

Package ‘paramix’

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Title Aggregate and Disaggregate Continuous Parameters for
Compartmental Models

Version 0.0.2

Description A convenient framework for aggregating and disaggregating continuously
varying parameters (for example, case fatality ratio, with age) for proper
parametrization of lower-resolution compartmental models (for example, with
broad age categories) and subsequent upscaling of model outputs to high resolution
(for example, as needed when calculating age-sensitive measures like years-life-lost).

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Author Carl Pearson [aut, cre] (ORCID:
<<https://orcid.org/0000-0003-0701-7860>>),
Simon Proctor [aut] (ORCID: <<https://orcid.org/0000-0002-0380-1503>>),
Lucy Goodfellow [aut] (ORCID: <<https://orcid.org/0009-0004-0434-5863>>)

Maintainer Carl Pearson <carl.ab.pearson@gmail.com>

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alembic	<i>Create the Blending and Distilling Object</i>
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Description

Based on model and output partitions, create a mixing partition and associated weights. That table of mixing values can be used to properly discretize a continuously varying (or otherwise high resolution) parameter to a relatively low resolution compartmental stratification, and then subsequently allocate the low-resolution model outcomes into the most likely high-resolution output partitions.

Usage

```
alembic(  
  f_param,  
  f_pop,  
  model_partition,  
  output_partition,  
  pars_interp_opts = interpolate_opts(fun = stats::splinefun, kind = "point", method =  
    "natural"),  
  pop_interp_opts = interpolate_opts(fun = stats::approxfun, kind = "integral", method =  
    "constant", yleft = 0, yright = 0)  
)
```

Arguments

f_param	a function, f(x) which transforms the feature (e.g. age), to yield the parameter values. Alternatively, a data.frame where the first column is the feature and the second is the parameter; see xy.coords() for details. If the latter, combined with pars_interp_opts to create a parameter function.
f_pop	like f_param, either a density function (though it does not have to integrate to 1 like a pdf) or a data.frame of values. If the latter, it is treated as a series of populations within intervals, and then interpolated with pop_interp_opts to create a density function.
model_partition	a numeric vector of cut points, which define the partitioning that will be used in the model; must be length > 1

output_partition	the partition of the underlying feature; must be length > 1
pars_interp_opts	a list, minimally with an element fun, corresponding to an interpolation function. Defaults to <code>splinefun()</code> "natural" interpolation.
pop_interp_opts	like pars_interp_opts, but for density. Defaults to <code>approxfun()</code> "constant" interpolation.

Details

The alembic function creates a mixing table, which governs the conversion between model and output partitions. The mixing table is a `data.table::data.table()` where each row corresponds to a mixing partition c_i , which is the union of the model and output partitions - i.e. each unique boundary is included. Within each row, there is a weight and relpop entry, corresponding to

$$\text{weight}_i = \int_{c_i} f(x)\rho(x)dx$$

$$\text{relpop}_i = \int_{c_i} \rho(x)dx$$

where $f(x)$ corresponds to the `f_param` argument and $\rho(x)$ corresponds to the `f_pop` argument.

This mixing table is used in the `blend()` and `distill()` functions.

When blending, the appropriately weighted parameter for a model partition is the sum of weight_i divided by the relpop_i associated with mixing partition(s) in that model partition. This corresponds to the properly, population weighted average of that parameter over the partition.

When distilling, model outcomes associated with weighted parameter from partition j are distributed to the output partition i by the sum of weights in mixing partitions in both j and i divided by the total weight in j . This corresponds to proportional allocation according to Bayes rule: the outcome in the model partition was relatively more likely in the higher weight mixing partition.

Value

a `data.table` with columns: `model_partition`, `output_partition`, `weight` and `relpop`. The first two columns identify partition lower bounds, for both the model and output, the other values are associated with; the combination of `model_partition` and `output_partition` forms a unique identifier, but individually they may appear multiple times. Generally, this object is only useful as an input to the `blend()` and `distill()` tools.

See Also

`blend()`
`distill()`

Examples

```

iffr_levin <- function(age_in_years) {
  (10^(-3.27 + 0.0524 * age_in_years))/100
}
age_limits <- c(seq(0, 69, by = 5), 70, 80, 101)
age_pyramid <- data.frame(
  from = 0:101, weight = ifelse(0:101 < 65, 1, .99^(0:101-64))
)
age_pyramid$weight[102] <- 0
# flat age distribution, then 1% annual deaths, no one lives past 101
iffr_alembic <- alembic(iffr_levin, age_pyramid, age_limits, 0:101)

```

blend

Blend Parameters

Description

blend extracts aggregate parameters from an alembic object.

