Package 'factorana'

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Type Package

Title Factor Model Estimation with Latent Variables

Version 1.7.1

Description A flexible framework for estimating factor models with multiple latent variables. Supports linear, probit, ordered probit, and multinomial logit model components. Features include multi-stage estimation, automatic parameter initialization, analytical gradients and Hessians, and parallel estimation. Methods are described in Heckman, Humphries, and Veramendi (2016) <doi:10.1016/j.jeconom.2015.12.001>, Heckman, Humphries, and Veramendi (2018) <doi:10.1086/698760>, and Humphries, Joensen, and Veramendi (2024) <doi:10.1257/pandp.20241026>.

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Contents

bootstrap_factorana *Single-node bootstrap driver (convenience over the primitives)*

Description

Generates R bootstrap samples, fits every replicate in a local loop (each fit is restartable via `stage_dir/sample_<id>.rds`), and collects the results. For a single estimation stage on one machine. For multi-stage, distributed, or restart-heavy workflows, use the primitives (`generate_bootstrap_samples()`, `bootstrap_fit_sample()`, `collect_bootstrap()`) directly so each stage and sample is an independent, resumable job.

Usage

```
bootstrap_factorana(
  model_system,
  data,
  R,
  cluster = NULL,
  stage_dir,
  control = NULL,
  seed = NULL,
  conf_level = 0.95,
  ...
)
```

Arguments

model_system	A `model_system`.
data	Data frame used for estimation.
R	Number of bootstrap replicates.
cluster	Optional cluster id: a column name in `data` or a vector of length `nrow(data)`. If `NULL`, an ordinary row (nonparametric) bootstrap is used (each row is its own cluster).
stage_dir	Directory for per-sample result files (and the samples object).
control	Estimation control.
seed	Optional integer seed for reproducibility.
conf_level	Confidence level for percentile intervals.
...	Passed to `estimate_model_rcpp()`.

Value

A `factorana_bootstrap` object (see `collect_bootstrap()`).

See Also

`generate_bootstrap_samples()`, `bootstrap_fit_sample()`, `collect_bootstrap()`

bootstrap_factorana_multistage *Multi-stage single-node bootstrap driver*

Description

Runs a multi-stage bootstrap on one machine: for each replicate, fits each stage in turn, chaining every stage on that replicate's own earlier-stage fits. Each (stage, sample) fit is written to `dir/stage_<k>/sample_<id>.rds` and skipped if it already exists, so an interrupted run resumes where it stopped. If a stage fails to converge for a replicate, its later stages are skipped (so a bad earlier fit is not chained forward).

Usage

```
bootstrap_factorana_multistage(
  stage_builders,
  data,
  R,
  cluster = NULL,
  dir,
  control = NULL,
  seed = NULL,
  conf_level = 0.95,
  ...
)
```

Arguments

`stage_builders`	A list of functions, one per stage, each with the signature `function(prev_fits, data)` returning the `model_system` for that stage. For the first stage `prev_fits` is an empty list; for later stages `prev_fits[[k]]` is the fitted result of stage `k` for the current replicate (use it to construct the stage's `previous_stage`).
`data`	Data frame.
`R`	Number of bootstrap replicates.
`cluster`	Optional cluster id (column name in `data` or a vector); see `generate_bootstrap_samples()`.
`dir`	Directory holding the samples object and the per-stage subdirectories (`stage_1/`, `stage_2/`, ...).
`control`	Estimation control.
`seed`	Optional seed for sample generation.
`conf_level`	Confidence level for percentile intervals.
`...`	Passed to `estimate_model_rcpp()` for every stage fit.

Details

For distributed (multi-node) runs, drive the same per-stage, per-sample work with `bootstrap_fit_sample()` directly (one array-job task per sample), which is what this driver does internally.

Value

A factorana_bootstrap_multistage list with a per-stage collect_bootstrap() summary in stages and final pointing at the last stage.

See Also

bootstrap_factorana(), bootstrap_fit_sample(), collect_bootstrap()

---

bootstrap_fit_sample *Estimate one stage for one bootstrap sample (restartable)*

Description

Fits model_system to the data reweighted by bootstrap sample sample_id and writes the result to stage_dir/sample_<id>.rds. If that file already exists it returns immediately, so an interrupted run (or a rebooted node) simply re-runs the missing samples. This is the unit of work to scatter across a compute cluster (one array-job task per sample_id).

Usage

```
bootstrap_fit_sample(
  model_system,
  data,
  samples,
  sample_id,
  stage_dir,
  control = NULL,
  ...,
  weight_col = ".bootw",
  overwrite = FALSE
)
```

Arguments

model_system	A model_system (already carrying previous_stage for this sample if estimating a later stage).
data	The full data frame used to generate the samples.
samples	A factorana_boot_samples object or a path to a bootstrap_samples.rds file.
sample_id	Integer replicate index (1..R).
stage_dir	Directory for this stage's per-sample result files.
control	Estimation control (see define_estimation_control()).
...	Passed to estimate_model_rcpp() (e.g. optimizer, parallel).
weight_col	Name of the temporary weight column added to the data.
overwrite	If TRUE, re-estimate even if the output file exists.

Details

Rows whose bootstrap weight is zero are dropped, and the remaining rows are given their integer frequency weight via `model_system$weights`. For a multi-stage workflow, set `model_system$previous_stage` (built from this sample's previous-stage fit) before calling, so each replicate chains on its own earlier stage.

Value

Invisibly, the path to the written result file.

See Also

`generate_bootstrap_samples()`, `collect_bootstrap()`

`build_dynamic_previous_stage` *Build a Stage 2 previous_stage object from a dynamic measurement fit*

Description

Constructs a dummy `previous_stage` result that plugs the anchor-period measurement intercepts into every factor slot, pairs them with the (tied) shared loadings and residual sigmas / thresholds, and is ready to pass as `previous_stage` to a Stage 2 `SE_linear` or `SE_quadratic` model via `define_model_system`.

Usage

```
build_dynamic_previous_stage(dyn, stage1_result, data, anchor_period = 1L)
```

Arguments

`dyn`	A `dynamic_measurement` object from `define_dynamic_measurement`.
`stage1_result`	The result object from `estimate_model_rcpp(dyn$model_system, ...)`.
`data`	The same data frame passed to `define_dynamic_measurement` (needed to rebuild the dummy model system's components; components do not retain the data they were defined on).
`anchor_period`	Integer index into `dyn$period_prefixes` giving the period whose measurement intercepts should be carried into Stage 2. The recommended choice is 1: under `E[f_1] = 0` this period's intercepts identify the true DGP intercepts. Default: 1.

Value

A list suitable as `previous_stage` in `define_model_system`: has fields `model_system`, `estimates`, `std_errors`, `convergence`, `loglik`. Every per-component measurement parameter is the corresponding Stage 1 estimate, with the intercepts overwritten to the anchor-period values for all periods.

See Also

define_dynamic_measurement.

`cleanup_parallel_workers` *Clean up orphaned parallel worker processes*

Description

When using parallel estimation with Ctrl-C interrupts, worker processes may continue running after the main process exits. This function finds and terminates any orphaned R worker processes started by the parallel package.

Usage

```
cleanup_parallel_workers(signal = "TERM", verbose = TRUE, list_only = FALSE)
```

Arguments

`signal`	Signal to send (default "TERM" for graceful shutdown, use "KILL" for force)
`verbose`	Whether to print messages (default TRUE)
`list_only`	If TRUE, only list potential workers without killing them (default FALSE)

Value

Invisible NULL (or vector of PIDs if list_only = TRUE)

Examples

```
# Safe to run: list potential orphaned parallel workers without killing them.
cleanup_parallel_workers(list_only = TRUE, verbose = FALSE)


# After interrupting a parallel job with Ctrl-C, terminate orphaned workers:
cleanup_parallel_workers()

# Force kill if graceful shutdown doesn't work:
cleanup_parallel_workers(signal = "KILL")
```

collect_bootstrap *Collect finished bootstrap samples into standard errors and intervals*

Description

Reads every `sample_<id>.rds` in `stage_dir`, stacks the estimates, and returns the bootstrap covariance, bootstrap standard errors, and percentile confidence intervals. Non-converged replicates are dropped by default.

