

# A note about values

Håvard Rue (hrue@r-inla.org) & Sigrunn Holbek Sørbye (sigrunn.sorbye@uit.no)

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## Introduction

This is a short note discussing the argument `values` in `f()`, to avoid unfortunate confusion. This is especially an issue for models like `ar1`, `ar` and `seasonal`, which are only defined for integer-valued arguments.

Consider the AR1-model

$$x_t = \phi x_{t-1} + \epsilon_t$$

for  $t = 1, 2, \dots, m$ .

In practice, we might use the AR1-model for various sequential indexes, like years, weeks, etc. In these cases, it is natural to write

```
y ~ ... + f(year, model = "ar1", ...)
```

where for example `year` is given by

```
year <- 2000:2025
```

What happens internally, is that the `year`-variable specifies the `values` (time points) at which the AR1-model is defined. So, the variable `year` would be mapped to the  $t$ -index, which runs from 1 to  $m$ .

To be more specific, a mapping between `year` and the  $t$ -index is defined as

```
values <- sort(unique(year[!is.na(year)]))
values
```

```
## [1] 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012
## [14] 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025
```

```
map.year.to.t <- function(year, values) {
  a <- numeric(length(year))
  for(i in seq_along(year))
    a[i] = which(year[i] == values)
  return (a)
}
yy <- c(2000, 2020, 2025)
print(cbind(year=yy, t=map.year.to.t(yy, values)))
```

```
##      year  t
## [1,] 2000  1
## [2,] 2020 21
## [3,] 2025 26
```

An unfortunate consequence is that if some years are missing, then “confusing” things happen. Suppose, we do not have observations for some years,

```
year <- c(2000:2020, 2023:2025)
```

Then the above mapping still applies but with

```
values <- sort(unique(year[!is.na(year)]))
values
```

```
## [1] 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012
## [14] 2013 2014 2015 2016 2017 2018 2019 2020 2023 2024 2025
```

in which the years 2021 and 2022 are missing. The internal mapping now gives

```
yy <- c(2000, 2020, 2025)
print(cbind(year = yy, t = map.year.to.t(yy, values)))
```

```
##      year  t
## [1,] 2000  1
## [2,] 2020 21
## [3,] 2025 24
```

Note that for  $\text{year} = 2025$  the index  $t$  is now 24 and not 26 as earlier. This implies that the correlation between year 2020 and 2023 is  $\phi$  while it was  $\phi^3$  as before. Often, this is not what we expect to happen.

Another case is when the argument denote non-integers, like

```
time <- c(1.1, 2.2, 3.3, 4.4, 10.0)
```

A call using `f(time, model = "ar1")` would run, but `time` will be mapped to the discrete indexes  $1, \dots, 5$ . This is because the models `ar1/ar/seasonal` are defined on integers and cannot handle irregular locations.

We can ensure consistent behaviour by adding the argument `values` to `f()`, specifying for which indexes the model is defined, like

```
y ~ ... + f(year, model = "ar1", values = 2000:2025)
```

or, if we want predictions for additional years,

```
y ~ ... + f(year, model = "ar1", values = 1990:2035)
```

In this case, the `values` are defined by the corresponding named argument and not by the variable `year` as before

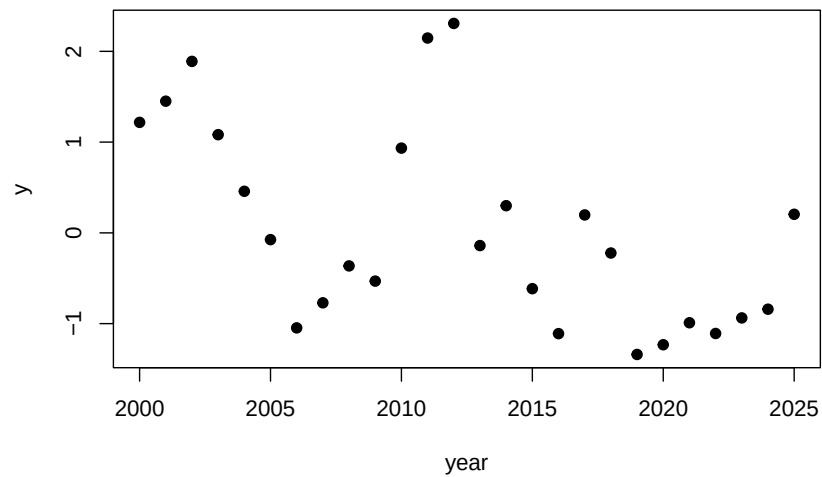
```
values <- sort(unique(values[!is.na(values)]))
```

The requirement for `year` is now that these are either NA-values or a subset of the defined `values`.