Usage

```
blend(alembic_dt)
```

Arguments

alembic_dt an [alembic\(\)](#) return value

Value

a data.table of with two columns: model_partition (partition lower bounds) and value (parameter values for those partitions)

Examples

```

iffr_levin <- function(age_in_years) {
  (10^(-3.27 + 0.0524 * age_in_years))/100
}

age_limits <- c(seq(0, 69, by = 5), 70, 80, 101)
age_pyramid <- data.frame(
  from = 0:101, weight = ifelse(0:101 < 65, 1, .99^(0:101-64))
)
age_pyramid$weight[102] <- 0
# flat age distribution, then 1% annual deaths, no one lives past 101

alembic_dt <- alembic(iffr_levin, age_pyramid, age_limits, 0:101)

iffr_blend <- blend(alembic_dt)

```

```

# the actual function
plot(
  60:100, ifr_levin(60:100),
  xlab = "age (years)", ylab = "IFR", type = "l"
)
# the properly aggregated blocks
lines(
  age_limits, c(ifr_blend$value, tail(ifr_blend$value, 1)),
  type = "s", col = "dodgerblue"
)
# naively aggregated blocks
ifr_naive <- ifr_levin(head(age_limits, -1) + diff(age_limits)/2)
lines(
  age_limits, c(ifr_naive, tail(ifr_naive, 1)),
  type = "s", col = "firebrick"
)
# properly aggregated, but not accounting for age distribution
bad_alembic_dt <- alembic(
  ifr_levin,
  within(age_pyramid, weight <- c(rep(1, 101), 0)), age_limits, 0:101
)
ifr_unif <- blend(bad_alembic_dt)
lines(
  age_limits, c(ifr_unif$value, tail(ifr_unif$value, 1)),
  type = "s", col = "darkgreen"
)

```

distill

Distill Outcomes

Description

distill takes a low-age resolution outcome, for example deaths, and proportionally distributes that outcome into a higher age resolution for use in subsequent analyses like years-life-lost style calculations.

Usage

```
distill(alembic_dt, outcomes_dt, groupcol = names(outcomes_dt)[1])
```

Arguments

alembic_dt	an <code>alembic()</code> return value
outcomes_dt	a long-format data.frame with a column either named from or model_from and a column value (other columns will be silently ignored)
groupcol	a string, the name of the outcome model group column. The outcomes_dt[[groupcol]] column must match the model_partition lower bounds, as provided when constructing the alembic_dt with <code>alembic()</code> .

Details

When the value column is re-calculated, note that it will aggregate all rows with matching groupcol entries in outcomes_dt. If you need to group by other features in your input data (e.g. if you need to distill outcomes across multiple simulation outputs or at multiple time points), that has to be done by external grouping then calling distill().

Value

a data.frame, with output_partition and recalculated value column

Examples

```
ifr_levin <- function(age_in_years) {
  (10^(-3.27 + 0.0524 * age_in_years))/100
}

age_limits <- c(seq(0, 69, by = 5), 70, 80, 101)
age_pyramid <- data.frame(
  from = 0:101, weight = ifelse(0:101 < 65, 1, .99^(0:101-64))
)
age_pyramid$weight[102] <- 0
# flat age distribution, then 1% annual deaths, no one lives past 101

alembic_dt <- alembic(ifr_levin, age_pyramid, age_limits, 0:101)

results <- data.frame(model_partition = head(age_limits, -1))
results$value <- 10
distill(alembic_dt, results)
```

distill_summary

Distillation Calculation Comparison Summary

Description

Implements several approaches to imputing higher resolution outcomes, then tables them up for convenient plotting.

Usage

```
distill_summary(alembic_dt, outcomes_dt, groupcol = names(outcomes_dt)[1])
```

Arguments

alembic_dt	an <code>alembic()</code> return value
outcomes_dt	a long-format data.frame with a column either named from or model_from and a column value (other columns will be silently ignored)

`groupcol` a string, the name of the outcome model group column. The `outcomes_dt[[groupcol]]` column must match the `model_partition` lower bounds, as provided when constructing the `alembic_dt` with `alembic()`.

Value

a `data.table`, columns:

- `partition`, the feature point corresponding to the value
- `value`, the translated `outcomes_dt$value`
- `method`, a factor with levels indicating how feature points are selected, and how value is weighted to those features:
 - `f_mid`: features at the `alembic_dt` outcome partitions, each with value corresponding to the total value of the corresponding model partition, divided by the number of outcome partitions in that model partition
 - `f_mean`: the features at the model partition means
 - `mean_f`: the features distributed according to the relative density in the outcome partitions
 - `wm_f`: the `alembic()` approach

Examples

```
library(data.table)
f_param <- function(age_in_years) {
  (10^(-3.27 + 0.0524 * age_in_years))/100
}

model_partition <- c(0, 5, 20, 65, 101)
density_dt <- data.table(
  from = 0:101, weight = c(rep(1, 66), exp(-0.075 * 1:35), 0)
)
alembic_dt <- alembic(
  f_param, density_dt, model_partition, seq(0, 101, by = 1L)
)

# for simplicity, assume a uniform force-of-infection across ages =>
# infections proportion to population density.
model_outcomes_dt <- density_dt[from != max(from), .(value = sum(f_param(from) * weight)),
  by = .(model_from = model_partition[findInterval(from, model_partition)])
]

ds_dt <- distill_summary(alembic_dt, model_outcomes_dt)
```

interpolate_opts *Interpolation Options*

Description

Creates and interpolation options object for use with `alembic()`.

