL = min(TL, C) where TL is the time of the long term event, C is the censoring time, and the second column is DL = 1*(TL < C) |
| t0           | the landmark time..  |
| tau          | the residual survival time for which probabilities are calculated.   |
| weight.given | an optional weight to be incorporated in estimation of this weight   |

**Value**

Inverse probability of censoring weight.

**Author(s)**

Layla Parast

**Examples**

```
data(data_example_landpred)
t0=2
tau = 8

W2i <- Wi.FUN(data_example_landpred[,1],data = data_example_landpred[,c(1:2)],t0=t0,tau=tau)
```

# Index

- \* **IPCW**
  - Wi.FUN, 17
- \* **arith**
  - cumsum2, 5
- \* **bandwidth**
  - Kern.FUN, 8
- \* **datasets**
  - data\_example\_landpred, 5
- \* **internal**
  - coefficient\_se, 4
  - fit\_glm\_normal, 6
  - fit\_short\_glm, 6
  - mse\_cv, 10
- \* **kernel**
  - Kern.FUN, 8
- \* **matrix**
  - VTM, 17
- \* **prediction accuracy**
  - AUC.landmark, 2
  - BS.landmark, 3
- \* **survival**
  - AUC.landmark, 2
  - BS.landmark, 3
  - Wi.FUN, 17

AUC.landmark, 2  
BS.landmark, 3  
coef.landpred\_model\_continuous, 4  
coefficient\_se, 4  
cumsum2, 5  
data\_example\_landpred, 5  
fit\_glm\_normal, 6  
fit\_short\_glm, 6  
get\_model, 7  
Ghat.FUN, 7  
helper.si, 8  
Kern.FUN, 8  
landpred, 9

- mse\_cv, 10
- optimize\_bandwidth, 11
- predict.landpred\_model\_continuous, 12
- predict.landpred\_model\_discrete, 12
- print.landpred\_model\_continuous, 13
- print.landpred\_model\_discrete, 13
- print.landpred\_object, 14
- Prob.Covariate, 14
- Prob.Covariate.ShortEvent, 15
- Prob.Null, 15
- summary.landpred\_model\_continuous, 16
- summary.landpred\_object, 16
- VTM, 17
- Wi.FUN, 17