Usage

```
collect_bootstrap(stage_dir, conf_level = 0.95, require_convergence = TRUE)
```

Arguments

`stage_dir`	Directory of per-sample result files.
`conf_level`	Confidence level for percentile intervals.
`require_convergence`	Drop replicates with `convergence != 0`.

Value

A `factorana_bootstrap` list with `boot_se`, `boot_cov`, `ci` (a data frame of percentile intervals and bootstrap SEs), the stacked `estimates`, and counts (`n_total`, `n_converged`, `n_used`).

See Also

`generate_bootstrap_samples()`, `bootstrap_fit_sample()`

components_table *Create a components table for a single model*

Description

Creates a table with model components as columns and parameter types as rows. This is similar to how SEM/CFA software displays results.

Usage

```
components_table(result, digits = 3, show_se = TRUE, stars = TRUE)
```

Arguments

`result`	A factorana_result object from estimate_model_rcpp()
`digits`	Number of decimal places (default 3)
`show_se`	Show standard errors in parentheses (default TRUE)
`stars`	Add significance stars (default TRUE)

Value

A data frame with the formatted table

Examples

```
# Estimate a small model and display the components table
set.seed(1); n <- 200
f <- rnorm(n)
dat <- data.frame(intercept = 1,
                  y1 = 1.0 * f + rnorm(n, 0, 0.5),
                  y2 = 0.8 * f + rnorm(n, 0, 0.5))
fm <- define_factor_model(n_factors = 1)
mc1 <- define_model_component("m1", dat, "y1", fm,
  covariates = "intercept", model_type = "linear",
  loading_normalization = 1)
mc2 <- define_model_component("m2", dat, "y2", fm,
  covariates = "intercept", model_type = "linear",
  loading_normalization = NA_real_)
ms <- define_model_system(components = list(mc1, mc2), factor = fm)
ctrl <- define_estimation_control(n_quad_points = 8, num_cores = 1)
fit <- estimate_model_rcpp(ms, dat, control = ctrl,
  optimizer = "nlminb", parallel = FALSE, verbose = FALSE)

components_table(fit)
```

---

components_to_latex *Export components table to LaTeX*

Description

Creates a LaTeX table from a factorana_result with components as columns.

Usage

```
components_to_latex(
  result,
  digits = 3,
  file = NULL,
  caption = NULL,
  label = NULL,
  stars = TRUE,
  note = NULL,
  booktabs = TRUE
)
```

Arguments

result	A factorana_result object from estimate_model_rcpp()
digits	Number of decimal places (default 3)
file	Optional file path to write the LaTeX table
caption	Table caption (optional)
label	Table label for cross-referencing (optional)
stars	Add significance stars (default TRUE)
note	Footnote text (optional, default includes significance codes)
booktabs	Use booktabs package formatting (default TRUE)

Value

A character string containing the LaTeX table code

---

define_dynamic_measurement

Define a dynamic measurement system for longitudinal factor models

---

Description

Builds a Stage 1 measurement model for a single latent construct observed at two or more time points. Measurement invariance is imposed on loadings and residual sigmas (tied across periods via equality_constraints), while measurement intercepts are left period-specific. This is the recommended Stage 1 setup for an SE_linear or SE_quadratic structural model in the second stage.

Usage

```
define_dynamic_measurement(
  data,
  items,
  period_prefixes,
  model_type = "linear",
  n_categories = NULL,
  covariates = "intercept",
  evaluation_indicator = NULL
)
```

Arguments

data	Wide-format data frame. Must contain a column named paste0(prefix, item) for every combination of period_prefixes and items, plus any columns named in covariates and evaluation_indicator.
items	Character vector of item names (e.g., c("m1", "m2", "m3")).

`period_prefixes`
: Character vector of column prefixes, one per period. Column names are assembled as `paste0(prefix, item)`. E.g., `c("Y_t1_", "Y_t2_")` yields data columns `"Y_t1_m1"`, `"Y_t2_m1"`, etc. Length of `period_prefixes` determines the number of latent factors in Stage 1 (one per period).

`model_type`
: One of `"linear"`, `"oprobit"`, `"probit"`, `"logit"`. The same type is used for every item and every period.

`n_categories`
: Required for `model_type = "oprobit"`; the number of ordered categories (shared across items and periods).

`covariates`
: Character vector of covariate column names; default `"intercept"`. Same covariates for every component.

`evaluation_indicator`
: Name of a column with 0/1 values indicating which observations contribute to each component's likelihood; `NULL` to use all rows.

Details

Why period-specific intercepts? Under the usual factor-model identification convention `E[f_k] = 0` for every factor k, pooling measurement intercepts across periods biases them by $\lambda_m \cdot E[f_2]/2$ when the period-mean drifts between waves, an artefact that propagates into an under-estimate of `se_intercept` in Stage 2. Leaving the intercepts period-specific and carrying the wave-1 intercepts into Stage 2 (via `build_dynamic_previous_stage`) sidesteps the bias.

Value

An object of class `"dynamic_measurement"`: a list with

- `model_system`: a `model_system` object ready to pass to `estimate_model_rcpp`.
- `factor_model`: the underlying `factor_model`.
- `items`, `period_prefixes`, `model_type`, `n_categories`, `covariates`, `evaluation_indicator`: the inputs, kept for use by `build_dynamic_previous_stage`.

See Also

`build_dynamic_previous_stage` constructs the Stage 2 `previous_stage` object from the Stage 1 estimation result.

Examples

```
# Simulate a simple dynamic single-factor model
set.seed(1); n <- 500
f1 <- rnorm(n); eps <- rnorm(n, 0, sqrt(0.5))
f2 <- 0.4 + 0.6 * f1 + eps
dat <- data.frame(
  intercept = 1, eval = 1L,
  Y_t1_m1 = 1.5 + f1 + rnorm(n, 0, 0.7),
  Y_t1_m2 = 1.0 + 0.9 * f1 + rnorm(n, 0, 0.75),
  Y_t1_m3 = 0.8 + 1.1 * f1 + rnorm(n, 0, 0.65),
  Y_t2_m1 = 1.5 + f2 + rnorm(n, 0, 0.7),
```

```
  Y_t2_m2 = 1.0 + 0.9 * f2 + rnorm(n, 0, 0.75),
  Y_t2_m3 = 0.8 + 1.1 * f2 + rnorm(n, 0, 0.65)
)
dyn <- define_dynamic_measurement(
  data = dat, items = c("m1", "m2", "m3"),
  period_prefixes = c("Y_t1_", "Y_t2_"),
  model_type = "linear", evaluation_indicator = "eval"
)
ctrl <- define_estimation_control(n_quad_points = 8, num_cores = 1)
s1 <- estimate_model_rcpp(dyn$model_system, dat, control = ctrl,
                          optimizer = "nlminb", parallel = FALSE,
                          verbose = FALSE)
prev <- build_dynamic_previous_stage(dyn, s1, dat)   # Stage 2 input
```

`define_estimation_control` *Define estimation control settings*

Description

Define estimation control settings

Usage

```
define_estimation_control(
  n_quad_points = 16,
  num_cores = 1,
  cluster_type = "auto",
  adaptive_integration = FALSE,
  adapt_int_thresh = 0.5
)
```

Arguments

`n_quad_points`	Integer. Number of Gauss-Hermite quadrature points for numerical integration (default = 16)
`num_cores`	Integer. Number of processes to use for parallel estimation (default = 1)
`cluster_type`	Character. Type of parallel cluster to use: "auto" (default), "FORK", or "PSOCK". "auto" uses FORK on Unix (faster, shared memory) and PSOCK on Windows. "FORK" forces fork-based parallelism (Unix only, faster due to shared memory). "PSOCK" forces socket-based parallelism (works on all platforms, more overhead).
`adaptive_integration`	Logical. Whether to use adaptive integration in second-stage estimation (default = FALSE). When TRUE, the number of quadrature points per observation is determined based on the standard error of factor scores from a previous estimation stage.

adapt_int_thresh
: Numeric. Threshold for adaptive integration (default = 0.5). Smaller values use more integration points. The formula is: `n_quad_obs = 1 + 2 * floor(factor_se / factor_var / adapt_int_thresh)`. When factor_se is small relative to factor variance, fewer quadrature points are used. Legacy code default is 0.5.

