Package: NPBBBdesigns (via r-universe)

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Type Package

Title Construction and a-Efficiency of Nested Partially Balanced Bipartite Block Designs

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Description Construction and evaluation of nested partially balanced bipartite block (NPBBB) designs for comparing a set of test treatments with a set of control treatments under a nested (blocks within blocks) structure. Six systematic construction methods are provided: composing partially balanced bipartite block designs with nested balanced incomplete block designs; augmenting nested partially balanced incomplete block designs with controls; merging rows of group-divisible nested designs; direct construction from group-divisible schemes; and expansion of partially balanced incomplete block designs (Vinayaka et al. 2026: In press). The A-efficiencies of the block and sub-block classifications are computed against the A-optimal completely symmetric reference design, following the test-versus-control optimality framework of Gupta and Parsad (1996) <doi:10.1080/03610929608831743> and Vinayaka et al. (2024) <doi:10.1080/03610926.2023.2251623>. These designs are particularly suited to agricultural, animal husbandry, industrial, and clinical trials involving multiple standard checks under nested experimental conditions, such as multi-environment trials where field heterogeneity (blocks) and within-field variation (sub-blocks) must be controlled simultaneously.

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Contents

`a_value` *A-Value of an NPBBB Design for Test-Versus-Control Contrasts*

Description

Returns the trace of the variance-covariance matrix of the estimators of the $v_1 v_2$ elementary test-versus-control contrasts $\tau_i - \tau_j$ (i a test treatment, j a control treatment), that is, the sum of their variances. When the information matrix is completely symmetric within the test set and within the control set (which holds for the A-optimal members of the catalogue) the value is computed in closed form from the canonical quantities f_1, f_2, f_4, f_5 (the average diagonal and off-diagonal entries of the test-test and control-control sub-matrices of C). This reproduces the values reported in the design catalogues of Vinayaka et al. (2026); see also Hedayat and Majumdar (1984) and Stufken (1988).

Usage

```
a_value(design, v1, v2)
```

Arguments

`design`	A matrix (or data frame) whose rows are the blocks or sub-blocks and whose entries are the treatment labels. Test treatments must be labelled `1, ..., v1` and control treatments `v1 + 1, ..., v1 + v2`.
`v1`	Number of test treatments.
`v2`	Number of control treatments.

Value

A single numeric value, the A-value (sum of variances of the $v_1 v_2$ test-versus-control elementary contrasts).

References

Hedayat AS, Majumdar D (1984) A-optimal incomplete block designs for test treatment-control comparisons. *Technometrics*, 26, 363–370.

Stufken J (1988) On bounds for the efficiency of block designs for comparing test treatments with a control. *Journal of Statistical Planning and Inference*, 19, 361–372.

Vinayaka, Parsad R, Mandal BN, LN Vinaykumar (2026) Nested partially balanced bipartite block designs for comparing test treatments with multiple controls. Journal of Statistical Theory and Practice. (In press).

Examples

```
d <- rbind(c(1, 2, 5, 6), c(3, 4, 5, 6))
a_value(d, v1 = 4, v2 = 2)
```

`a_value_optimal` *A-Value of the A-Optimal Completely Symmetric Reference Design*

Description

Computes the smallest attainable A-value (sum of variances of the $v_1 v_2$ test-versus-control elementary contrasts) within the class of connected (sub-)block designs that are completely symmetric in the test and in the control treatments, for a control replication r_0. This is the benchmark against which the A-efficiency is measured. The expression is the nested-design analogue of the Hedayat-Majumdar / Stufken optimal A-value; see Vinayaka et al. (2026).

Usage

```
a_value_optimal(v1, v2, b, k, r0)
```

Arguments

`v1`	Number of test treatments.
`v2`	Number of control treatments.
`b`	Number of blocks (or sub-blocks) in the classification.
`k`	Block (or sub-block) size.
`r0`	Replication of each control treatment in the classification.