## An example

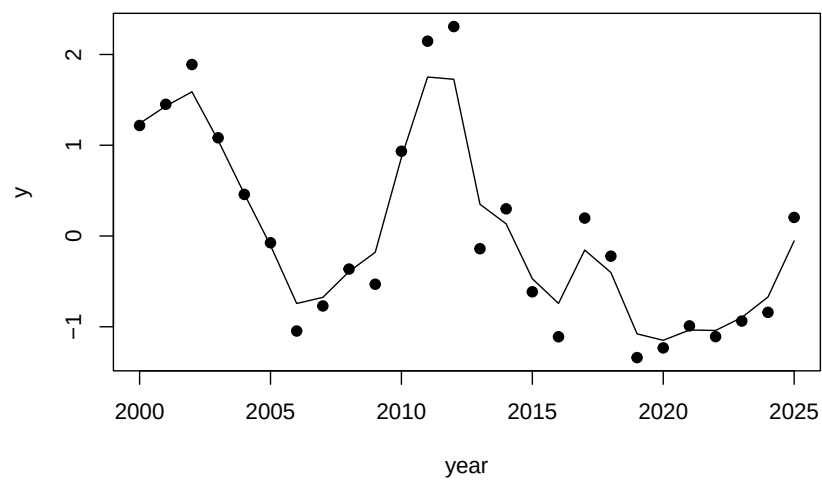
This is a simple simulated example demonstrating the issue about `values`, having missing observations.

```
year <- 2000:2025
n <- length(year)
phi <- 0.9
phi.intern <- inla.models()$latent$ar1$hyper$theta2$to.theta(phi)
x <- scale(arima.sim(n, model=list(ar=phi)))
s <- 0.3
y <- x + rnorm(n, sd=s)
plot(year, y, pch=19)
```



Let us fit an AR1 model

```
r <- inla(y ~ -1 + f(year, model="ar1",
  hyper = list(prec = list(initial=0,
    fixed=TRUE),
    rho = list(initial=phi.intern,
    fixed=TRUE))),
  family="gaussian",
  control.family = list(hyper = list(
    prec = list(initial=log(1/s^2),
    fixed = TRUE))),
  data = data.frame(y, year))
plot(year, y, pch=19)
lines(year, r$summary.random$year$mean)
```



Assume `y[10]` is missing, then we will get the wrong results by removing `y[10]` from the data, because values are not given (hence `year[10]` is removed as well).

```
## this is correct
y[10] <- NA
r <- inla(y ~ -1 + f(year, model="ar1",
                    hyper = list(prec = list(initial=0,
                                              fixed=TRUE),
                                rho = list(initial=phi.intern,
                                              fixed=TRUE))),
          family="gaussian",
          control.family = list(hyper = list(
                                prec = list(initial=log(1/s^2),
                                              fixed = TRUE))),
          data = data.frame(y, year)) ## missing data included

## this is wrong
rr <- inla(y ~ -1 + f(year, model="ar1",
                     hyper = list(prec = list(initial=0,
                                               fixed=TRUE),
                                   rho = list(initial=phi.intern,
                                               fixed=TRUE))),
           family="gaussian",
           control.family = list(hyper = list(
                                   prec = list(initial=log(1/s^2),
                                               fixed = TRUE))),
           data = data.frame(y, year)[-10,]) ## missing data removed

## we compare the results
r$mlik - rr$mlik
```

```
##                                [,1]
## log marginal-likelihood (integration) 1.3
## log marginal-likelihood (Gaussian)    1.3
```

If we add values, then we get the correct result when we remove missing data.

```
rrr <- inla(y ~ -1 + f(year, model="ar1",
                      values = 2000:2025, ## values added
                      hyper = list(prec = list(initial=0,
                                                fixed=TRUE),
                                    rho = list(initial=phi.intern,
                                                fixed=TRUE))),
            family="gaussian",
            control.family = list(hyper = list(
                                    prec = list(initial=log(1/s^2),
                                                fixed = TRUE))),
            data = data.frame(y, year)[-10,]) ## missing data removed

## we compare the results
r$mlik - rrr$mlik
```

```
##                                [,1]
## log marginal-likelihood (integration) 0
## log marginal-likelihood (Gaussian)    0
```

## Another example

We can extend the range using `values`, to get predictions.

```
values <- 1990:2035
r <- inla(y ~ -1 + f(year, model="ar1",
  values = values, ## values added
  hyper = list(prec = list(initial=0,
    fixed=TRUE),
    rho = list(initial=phi.intern,
    fixed=TRUE))),
  family="gaussian",
  control.family = list(hyper = list(
    prec = list(initial=log(1/s^2),
    fixed = TRUE))),
  data = list(y=y, year=year, values=values))
plot(year, y, pch=19, xlim=range(values))
lines(values, r$summary.random$year$mean)
```