Details

Adaptive integration is useful in two-stage estimation where factor scores have been estimated in a first stage. The key insight is that observations with well-identified factor scores (small SE) need fewer integration points, while observations with poorly-identified factors (large SE) need full quadrature.

To use adaptive integration:

1. Estimate Stage 1 model to get factor scores via `estimate_factorscores_rcpp()`
2. Initialize FactorModel for Stage 2 via `initialize_factor_model_cpp()`
3. Call `set_adaptive_quadrature_cpp()` with factor scores, SEs, and variances
4. Run estimation - the adaptive settings are applied automatically

The diagnostic output from `set_adaptive_quadrature_cpp(verbose=TRUE)` shows:

- Distribution of integration points across observations
- Average integration points vs standard (shows computational savings)
- Computational reduction percentage

Value

An object of class estimation_control containing control settings

---

`define_factor_model` *Define latent factor model structure*

Description

Creates an object of class `"factor_model"` that specifies the structure of the unobserved latent factors. This includes the number of factors and mixture components. Loading constraints are specified at the component level via `define_model_component()`. Numerical integration settings (quadrature points) are specified in `define_estimation_control()`.

Usage

```
define_factor_model(
  n_factors,
  n_types = 1,
  factor_structure = "independent",
  n_mixtures = 1,
  factor_covariates = NULL,
  se_covariates = NULL
)
```

Arguments

`n_factors` Integer. Number of latent factors (>=0). Use 0 for models without latent factors.

`n_types` Integer. Number of types (>=1)

`factor_structure`
Character. Structure of factor dependencies. Options:

- `"independent"` (default): Factors are independent
- `"correlation"`: Correlated factors via Cholesky decomposition (2 factors only)
- `"SE_linear"`: Structural equation `f_k = alpha + alpha_1 f_1 + ... + epsilon`
- `"SE_quadratic"`: Adds quadratic terms: `f_k = alpha + alpha_1 f_1 + alpha_q1 f_1^2 + ... +`
- `"SE_interactions"`: Adds cross-product terms `alpha_ab f_a f_b` for input factor pairs a < b
- `"SE_full"`: Adds both quadratic and cross-product terms. Cross-product terms require at least two input factors (n_factors >= 3); with a single input factor `"SE_interactions"` downgrades to `"SE_linear"` and `"SE_full"` downgrades to `"SE_quadratic"`.

`n_mixtures` Integer. Number of discrete mixtures (default = 1, allowed: 1-3)

`factor_covariates`
Character vector. Names of covariates that shift factor means. When specified, the factor distribution becomes f_i ~ N((X_i - mean(X)) * gamma, Sigma) where X_i is the covariate vector for observation i and gamma is a matrix of coefficients (one column per factor). This allows factor means to vary by observed characteristics. The covariates must be present in the data passed to `estimate_model_rcpp()`. **Note:** All covariates are automatically demeaned internally to ensure the overall factor mean is zero (required for identification). Including an intercept/constant has no effect since it becomes zero after demeaning. For SE structural-equation structures, covariates only affect input factor means (not the outcome factor which is determined by the structural equation).

`se_covariates` Character vector. Names of covariates that directly affect the outcome factor in SE models. When specified, the structural equation becomes f_k = intercept + sum(alpha_j * f_j) + sum(beta_m * X_m) + epsilon. Valid for any SE structural-equation factor structure (SE_linear, SE_quadratic, SE_interactions, SE_full). All covariates are automatically demeaned internally for identification.

Value

An object of class "factor_model"

Examples

```
# Single factor model
fm <- define_factor_model(n_factors = 1)

# Two-factor structural equation model
fm_se <- define_factor_model(n_factors = 2, factor_structure = "SE_linear")
```

`define_model_component` *Define a model component*

Description

Define a model component

Usage

```
define_model_component(
  name,
  data,
  outcome,
  factor,
  evaluation_indicator = NULL,
  covariates = NULL,
  model_type = c("linear", "logit", "probit", "oprobit"),
  intercept = TRUE,
  num_choices = 2,
  nrank = NULL,
  exclude_chosen = TRUE,
  rankshare_var = NULL,
  loading_normalization = NULL,
  factor_index = NULL,
  factor_spec = c("linear", "quadratic", "interactions", "full"),
  use_types = FALSE,
  skip_collinearity_check = FALSE
)
```

Arguments

`name`	name of model component ####Long name and s name (like in the C++)
`data`	data.frame for validation
`outcome`	Character. Name of the outcome variable.
`factor`	model. Object of Class factor_model.
`evaluation_indicator`	Character (optional). Variable used for evaluation subsample.
`covariates`	Character vector. Names of covariate columns in `data` (include `"intercept"` for an intercept). Defaults to `NULL` (no covariates), so a pure measurement item needs no `covariates` argument.
`model_type`	Character. Type of model (e.g., "linear", "logit", "probit").
`intercept`	Logical. Whether to include an intercept (default = TRUE).
`num_choices`	Integer. Number of choices (for multinomial models).

nrank Integer (optional). Rank for exploded multinomial logit.

exclude_chosen Logical. For exploded logit, whether to exclude already-chosen alternatives from later ranks (default TRUE). Set to FALSE for exploded nested logit where the same nest can be chosen multiple times.

rankshare_var Character (optional). Column name (or prefix) for rank-share correction variables. These provide rank-and-choice-specific adjustments to the linear predictor. Data layout: (num_choices-1) * nrank columns, accessed as rankshare_var + (num_choices-1)*irank + icat for irank=0..nrank-1, icat=0..num_choices-2.

loading_normalization
Numeric vector of length n_factors. This is how an item is assigned to factor(s): one entry per factor, with the convention

- 0 –> item does not load on that factor (off-factor),
- 1 –> loading fixed at 1 (the anchor that sets the factor's scale),
- NA –> loading is free (estimated). For example, in a 3-factor model c(NA, 0, 0) means the item loads freely on factor 1 only, and c(1, 0, 0) makes it the anchor for factor 1. Each factor needs exactly one anchor (a 1) somewhere in the system for identification. If NULL (default), all loadings are free. See also factor_index for a shorthand when an item loads on a single factor.

factor_index Integer (optional). Convenience for assigning an item to a single factor: the item loads only on factor factor_index (all other factors fixed at 0), and loading_normalization is then interpreted as the single value at that position (NA for a free loading, 1 for the anchor, or a fixed number). For instance factor_index = 2, loading_normalization = 1 is shorthand for loading_normalization = c(0, 1, 0) in a 3-factor model. Leave NULL to specify the full vector directly.

factor_spec Character. Specification for factor terms in linear predictor.

- "linear" (default): Only linear factor terms (lambda * f)
- "quadratic": Linear + quadratic terms (lambda * f + lambda_quad * f^2)
- "interactions": Linear + interaction terms (lambda * f + lambda_inter * f_j * f_k)
- "full": Linear + quadratic + interaction terms Note: Interaction terms require n_factors >= 2.

use_types Logical. Whether this component uses type-specific intercepts when n_types > 1 in the factor model. Default FALSE. When TRUE and n_types > 1, the component will have (n_types - 1) type-specific intercept parameters that shift the linear predictor for each non-reference type. This allows types to affect outcome models while keeping measurement models type-invariant.

skip_collinearity_check
Logical. If TRUE, skip the multicollinearity check on the design matrix. Useful when many coefficients will be fixed via fix_coefficient() after component creation, which resolves the collinearity. Default FALSE.