Usage

```
interpolate_opts(fun, kind = c("point", "integral"), ...)
```

Arguments

<code>fun</code>	a function
<code>kind</code>	a string; either "point" or "integral". How to interpret the x, y values being interpolated. Either as point observations of a function OR as the integral of the function over the interval.
<code>...</code>	arbitrary other arguments, but checked against signature of fun

Details

This method creates the interpolation object for use with `alembic()`; this is a convenience method, which does basic validation on arguments and ensures the information used in `alembic()` to do interpolation is available.

The `...` arguments will be provided to `fun` when it is invoked to interpolate the tabular "functional" form of arguments to `alembic()`. If `fun` has an argument `kind`, that parameter will also be passed when invoking the function; if not, then the input data will be transformed to $\{x, z\}$ pairs, such that $x_{i+1} - x_i * z_i = y_i$ - i.e., transforming to a point value and a functional form which is assumed constant until the next partition.

Value

a list, with `fun` and `kind` keys, as well as whatever other valid keys appear in `...`

Examples

```
interpolate_opts(
  fun = stats::splinesfun, method = "natural", kind = "point"
)
interpolate_opts(
  fun = stats::approxfun, method = "constant", yleft = 0, yright = 0,
  kind = "integral"
)
```

Description

Implements several approaches to computing partition-aggregated parameters, then tables them up for convenient plotting.

Usage

```
parameter_summary(f_param, f_pop, model_partition, resolution = 101L)
```

Arguments

- | | |
|-----------------|--|
| f_param | a function, $f(x)$ which transforms the feature (e.g. age), to yield the parameter values. Alternatively, a <code>data.frame</code> where the first column is the feature and the second is the parameter; see xy.coords() for details. If the latter, combined with <code>pars_interp_opts</code> to create a parameter function. |
| f_pop | like <code>f_param</code> , either a density function (though it does not have to integrate to 1 like a pdf) or a <code>data.frame</code> of values. If the latter, it is treated as a series of populations within intervals, and then interpolated with <code>pop_interp_opts</code> to create a density function. |
| model_partition | a numeric vector of cut points, which define the partitioning that will be used in the model; must be length > 1 |
| resolution | the number of points to calculate for the underlying <code>f_param</code> function. The default 101 points means 100 partitions. |

Value

a `data.table`, columns:

- `model_category`, a integer corresponding to which of the intervals of `model_partition` the `x` value is in
- `x`, a numeric series from the first to last elements of `model_partition` with length `resolution`
- `method`, a factor with levels:
 - `f_val`: `f_param(x)`
 - `f_mid`: `f_param(x_mid)`, where `x_mid` is the midpoint `x` of the `model_category`
 - `f_mean`: `f_param(weighted.mean(x, w))`, where `w` defined by densities and `model_category`
 - `mean_f`: `weighted.mean(f_param(x), w)`, same as previous
 - `wm_f`: the result as if having used `paramix::blend()`; this should be very similar to `mean_f`, though will be slightly different since `blend` uses `integrate()`

Examples

```
# COVID IFR from Levin et al 2020 https://doi.org/10.1007/s10654-020-00698-1
f_param <- function(age_in_years) {
  (10^(-3.27 + 0.0524 * age_in_years))/100
}

densities <- data.frame(
  from = 0:101,
  weight = c(rep(1, 66), exp(-0.075 * 1:35), 0)
)

model_partition <- c(0, 5, 20, 65, 101)

ps_dt <- parameter_summary(f_param, densities, model_partition)
ps_dt

ggplot(ps_dt) + aes(x, y = value, color = method) +
  geom_line(data = function(dt) subset(dt, method == "f_val")) +
  geom_step(data = function(dt) subset(dt, method != "f_val")) +
  theme_bw() + theme(
    legend.position = "inside", legend.position.inside = c(0.05, 0.95),
    legend.justification = c(0, 1)
  ) + scale_color_discrete(
    "Method", labels = c(
      f_val = "f(x)", f_mid = "f(mid(x))", f_mean = "f(E[x])",
      mean_f = "discrete E[f(x)]", wm_f = "integrated E[f(x)]"
    )
  ) +
  scale_x_continuous("Age", breaks = seq(0, 100, by = 10)) +
  scale_y_log10("IFR", breaks = 10^c(-6, -4, -2, 0), limits = 10^c(-6, 0))
```

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