Value

A single numeric value, the optimal (minimum) A-value.

References

Hedayat AS, Majumdar D (1984) A-optimal incomplete block designs for test treatment-control comparisons. *Technometrics*, 26, 363–370.

Stufken J (1988) On bounds for the efficiency of block designs for comparing test treatments with a control. *Journal of Statistical Planning and Inference*, 19, 361–372.

Vinayaka, Parsad R, Mandal BN, LN Vinaykumar (2026) Nested partially balanced bipartite block designs for comparing test treatments with multiple controls. Journal of Statistical Theory and Practice. (In press).

Examples

```
# Optimal block-classification A-value for an NPBBB with v1 = 9, v2 = 2
a_value_optimal(v1 = 9, v2 = 2, b = 6, k = 10, r0 = 12)
```

`construct_method1` *Construct an NPBBB Design by Composing a PBBB Design with an NBIB Design*

Description

Implements Method 1 of Vinayaka et al. (2026). Each block of a partially balanced bipartite block (PBBB) design of size k' is replaced by a copy of a nested balanced incomplete block (NBIB) design on $v^* = k'$ symbols, by identifying the k' symbols of the NBIB design with the k' entries of the PBBB block.

Usage

```
construct_method1(pbbb_blocks, nbib_subblocks, q, v2 = 2)
```

Arguments

pbbb_blocks — A list of integer vectors of common length k', the blocks of a PBBB design, with test treatments labelled `1, ..., v1` and controls `v1 + 1, ..., v1 + v2`.

nbib_subblocks — A list of integer vectors over the symbols $1, \ldots, k'$ giving the *sub-blocks* of an NBIB design, supplied in block order (`q` sub-blocks per block).

q — Number of sub-blocks per block of the NBIB design.

v2 — Number of control treatments in the PBBB design (default 2).

Value

An object of class `"npbbb"`: a list with the following components:

- **method**: a character string naming the construction used.
- **v1**, **v2**: numbers of test and control treatments.
- **parameters**: a list of the design parameters `v1`, `v2`, `b1`, `b2`, `r1`, `r2`, `k1`, `k2`, `q`.
- **block_design**: an integer matrix with `b1` rows and `k1` columns; each row is a block written as its concatenated sub-blocks.
- **subblock_design**: an integer matrix with `b2` rows and `k2` columns; each row is a sub-block.
- **E1**, **E2**: block and sub-block A-efficiencies.
- **efficiency**: an object of class `"npbbb_efficiency"` holding the underlying A-values and optimal references.

References

Vinayaka, Parsad R, Mandal BN, LN Vinaykumar (2026) Nested partially balanced bipartite block designs for comparing test treatments with multiple controls. Journal of Statistical Theory and Practice. (In press).

Examples

```
# PBBB design: 4 test treatments (1-4), 2 controls (5, 6); block size k' = 4
pbbb <- list(c(1,2,5,6), c(1,3,5,6), c(1,4,5,6),
             c(2,3,5,6), c(2,4,5,6), c(3,4,5,6))
# NBIB on k' = 4 symbols from a one-factorisation of K4 (q = 2 sub-blocks/block)
nbib <- list(c(1,2), c(3,4),  c(1,3), c(2,4),  c(1,4), c(2,3))
d <- construct_method1(pbbb, nbib, q = 2, v2 = 2)
d
```

construct_method2 *Construct an NPBBB Design by Augmenting an NPBIB Design with Controls*

Description

Implements Method 2 of Vinayaka et al. (2026). Starting from a nested partially balanced incomplete block (NPBIB) design with `q` sub-blocks per block, `v2` control treatments are added to every sub-block. Because the controls appear in every sub-block, every test treatment meets every control the same number of times and every pair of controls co-occurs the same number of times; the resulting design is completely symmetric in the controls and, whenever the parent NPBIB design is itself well balanced, A-optimal for both classifications.