Value

An object of class "model_component". A list representing the model component

Examples

```
dat <- data.frame(y = rnorm(50), intercept = 1)
fm <- define_factor_model(n_factors = 1)
mc <- define_model_component("Y", dat, "y", fm,
  covariates = "intercept", model_type = "linear",
  loading_normalization = 1)

# Multi-factor: assign an item to a factor with the length-n_factors vector.
dat2 <- data.frame(y1 = rnorm(50), y2 = rnorm(50))
fm2 <- define_factor_model(n_factors = 2)
# item loads on factor 1 only, as its anchor (loading fixed at 1):
a1 <- define_model_component("a1", dat2, "y1", fm2,
  loading_normalization = c(1, 0))
# item loads freely on factor 2 only -- same thing via factor_index:
a2 <- define_model_component("a2", dat2, "y2", fm2,
  factor_index = 2, loading_normalization = NA_real_)
```

---

define_model_system *Define a model system*

Description

Define a model system

Usage

```
define_model_system(
  components,
  factor,
  previous_stage = NULL,
  weights = NULL,
  equality_constraints = NULL,
  free_params = NULL
)
```

Arguments

components	A named list of model_component objects
factor	A factor_model object
previous_stage	Optional result from a previous estimation stage. If provided, the previous stage components and parameters will be fixed and prepended to the new components. This enables sequential/multi-stage estimation where early stages are held fixed while later stages are optimized.
weights	Optional. Name of a variable in the data containing observation weights. When specified, each observation's contribution to the log-likelihood is multiplied by its weight. Useful for survey weights, importance sampling, or giving different observations different influence on the estimation. Weights should be positive. The variable is extracted from the data passed to `estimate_model_rcpp()`.

`equality_constraints`
: Optional. A list of character vectors, where each vector specifies parameter names that should be constrained to be equal during estimation. The first parameter in each group is the "primary" (freely estimated), and all other parameters in the group are set equal to the primary. Example: `list(c("Y1_loading_1", "Y2_loading_2"), c("Y1_sigma", "Y2_sigma"))` This is useful for measurement invariance constraints in longitudinal models.

`free_params`
: Optional. A character vector of parameter names from previous_stage that should remain FREE (not fixed) in the current stage. This allows selectively freeing specific parameters while keeping others fixed. Commonly used to free factor variances while keeping measurement loadings/thresholds fixed. Example: `c("factor_var_1", "factor_var_2")` to free factor variances. Only used when previous_stage is provided.

Value

An object of class "model_system". A list of model_component objects and one factor_model object.

Examples

```
dat <- data.frame(y1 = rnorm(50), y2 = rnorm(50), intercept = 1)
fm <- define_factor_model(n_factors = 1)
mc1 <- define_model_component("m1", dat, "y1", fm,
  covariates = "intercept", model_type = "linear",
  loading_normalization = 1)
mc2 <- define_model_component("m2", dat, "y2", fm,
  covariates = "intercept", model_type = "linear",
  loading_normalization = NA_real_)
ms <- define_model_system(components = list(mc1, mc2), factor = fm)
```

---

disable_adaptive_quadrature_cpp

Disable adaptive quadrature

Description

Reverts to standard (non-adaptive) quadrature integration.

Usage

```
disable_adaptive_quadrature_cpp(fm_ptr)
```

Arguments

`fm_ptr`
: External pointer to FactorModel object

Value

No return value. Called for its side effect of disabling adaptive quadrature and clearing any observation weights on the FactorModel pointed to by `fm_ptr`.

`estimate_and_write` *Run estimation and write standard output files*

Description

Calls estimate_model(), then writes the four expected output files:

- model_config.csv
- meas_par.csv
- system_inits_long.csv
- simulated_data.csv

Usage

```
estimate_and_write(
  model_system,
  factor_model,
  control,
  data = NULL,
  results_dir
)
```

Arguments

`model_system`	model_system object
`factor_model`	factor_model object
`control`	estimation_control object
`data`	Optional data frame (to save as simulated_data.csv)
`results_dir`	Directory for writing output files. This argument is required; the function writes nothing without an explicit path. Use `tempdir()` in examples or tests.

Value

Invisibly returns a list with two components: `results` (a data frame of initial parameter values per component, as produced by `estimate_model()`) and `packed` (a list with `values` and `ses` giving the packed parameter vector and standard errors written to `meas_par.csv`). Called primarily for the side effect of writing `model_config.csv`, `meas_par.csv`, `system_inits_long.csv`, and optionally `simulated_data.csv` into `results_dir`.

`estimate_factorscores_rcpp` *Estimate Factor Scores*

Description

Estimates factor scores for each observation after model estimation. The model parameters are held fixed at their estimated values, and factor scores are computed as the posterior mode for each observation.

Usage

```
estimate_factorscores_rcpp(
  result,
  data,
  control = NULL,
  parallel = FALSE,
  verbose = TRUE,
  include_prior = FALSE,
  id_var = NULL
)
```

Arguments

`result`	A factorana_result object from estimate_model_rcpp()
`data`	Data frame containing all variables (same as used in estimation)
`control`	Optional estimation control object. If NULL, uses default.
`parallel`	Whether to use parallel computation (default FALSE). When TRUE, uses the num_cores setting from control.
`verbose`	Whether to print progress (default TRUE)
`include_prior`	Whether to include the factor prior in likelihood/SE computation (default FALSE). When FALSE, matches legacy C++ behavior where SEs are based only on observation likelihood. When TRUE, includes the prior contribution to the Hessian, resulting in smaller SEs.
`id_var`	Optional character string specifying the name of an ID variable in data. If provided, this variable is included in the output data frame for easier merging with other datasets. The ID values are taken from the original data in the order observations were processed. Note: The ID column must be numeric (not character) since data is converted to a numeric matrix. For character IDs, use the obs_id column to merge with your original data.

Details

Factor scores are estimated by maximizing the posterior density:

$$L(f|y_i, \theta) = p(y_i|f, \theta) \cdot \phi(f|0, \sigma^2)$$

where:

- f is the vector of factor values for observation i
- y_i is the observed data for observation i
- θ are the fixed model parameters (from previous estimation)
- $\phi(f|0, \sigma^2)$ is the normal prior on factors

Standard errors are computed from the diagonal of the inverse Hessian of the log-posterior at the mode. By default (include_prior=FALSE), the SE is based only on the observation likelihood Hessian, matching the legacy C++ implementation. Set include_prior=TRUE to include the prior's Hessian contribution (-1/sigma^2) which produces smaller SEs.

When parallel=TRUE, observations are distributed across cores using doParallel/foreach, with each worker processing a subset of observations.

Value

A data frame with columns:

- `obs_id` - Observation index (1-based)
- `<id_var>` - ID variable values (if id_var was specified)
- `factor_1, factor_2, ...` - Estimated factor scores
- `se_factor_1, se_factor_2, ...` - Standard errors
- `converged` - Whether optimization converged for this observation
- `log_posterior` - Log-posterior value at the mode

Examples

```
# Estimate a small one-factor model, then recover factor scores
set.seed(1); n <- 200
f <- rnorm(n)
dat <- data.frame(intercept = 1,
                  y1 = 1.0 * f + rnorm(n, 0, 0.5),
                  y2 = 0.8 * f + rnorm(n, 0, 0.5))
fm <- define_factor_model(n_factors = 1)
mc1 <- define_model_component("m1", dat, "y1", fm,
  covariates = "intercept", model_type = "linear",
  loading_normalization = 1)
mc2 <- define_model_component("m2", dat, "y2", fm,
  covariates = "intercept", model_type = "linear",
  loading_normalization = NA_real_)
ms <- define_model_system(components = list(mc1, mc2), factor = fm)
ctrl <- define_estimation_control(n_quad_points = 8, num_cores = 1)
fit <- estimate_model_rcpp(ms, dat, control = ctrl,
  optimizer = "nlminb", parallel = FALSE, verbose = FALSE)

fscores <- estimate_factorscores_rcpp(fit, dat, control = ctrl,
                                      parallel = FALSE, verbose = FALSE)
head(fscores)
```

estimate_model *Estimate model*

Description

Estimate model

Usage

```
estimate_model(ms, control)
```

Arguments

ms	an object of class model_system
control	an object of class estimation_control

Value

description

estimate_model_rcpp *Estimate factor model using R-based optimization*

Description

This function estimates a factor model by optimizing the likelihood using C++ for fast evaluation and R for optimization and parallelization.

Usage

```
estimate_model_rcpp(
  model_system,
  data,
  init_params = NULL,
  control = NULL,
  optimizer = "nlminb",
  parallel = TRUE,
  verbose = TRUE,
  max_restarts = 5,
  factor_scores = NULL,
  factor_ses = NULL,
  factor_vars = NULL,
  init_factor_scores = NULL,
  checkpoint_file = NULL
)
```

Arguments

`model_system`	A model_system object from define_model_system()
`data`	Data frame containing all variables
`init_params`	Initial parameter values (optional)
`control`	Estimation control object from define_estimation_control()
`optimizer`	Optimizer to use (default "nloptr"): • `"nloptr"` - L-BFGS via nloptr (gradient only, no Hessian) • `"optim"` - L-BFGS-B via stats::optim (gradient only, no Hessian) • `"nlminb"` - Uses analytical gradient AND Hessian (more efficient!) • `"trust"` - Trust region method with analytical Hessian (requires trustOptim package)
`parallel`	Whether to use parallel computation (default TRUE)
`verbose`	Whether to print progress (default TRUE)
`max_restarts`	Maximum number of eigenvector-based restarts for escaping saddle points (default 5). Set to 0 to disable.
`factor_scores`	Matrix (n_obs x n_factors) of factor score estimates from a previous stage. Used for adaptive quadrature. (default NULL)
`factor_ses`	Matrix (n_obs x n_factors) of factor score standard errors from a previous stage. Used for adaptive quadrature. (default NULL)
`factor_vars`	Named numeric vector of factor variances from a previous stage. Used for adaptive quadrature. (default NULL)
`init_factor_scores`	Matrix (n_obs x n_factors) of factor scores to use for initializing factor loadings. When provided, loadings are estimated by treating factor scores as regressors, giving better starting values than the default (0.5). Useful for two-stage estimation where Stage 1 factor scores can improve Stage 2 initialization. (default NULL)
`checkpoint_file`	Path to file for saving checkpoint parameters during optimization. When specified, parameters are saved each time the Hessian is evaluated at a point with improved likelihood. Useful for long-running estimations that may need to be restarted. The file contains parameter names and values as CSV with metadata headers. (default NULL = no checkpointing)

Details

For maximum efficiency, use `optimizer = "nlminb"` or `optimizer = "trust"` which exploit the analytical Hessian computed in C++. The default L-BFGS methods only use the gradient and approximate the Hessian from gradient history.

When optimization fails to converge (possibly at a saddle point), the function will attempt to escape by moving in the direction of negative Hessian eigenvalues. This is controlled by the `max_restarts` parameter.

Value

List with parameter estimates, standard errors, log-likelihood, etc.

See Also

vcov_factorana() and robust_se() for robust and cluster-robust standard errors from a fitted model.

Examples

```
# Simulate a simple one-factor model with two linear indicators
set.seed(1); n <- 100
f <- rnorm(n)
dat <- data.frame(intercept = 1,
  y1 = 1.0 * f + rnorm(n, 0, 0.5),
  y2 = 0.8 * f + rnorm(n, 0, 0.5))
fm <- define_factor_model(n_factors = 1)
mc1 <- define_model_component("m1", dat, "y1", fm,
  covariates = "intercept", model_type = "linear",
  loading_normalization = 1)
mc2 <- define_model_component("m2", dat, "y2", fm,
  covariates = "intercept", model_type = "linear",
  loading_normalization = NA_real_)
ms <- define_model_system(components = list(mc1, mc2), factor = fm)
ctrl <- define_estimation_control(n_quad_points = 8, num_cores = 1)
result <- estimate_model_rcpp(ms, dat, control = ctrl,
  optimizer = "nlminb", parallel = FALSE, verbose = FALSE)
result$estimates
# Robust (Huber-White) standard errors from the same fit:
robust_se(result, dat, type = "robust")
```

---

evaluate_factorscore_likelihood_cpp

Evaluate log-likelihood for a single observation at given factor values

---

Description

Used for factor score estimation. The model parameters are held fixed, and the factor values are treated as the parameters to optimize.

Usage

```
evaluate_factorscore_likelihood_cpp(
  fm_ptr,
  iobs,
  factor_values,
  model_params,
```

```
  compute_gradient = FALSE,
  compute_hessian = FALSE,
  include_prior = TRUE
)
```

Arguments

fm_ptr	External pointer to FactorModel object
iobs	Observation index (0-based)
factor_values	Vector of factor values (size n_factors)
model_params	Vector of ALL model parameters (from previous estimation)
compute_gradient	Whether to compute gradient (default FALSE)
compute_hessian	Whether to compute Hessian (default FALSE)
include_prior	Whether to include factor prior in likelihood (default TRUE). Set to FALSE to match legacy C++ behavior (observation likelihood only).

Value

List with log-likelihood, gradient (if requested), and Hessian (if requested)

---

evaluate_likelihood_cpp

Evaluate log-likelihood for given parameters

Description

Evaluate log-likelihood for given parameters

Usage

```
evaluate_likelihood_cpp(
  fm_ptr,
  params,
  compute_gradient = FALSE,
  compute_hessian = FALSE
)
```

Arguments

fm_ptr	External pointer to FactorModel object
params	Vector of parameters
compute_gradient	Whether to compute gradient (default FALSE)
compute_hessian	Whether to compute Hessian (default FALSE)

Value

List with:

- logLikelihood: scalar log-likelihood value
- gradient: vector of length n_param_free (if requested)
- hessian: vector of length n_param_free*(n_param_free+1)/2 stored as upper-triangular in row-major order (if requested). To expand to full symmetric matrix in R: `idx <- 1; for(i in 1:n) for(j in i:n) { H[i,j] <- H[j,i] <- hess[idx]; idx <- idx + 1 }`

`evaluate_loglik_only_cpp` *Evaluate log-likelihood only (for optimization)*

Description

Evaluate log-likelihood only (for optimization)

Usage

```
evaluate_loglik_only_cpp(fm_ptr, params)
```

Arguments

`fm_ptr`	External pointer to FactorModel object
`params`	Vector of parameters

Value

Log-likelihood value

`evaluate_obs_scores_cpp` *Per-observation scores for sandwich / cluster-robust standard errors*

Description

Evaluates the model at the supplied FREE parameters and returns the per-observation score matrix d(log L_i)/d(theta_free), i.e. the gradient of each observation's marginal (factor-integrated) log-likelihood with respect to the free parameters. Rows are observations (in the FactorModel's data order), columns are free parameters. Summing the rows reproduces the total gradient returned by `evaluate_likelihood_cpp`. This is the "meat" ingredient of a sandwich covariance estimator.

Usage

```
evaluate_obs_scores_cpp(fm_ptr, params)
```

Arguments

fm_ptr	External pointer to FactorModel object
params	Vector of FREE parameters (typically the MLE)

Value

Numeric matrix (nobs x nparam_free) of per-observation scores

---

extract_free_params_cpp *Extract free parameters from full parameter vector*

Description

Given a full parameter vector (including fixed parameters), extract only the free parameters based on the model's fixed parameter mask.

Usage

```
extract_free_params_cpp(fm_ptr, full_params)
```

Arguments

fm_ptr	External pointer to FactorModel object
full_params	Full parameter vector (size n_param)

Value

Vector of free parameters only (size n_param_free)

---

fix_coefficient *Fix a coefficient in a model component*

Description

Constrains a regression coefficient (beta) to a fixed value during estimation. The coefficient will not be optimized - it remains at the specified value.