Usage

```
construct_method2(npbib_subblocks, q, v2 = 2)
```

Arguments

`npbib_subblocks`
: A list of integer vectors, one per sub-block of the parent NPBIB design, giving its test treatments labelled `1, ..., v1`. Sub-blocks must be supplied in block order: the first `q` entries form block 1, the next `q` entries block 2, and so on.

`q`
: Number of sub-blocks per block of the parent NPBIB design.

`v2`
: Number of control treatments to add (default 2).

Value

An object of class `"npbbb"`: a list with the following components:

- **method**: a character string naming the construction used.
- **v1**, **v2**: numbers of test and control treatments.
- **parameters**: a list of the design parameters `v1, v2, b1, b2, r1, r2, k1, k2, q`.
- **block_design**: an integer matrix with `b1` rows and `k1` columns; each row is a block written as its concatenated sub-blocks.
- **subblock_design**: an integer matrix with `b2` rows and `k2` columns; each row is a sub-block.
- **E1**, **E2**: block and sub-block A-efficiencies.
- **efficiency**: an object of class `"npbbb_efficiency"` holding the underlying A-values and optimal references.

References

Vinayaka, Parsad R, Mandal BN, LN Vinaykumar (2026) Nested partially balanced bipartite block designs for comparing test treatments with multiple controls. Journal of Statistical Theory and Practice. (In press).

Examples

```
# L2-type NPBIB on v = 9 (Example 3.2 of Vinayaka et al. (2026))
sub <- list(c(1,2,3), c(4,5,6),  c(1,2,3), c(7,8,9),  c(4,5,6), c(7,8,9),
            c(1,4,7), c(2,5,8),  c(1,4,7), c(3,6,9),  c(2,5,8), c(3,6,9))
d <- construct_method2(sub, q = 2, v2 = 2)
d
```

---

construct_method3 — *Construct an NPBBB Design by Merging Rows of a Group-Divisible NPBIB Design*

Description

Implements Method 3 of Vinayaka et al. (2026). In a group-divisible NPBIB design on $v = mn$ treatments arranged in an $m \times n$ array, the treatments of v2 selected rows are each merged into a single control treatment. The test treatments are the $n(m - v_2)$ remaining array entries, relabelled 1, ..., v1; the merged rows become controls v1 + 1, ..., v1 + v2. A control may occur more than once in a sub-block (see Note 3.1 of the paper); such multiplicities are retained.

Usage

```
construct_method3(
  gd_npbib_subblocks,
  m,
  n,
  q,
  merge_rows = seq_len(v2),
  v2 = 2
)
```

Arguments

gd_npbib_subblocks	A list of integer vectors, one per sub-block of the parent group-divisible NPBIB design, with treatments labelled 1, ..., mn. Sub-blocks must be supplied in block order.
m	Number of rows of the group-divisible scheme.
n	Number of treatments per row.
q	Number of sub-blocks per block.
merge_rows	Integer vector of length v2 giving the rows to merge into controls (default: the first v2 rows).
v2	Number of control treatments (default 2).

Value

An object of class "npbbb": a list with the following components:

- **method**: a character string naming the construction used.
- **v1**, **v2**: numbers of test and control treatments.
- **parameters**: a list of the design parameters v1, v2, b1, b2, r1, r2, k1, k2, q.
- **block_design**: an integer matrix with b1 rows and k1 columns; each row is a block written as its concatenated sub-blocks.
- **subblock_design**: an integer matrix with b2 rows and k2 columns; each row is a sub-block.
- **E1**, **E2**: block and sub-block A-efficiencies.
- **efficiency**: an object of class "npbbb_efficiency" holding the underlying A-values and optimal references.

References

Vinayaka, Parsad R, Mandal BN, LN Vinaykumar (2026) Nested partially balanced bipartite block designs for comparing test treatments with multiple controls. Journal of Statistical Theory and Practice. (In press).