Usage

```
fix_coefficient(component, covariate, value, choice = NULL)
```

Arguments

component	A model_component object from define_model_component()
covariate	Character. Name of the covariate whose coefficient to fix. Must be one of the covariates specified when creating the component.
value	Numeric. The value to fix the coefficient to.
choice	Integer (optional). For multinomial logit models with num_choices > 2, specifies which choice's coefficient to fix. Must be between 1 and (num_choices - 1). Choice 0 (reference category) has no parameters. For other model types, this should be NULL (default).

Details

Fixed coefficients are stored in the component and used during:

- Parameter initialization: fixed values are used directly (no estimation)
- Optimization: fixed parameters are excluded from the optimization
- Likelihood evaluation: fixed values are inserted into the parameter vector

Note: This function only fixes regression coefficients (betas), not:

- Factor loadings (use loading_normalization in define_model_component)
- Sigma (for linear models)
- Thresholds (for ordered probit)

Value

The modified model_component object with the fixed coefficient constraint added.

Examples

```
# Build a minimal model component and fix a coefficient
dat <- data.frame(intercept = 1, x1 = rnorm(20), y = rnorm(20))
fm <- define_factor_model(n_factors = 1)
mc <- define_model_component(
  name = "y", data = dat, outcome = "y", factor = fm,
  covariates = c("intercept", "x1"), model_type = "linear",
  loading_normalization = 1
)

# Fix intercept to 0 and x1 coefficient to 0.1
mc <- fix_coefficient(mc, covariate = "intercept", value = 0.0)
mc <- fix_coefficient(mc, covariate = "x1", value = 0.1)
length(mc$fixed_coefficients)  # 2 constraints stored on the component
```

fix_factor_param *Fix a factor-distribution parameter at model-definition time*

Description

Constrains a parameter in the latent-factor distribution (factor variance, SE-equation slope / intercept / residual variance, type-probability intercept, type-probability loading, factor-mean covariate coefficient, or SE covariate coefficient) to a fixed value. The parameter will be held at that value during estimation, excluded from the optimizer's free vector, and reported in `result$estimates` with `result$std_errors == 0` and `result$param_table$fixed == TRUE`.

Usage

```
fix_factor_param(factor_model, name, value = NULL)
```

Arguments

`factor_model`	A `factor_model` object from `define_factor_model()`.
`name`	Either a single character string naming the factor-distribution parameter to fix, or a character vector of names paired element-wise with `value`, or a named numeric vector whose names are the parameter names and whose values are the fixed values (in which case `value` must be omitted).
`value`	Numeric. The value to fix the parameter to. Pass `NA` to release a previously fixed parameter (unfix). Length must match `name` (length 1 is recycled).

Details

Use this for substantive restrictions known at model-definition time, e.g., setting a `type_<t>_loading_<k>` to 0 when factor `k` is known not to enter the type-probability model. Estimating such a loading free can leak identification, push the optimizer along a flat ridge, and inflate the standard errors of the remaining type-model parameters.

Value

The modified `factor_model` object. The fix is stored in `factor_model$fixed_params` as a named numeric vector.

Conflicts with `previous_stage` / `free_params`

When `define_model_system(previous_stage = ..., free_params = ...)` is used, `fix_factor_param()` always wins. The user-fixed value is the binding constraint; any value for the same name in `previous_stage$ estimates` is ignored, and inclusion of the same name in `free_params` is silently honoured (the parameter stays fixed regardless). A warning is emitted once per conflict so accidental misuse surfaces during debugging without spamming routine workflows.

Auto-fixed slots

For SE structures, type_<t>_loading_<n_factors> (the type loading on the outcome factor) is auto-fixed at 0 because the type probability model must depend only on input factors. Calling fix_factor_param(fm, "type_<t>_loading_<n_factors>", 0) is a no-op. Calling it with any non-zero value is an error.

When a factor variance is non-identified (no measurement component fixes a non-zero loading on that factor), it is normally auto-fixed at its initial value of 1. An explicit fix_factor_param(fm, "factor_var_<k>", v) overrides the auto-fix and uses the user-supplied value.

Examples

```
fm <- define_factor_model(n_factors = 3, n_types = 2,
                          factor_structure = "SE_linear")

# Single fix
fm <- fix_factor_param(fm, "type_2_loading_2", 0.0)

# Batch via named numeric
fm <- fix_factor_param(fm, c(type_2_loading_2 = 0.0,
                             type_2_loading_3 = 0.0))

# Unfix
fm <- fix_factor_param(fm, "type_2_loading_2", NA_real_)
```

---

fix_type_intercepts *Fix type-specific intercepts to zero for a model component*

Description

For models with n_types > 1, each component has type-specific intercepts that shift the linear predictor for each non-reference type. This function constrains those intercepts to zero, effectively removing the type-specific shift for this component.

Usage

```
fix_type_intercepts(component, types = NULL, choice = NULL)
```

Arguments

component	A model_component object from define_model_component()
types	Integer vector (optional). Which types to fix. Must be between 2 and n_types (type 1 is the reference with no intercept). Default is NULL, meaning all non-reference types.
choice	Integer (optional). For multinomial logit models with num_choices > 2, specifies which choice's type intercepts to fix. Must be between 1 and (num_choices - 1). Default is NULL, meaning all choices.

Details

When n_types > 1, the model includes a latent type structure where different types can have different intercepts in each measurement equation. By default, these intercepts are freely estimated. Fixing them to zero constrains the outcome equation to have no type-specific shifts (though the type model loadings at the factor level may still differ).

This is useful when you want the type model to affect outcomes only through factor loadings, not through direct type-specific intercepts.

Fixed type intercepts are stored in the component and used during:

- Parameter initialization: fixed values are used directly (no estimation)
- Optimization: fixed parameters are excluded from the optimization
- Likelihood evaluation: fixed values are inserted into the parameter vector

Value

The modified model_component object with the fixed type intercept constraints added.

Examples

```
# Build a component with n_types = 2 and fix the type-2 intercept
dat <- data.frame(intercept = 1, y = rnorm(20))
fm <- define_factor_model(n_factors = 1, n_types = 2)
mc <- define_model_component(
  name = "y", data = dat, outcome = "y", factor = fm,
  covariates = "intercept", model_type = "linear",
  loading_normalization = 1, use_types = TRUE
)
mc <- fix_type_intercepts(mc)
length(mc$fixed_type_intercepts)
```

---

gauss_hermite_quadrature

Compute Gauss-Hermite quadrature nodes and weights

Description

Compute Gauss-Hermite quadrature nodes and weights

Usage

```
gauss_hermite_quadrature(n)
```

Arguments

n	Number of quadrature points

Value

List with nodes and weights

`generate_bootstrap_samples` *Generate and persist bootstrap resampling weights*

Description

Draws `R` bootstrap replicates by resampling clusters (or rows) with replacement and records, for each replicate, the integer frequency weight of every row (the number of times its cluster was drawn). The weights are saved once so that the same replicate is reproducible across nodes and across restarts.

Usage

```
generate_bootstrap_samples(data, R, cluster = NULL, dir = NULL, seed = NULL)
```

Arguments

`data`	Data frame used for estimation.
`R`	Number of bootstrap replicates.
`cluster`	Optional cluster id: a column name in `data` or a vector of length `nrow(data)`. If `NULL`, an ordinary row (nonparametric) bootstrap is used (each row is its own cluster).
`dir`	Optional directory to write the samples object to (as `bootstrap_samples.rds`). Created if it does not exist.
`seed`	Optional integer seed for reproducibility.

Value

A `factorana_boot_samples` list with `weights` (an integer `nrow(data)` x `R` matrix), and metadata (`R`, `nobs`, `n_clusters`). Invisibly returns the same object when `dir` is supplied.