Examples

```
# Group-divisible NPBIB on v = m*n = 8 treatments (m = 4 rows, n = 2),
# with q = 2 sub-blocks per block; merge the first two rows into v2 = 2 controls
gd <- list(c(1,3), c(2,4),  c(5,7), c(6,8),  c(1,5), c(2,6),
           c(3,7), c(4,8),  c(1,7), c(2,8),  c(3,5), c(4,6))
d <- construct_method3(gd, m = 4, n = 2, q = 2, merge_rows = c(1, 2), v2 = 2)
d
```

---

construct_method4 *Construct an NPBBB Design Directly from a Group-Divisible Scheme*

Description

Implements Method 4 of Vinayaka et al. (2026). The $v_1 = mn$ test treatments are arranged in an $m \times n$ array. For each row, n sub-blocks are formed, each consisting of one treatment from that row together with all v2 controls; the n sub-blocks of a row constitute a block. The construction yields an A-optimal design for both classifications.

Usage

```
construct_method4(m, n, v2 = 2)
```

Arguments

m	Number of rows (groups) of the group-divisible scheme.
n	Number of treatments per row.
v2	Number of control treatments (default 2).

Value

An object of class "npbbb": a list with the following components:

- **method**: a character string naming the construction used.
- **v1**, **v2**: numbers of test and control treatments.
- **parameters**: a list of the design parameters `v1, v2, b1, b2, r1, r2, k1, k2, q`.
- **block_design**: an integer matrix with `b1` rows and `k1` columns; each row is a block written as its concatenated sub-blocks.
- **subblock_design**: an integer matrix with `b2` rows and `k2` columns; each row is a sub-block.
- **E1**, **E2**: block and sub-block A-efficiencies.
- **efficiency**: an object of class "npbbb_efficiency" holding the underlying A-values and optimal references.

References

Vinayaka, Parsad R, Mandal BN, LN Vinaykumar (2026) Nested partially balanced bipartite block designs for comparing test treatments with multiple controls. Journal of Statistical Theory and Practice. (In press).

Examples

```
d <- construct_method4(m = 4, n = 3, v2 = 2)
d
```

---

construct_method5 *Construct an NPBBB Design by Expanding the Size-4 Blocks of a PBIB Design*

Description

Implements Method 5 of Vinayaka et al. (2026) (specific to `v2 = 2`). Each block (x_1, x_2, x_3, x_4) of a PBIB design with block size 4 is expanded, with the two controls $0_1, 0_2$, into four blocks of size 6 (each consisting of two sub-blocks of size 3): the i-th block places x_i with both controls in one sub-block and the remaining three treatments in the other.

Usage

```
construct_method5(pbib_blocks)
```

Arguments

`pbib_blocks`	A list of integer vectors of length 4, the blocks of a PBIB design with test treatments labelled `1, ..., v1`.

Value

An object of class "npbbb" with v2 = 2: a list with the following components:

- **method**: a character string naming the construction used.
- **v1**, **v2**: numbers of test and control treatments.
- **parameters**: a list of the design parameters v1, v2, b1, b2, r1, r2, k1, k2, q.
- **block_design**: an integer matrix with b1 rows and k1 columns; each row is a block written as its concatenated sub-blocks.
- **subblock_design**: an integer matrix with b2 rows and k2 columns; each row is a sub-block.
- **E1**, **E2**: block and sub-block A-efficiencies.
- **efficiency**: an object of class "npbbb_efficiency" holding the underlying A-values and optimal references.

References

Vinayaka, Parsad R, Mandal BN, LN Vinaykumar (2026) Nested partially balanced bipartite block designs for comparing test treatments with multiple controls. Journal of Statistical Theory and Practice. (In press).