See Also

`bootstrap_fit_sample()`, `collect_bootstrap()`, `bootstrap_factorana()`

get_parameter_info_cpp *Get parameter counts from FactorModel*

Description

Get parameter counts from FactorModel

Usage

```
get_parameter_info_cpp(fm_ptr)
```

Arguments

fm_ptr	External pointer to FactorModel object

Value

List with parameter count information

initialize_factor_model_cpp *Initialize a FactorModel C++ object from R model system*

Description

Initialize a FactorModel C++ object from R model system

Usage

```
initialize_factor_model_cpp(
  model_system,
  data,
  n_quad = 8L,
  init_params = NULL
)
```

Arguments

model_system	R model_system object
data	Data frame or matrix with all variables
n_quad	Number of quadrature points
init_params	Optional initial parameter vector (used to set fixed parameter values)

Value

External pointer to FactorModel object

`initialize_parameters` *Initialize parameters for factor model estimation*

Description

Estimates each model component separately in R (ignoring factors) to obtain good starting values. Also checks factor identification.

Usage

```
initialize_parameters(model_system, data, factor_scores = NULL, verbose = TRUE)
```

Arguments

`model_system`	A model_system object from define_model_system()
`data`	Data frame containing all variables
`factor_scores`	Optional matrix of factor scores (nobs x n_factors). When provided, factor loadings are estimated by including factor scores as regressors in the initialization regressions. This is useful for two-stage estimation where factor scores from Stage 1 can be used to initialize loadings in Stage 2 outcomes.
`verbose`	Whether to print progress (default TRUE)

Details

Factor identification: For each factor, if NO component has a non-zero fixed loading, then the factor variance is not identified and must be fixed to 1.0.

When `factor_scores` is provided, the initialization will estimate loadings by treating factor scores as additional regressors. For example, for a linear model: `Y ~ X + factor_scores` and the coefficients on factor_scores become the loading estimates. This typically provides better starting values than the default (0.5).

Value

List with:

- `init_params` - Initial parameter values
- `factor_variance_fixed` - Logical vector indicating which factor variances must be fixed

`print.components_table` *Print method for components_table*

Description

Print method for components_table

Usage

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

Arguments

`x`	A components_table object
`...`	Additional arguments (ignored)

Value

Invisibly returns `x`. Called for its side effect of printing a components-as-columns view of model estimates (one column per model component, factor parameters in a separate section) to the console.

`print.factorana_factorscores` *Print method for factorana_factorscores*

Description

Print method for factorana_factorscores

Usage

```
## S3 method for class 'factorana_factorscores'
print(x, n = 10, ...)
```

Arguments

`x`	A factorana_factorscores object
`n`	Number of rows to print (default 10)
`...`	Additional arguments (ignored)

Value

Invisibly returns `x`. Called for its side effect of printing a summary of the factor score estimates (convergence rate, per-factor summary statistics, and the first `n` rows) to the console.

print.factorana_result *Print and Summary Methods for Factor Model Results*

Description

Functions for displaying and exporting factor model estimation results in formatted tables, including LaTeX output. Print method for factorana_result objects

Usage

```
## S3 method for class 'factorana_result'
print(x, digits = 4, ...)
```

Arguments

x	A factorana_result object from estimate_model_rcpp()
digits	Number of decimal places (default 4)
...	Additional arguments (ignored)

Value

Invisibly returns x. Called for its side effect of printing a formatted summary (convergence status, log-likelihood, and a parameter table with estimates and standard errors) to the console.

print.factorana_table *Print method for factorana_table*

Description

Print method for factorana_table

Usage

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

Arguments

x	A factorana_table object
...	Additional arguments (ignored)

Value

Invisibly returns x. Called for its side effect of printing a side-by-side model-comparison table (parameters grouped by component, with estimates and standard errors) to the console.

print.model_component *Print method for model_component objects*

Description

Print method for model_component objects

Usage

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

Arguments

x	An object of class "model_component".
...	Not used.

Value

Invisibly returns x. Called for its side effect of printing a human-readable summary of the component to the console.

print.summary.factorana_result *Print method for summary.factorana_result*

Description

Print method for summary.factorana_result

Usage

```
## S3 method for class 'summary.factorana_result'
print(x, digits = 4, ...)
```

Arguments

x	A summary.factorana_result object
digits	Number of decimal places (default 4)
...	Additional arguments (ignored)

Value

Invisibly returns x. Called for its side effect of printing a detailed estimation summary (convergence, log-likelihood, and a coefficient table with z-values and significance stars) to the console.

`results_table` *Create a formatted results table for multiple models*

Description

Creates a table comparing estimates across multiple models, with standard errors in parentheses below each estimate.

Usage

```
results_table(
  ...,
  model_names = NULL,
  digits = 3,
  se_format = c("parentheses", "brackets", "below"),
  include_loglik = TRUE,
  include_n = TRUE,
  stars = TRUE
)
```

Arguments

`...`	One or more factorana_result objects, or a list of them
`model_names`	Optional character vector of model names for column headers
`digits`	Number of decimal places (default 3)
`se_format`	How to display standard errors: "parentheses" (default), "brackets", or "below"
`include_loglik`	Include log-likelihood row (default TRUE)
`include_n`	Include number of observations (default TRUE)
`stars`	Add significance stars (default TRUE)

Value

A data frame with the formatted table

Examples

```
# Estimate a small one-factor model and format the result as a table
set.seed(1); n <- 200
f <- rnorm(n)
dat <- data.frame(intercept = 1,
                  y1 = 1.0 * f + rnorm(n, 0, 0.5),
                  y2 = 0.8 * f + rnorm(n, 0, 0.5))
fm <- define_factor_model(n_factors = 1)
mc1 <- define_model_component("m1", dat, "y1", fm,
  covariates = "intercept", model_type = "linear",
  loading_normalization = 1)
```

```
mc2 <- define_model_component("m2", dat, "y2", fm,
  covariates = "intercept", model_type = "linear",
  loading_normalization = NA_real_)
ms <- define_model_system(components = list(mc1, mc2), factor = fm)
ctrl <- define_estimation_control(n_quad_points = 8, num_cores = 1)
fit <- estimate_model_rcpp(ms, dat, control = ctrl,
  optimizer = "nlminb", parallel = FALSE, verbose = FALSE)

results_table(fit, model_names = "Baseline")
```

`results_to_latex` *Export results table to LaTeX*

Description

Creates a LaTeX table from factorana results, suitable for academic papers.

Usage

```
results_to_latex(
  ...,
  model_names = NULL,
  digits = 3,
  file = NULL,
  caption = NULL,
  label = NULL,
  stars = TRUE,
  note = NULL,
  booktabs = TRUE,
  include_loglik = TRUE,
  param_labels = NULL
)
```

Arguments

`...`	One or more factorana_result objects, or a list of them
`model_names`	Optional character vector of model names for column headers
`digits`	Number of decimal places (default 3)
`file`	Optional file path to write the LaTeX table
`caption`	Table caption (optional)
`label`	Table label for cross-referencing (optional)
`stars`	Add significance stars (default TRUE)
`note`	Footnote text (optional, default includes significance codes)
`booktabs`	Use booktabs package formatting (default TRUE)
`include_loglik`	Include log-likelihood row (default TRUE)
`param_labels`	Optional named list mapping parameter names to display labels

Value

A character string containing the LaTeX table code

Examples

```
# Estimate a small model and export the result as a LaTeX table
set.seed(1); n <- 200
f <- rnorm(n)
dat <- data.frame(intercept = 1,
                  y1 = 1.0 * f + rnorm(n, 0, 0.5),
                  y2 = 0.8 * f + rnorm(n, 0, 0.5))
fm <- define_factor_model(n_factors = 1)
mc1 <- define_model_component("m1", dat, "y1", fm,
  covariates = "intercept", model_type = "linear",
  loading_normalization = 1)
mc2 <- define_model_component("m2", dat, "y2", fm,
  covariates = "intercept", model_type = "linear",
  loading_normalization = NA_real_)
ms <- define_model_system(components = list(mc1, mc2), factor = fm)
ctrl <- define_estimation_control(n_quad_points = 8, num_cores = 1)
fit <- estimate_model_rcpp(ms, dat, control = ctrl,
  optimizer = "nlminb", parallel = FALSE, verbose = FALSE)

# Return LaTeX as a character string
tex <- results_to_latex(fit, model_names = "Baseline")

# Or write to a file inside tempdir()
results_to_latex(fit,
                 model_names = "Baseline",
                 file = file.path(tempdir(), "results_table.tex"))
```

`robust_se` *Robust / cluster-robust standard errors for a fitted factorana model*

Description

Convenience wrapper returning `sqrt(diag(vcov_factorana(...)))` as a named vector over the full parameter vector. See `vcov_factorana()` for details and caveats.

Usage

```
robust_se(
  object,
  data,
  type = c("robust", "cluster"),
  cluster = NULL,
  n_quad = NULL,
  finite_sample = TRUE
)
```

Arguments

object	A factorana_result from estimate_model_rcpp().
data	The data frame used to fit object (same rows, same order).
type	Covariance type: "hessian" (inverse information, the default, reproduces the fit's standard errors), "robust" (Huber-White), or "cluster" (cluster-robust).
cluster	For type = "cluster": either the name of a column in data holding the cluster id, or a vector of length nrow(data).
n_quad	Number of quadrature points for recomputing the per-observation scores. Defaults to the value used at estimation (stored on object).
finite_sample	Logical; apply the usual finite-sample scaling (n/(n-k) for robust; G/(G-1) * (N-1)/(N-k) for cluster). Default TRUE.

Value

Named numeric vector of standard errors (fixed/tied parameters are 0).

See Also

vcov_factorana()

---

set_adaptive_quadrature_cpp

Set up adaptive quadrature based on factor scores and standard errors

---

Description

Enables adaptive integration where the number of quadrature points varies by observation based on the precision of factor score estimates. When factor scores are well-determined (small SE), fewer integration points are used. Importance sampling weights are computed automatically.

Usage

```
set_adaptive_quadrature_cpp(
  fm_ptr,
  factor_scores,
  factor_ses,
  factor_vars,
  threshold = 0.5,
  max_quad = 16L,
  verbose = TRUE
)
```

Arguments

fm_ptr	External pointer to FactorModel object
factor_scores	Matrix (n_obs x n_factors) of factor score estimates
factor_ses	Matrix (n_obs x n_factors) of standard errors
factor_vars	Vector (n_factors) of factor variances from previous stage
threshold	Threshold for determining quadrature points (default 0.5, matching legacy)
max_quad	Maximum quadrature points per factor (default 16)
verbose	Whether to print summary of adaptive quadrature setup (default TRUE)

Value

No return value. Called for its side effect of enabling adaptive quadrature on the FactorModel pointed to by fm_ptr and (when verbose = TRUE) printing a summary of the per-observation integration-point distribution.

---

set_observation_weights_cpp

Set observation weights for weighted likelihood estimation

Description

Sets per-observation weights for the likelihood calculation. When weights are set, each observation's contribution to the log-likelihood is multiplied by its weight. This is used for importance sampling in adaptive integration.

Usage

```
set_observation_weights_cpp(fm_ptr, weights)
```

Arguments

fm_ptr	External pointer to FactorModel object
weights	Numeric vector of observation weights (length = n_obs)

Value

No return value. Called for its side effect of setting the per-observation likelihood weights on the FactorModel pointed to by fm_ptr.

`simulate_factor_model` *Simulate data from a factorana model*

Description

Generates a simulated data set from a fitted or fully specified factorana model, following the legacy simulation algorithm: for each simulated unit a base row is drawn from `data` (with weights) to supply the covariates, the latent factor(s) are drawn from the model's unconditional distribution, and each component's outcome is drawn from its model (linear, probit, logit, or ordered probit) given the covariates and factors.

Usage

```
simulate_factor_model(
  object,
  data,
  n = NULL,
  params = NULL,
  weights = NULL,
  seed = NULL,
  detail = TRUE
)
```

Arguments

`object`	A `factorana_result` from `estimate_model_rcpp()`, or a `model_system`. If a `model_system`, supply `params`.
`data`	Data frame whose rows are resampled to supply the covariates.
`n`	Number of units to simulate (default: `nrow(data)`).
`params`	Named parameter vector. Defaults to `object$estimates` when `object` is a fitted result.
`weights`	Optional resampling weights: a column name in `data` or a numeric vector of length `nrow(data)`.
`seed`	Optional integer seed.
`detail`	If `TRUE` (default), include per-component linear predictor (`Vobs`), factor contributions (`Vfac<k>`), shock (`eps`), and choice probabilities, like the legacy detailed output.

Details

Supports all four model types (linear, probit, logit including multinomial, ordered probit), latent types, mixtures of normals, and the independent, correlated, and structural-equation (`SE_*`) factor structures. The simulated outcome column is named after each component's outcome variable, so the returned data frame can be re-estimated with the same model system.

Value

A data frame with one row per simulated unit: an `xid`, the resampled covariates, the drawn latent factor(s) (`factor_<k>`), and per component the simulated outcome (named after the component) plus, when `detail = TRUE`, the diagnostic columns.

See Also

`estimate_model_rcpp()`

`summary.factorana_result` *Summary method for factorana_result objects*

Description

Summary method for factorana_result objects

Usage

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

Arguments

`object`	A factorana_result object from estimate_model_rcpp()
`...`	Additional arguments (ignored)

Value

A summary object with formatted tables

`vcov_factorana` *Robust and cluster-robust covariance for a fitted factorana model*

Description

Computes a sandwich (Huber-White) or cluster-robust covariance matrix for a model fitted with `estimate_model_rcpp()`, as a post-hoc alternative to the default inverse-Hessian (model-based) standard errors. The estimator is

$$V = H^{-1} B H^{-1},$$

where the "bread" H^{-1} is the inverse observed information already computed at fit time and the "meat" B is built from the per-observation scores of the marginal (factor-integrated) log-likelihood: $B = \sum_i g_i g_i'$ (robust) or $B = \sum_c s_c s_c'$ with $s_c = \sum_{i \in c} g_i$ (cluster).

Usage

```
vcov_factorana(
  object,
  data,
  type = c("hessian", "robust", "cluster"),
  cluster = NULL,
  n_quad = NULL,
  finite_sample = TRUE
)
```

Arguments

`object`	A `factorana_result` from `estimate_model_rcpp()`.
`data`	The data frame used to fit `object` (same rows, same order).
`type`	Covariance type: `"hessian"` (inverse information, the default, reproduces the fit's standard errors), `"robust"` (Huber-White), or `"cluster"` (cluster-robust).
`cluster`	For `type = "cluster"`: either the name of a column in `data` holding the cluster id, or a vector of length `nrow(data)`.
`n_quad`	Number of quadrature points for recomputing the per-observation scores. Defaults to the value used at estimation (stored on `object`).
`finite_sample`	Logical; apply the usual finite-sample scaling (`n/(n-k)` for robust; `G/(G-1) * (N-1)/(N-k)` for cluster). Default `TRUE`.

Details

One factorana observation is one row of `data`, with its measurements integrated jointly over the latent factors. The latent factor therefore already models the within-row dependence. Clustering is meaningful only when a cluster groups several rows (for example several individuals in the same household or school, or several stacked person-wave rows for one person in a long-format second stage). With one row per cluster, the cluster estimator reduces to the ordinary robust estimator.

For two-stage estimates these standard errors treat the first-stage (measurement) parameters and any plug-in factor scores as known, so they understate uncertainty (the generated-regressor problem). Use a bootstrap that re-runs both stages for honest two-stage inference.

Value

A `nparam x nparam` covariance matrix over the full parameter vector, with row/column names equal to the parameter names. Fixed and equality-tied parameters have zero rows and columns. Standard errors are `sqrt(diag(.))`.

See Also

`estimate_model_rcpp()`

write_model_config_csv *Write a single CSV with all configuration rows*

Description

Write a single CSV with all configuration rows

Usage

```
write_model_config_csv(model_system, factor_model, estimation_control, file)
```

Arguments

model_system	a model_system object
factor_model	a factor_model object
estimation_control	an estimation_control object
file	Path to CSV to write. Required; pass an explicit path (use tempdir() in examples or tests).

Value

Invisibly returns the data frame of configuration rows that was written to file (columns section, component, key, value, dtype). Called primarily for its side effect of writing a CSV.

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