Examples

```
# Singular GD design S1: v = 6, b = 3, k = 4
s1 <- list(c(1,2,3,4), c(1,2,5,6), c(3,4,5,6))
d <- construct_method5(s1)
d
```

---

construct_method6 — *Construct an NPBBB Design by Expanding the Size-2 Blocks of a PBIB Design*

Description

Implements Method 6 of Vinayaka et al. (2026) (specific to v2 = 2). Each block (x_1, x_2) of a PBIB design with block size 2 is expanded, with the two controls $0_1, 0_2$, into three blocks of size 4 (two sub-blocks of size 2): $[(x_1, x_2); (0_1, 0_2)]$, $[(x_1, 0_1); (x_2, 0_2)]$ and $[(x_1, 0_2); (x_2, 0_1)]$.

Usage

```
construct_method6(pbib_blocks)
```

Arguments

pbib_blocks	A list of integer vectors of length 2, the blocks of a PBIB design with test treatments labelled 1, ..., v1.

Value

An object of class "npbbb" with v2 = 2: a list with the following components:

- **method**: a character string naming the construction used.
- **v1**, **v2**: numbers of test and control treatments.
- **parameters**: a list of the design parameters v1, v2, b1, b2, r1, r2, k1, k2, q.
- **block_design**: an integer matrix with b1 rows and k1 columns; each row is a block written as its concatenated sub-blocks.
- **subblock_design**: an integer matrix with b2 rows and k2 columns; each row is a sub-block.
- **E1**, **E2**: block and sub-block A-efficiencies.
- **efficiency**: an object of class "npbbb_efficiency" holding the underlying A-values and optimal references.

References

Vinayaka, Parsad R, Mandal BN, LN Vinaykumar (2026) Nested partially balanced bipartite block designs for comparing test treatments with multiple controls. Journal of Statistical Theory and Practice. (In press).

Examples

```
# Semi-regular GD design SR1: v = 4, b = 4, k = 2
sr1 <- list(c(1,3), c(1,4), c(2,3), c(2,4))
d <- construct_method6(sr1)
d
```

---

info_matrix — *Information Matrix of a (Sub-)Block Design for Test-Versus-Control Comparisons*

Description

Computes the reduced (treatment) information matrix $C = R - NK^{-1}N'$ for a single classification (blocks or sub-blocks) of a nested partially balanced bipartite block (NPBBB) design. Here R is the diagonal matrix of treatment replications, N is the treatment-by-(sub-)block incidence matrix and K is the diagonal matrix of (sub-)block sizes. Control treatments may occur more than once in a (sub-)block (for example, designs obtained by merging rows of a group-divisible scheme); such multiplicities are counted in N so that C is the correct information matrix under the homoscedastic fixed-effects nested model. For more details see Vinayaka et al. (2026).

Usage

```
info_matrix(design, v1, v2)
```

Arguments

`design`	A matrix (or data frame) whose rows are the blocks or sub-blocks and whose entries are the treatment labels. Test treatments must be labelled `1, ..., v1` and control treatments `v1 + 1, ..., v1 + v2`.
`v1`	Number of test treatments.
`v2`	Number of control treatments.

Value

A numeric `(v1 + v2)` by `(v1 + v2)` information matrix C.

References

Vinayaka, Parsad R, Mandal BN, LN Vinaykumar (2026) Nested partially balanced bipartite block designs for comparing test treatments with multiple controls. Journal of Statistical Theory and Practice. (In press).

Examples

```
# Two blocks of size 4 on 4 test treatments (1-4) and 2 controls (5, 6)
d <- rbind(c(1, 2, 5, 6), c(3, 4, 5, 6))
info_matrix(d, v1 = 4, v2 = 2)
```

`n_units` *Total Number of Experimental Units of an NPBBB Design*

Description

Returns the total number of experimental units of a nested partially balanced bipartite block design, $N = b_2 k_2 = b_1 k_1$.

Usage

```
n_units(x)
```

Arguments

`x`	An object of class `"npbbb"`, as returned by the `construct_method*` functions.

Value

A single numeric value, the total number of experimental units $N = b_2 k_2 = b_1 k_1$.

Examples

```
d <- construct_method4(m = 3, n = 2, v2 = 2)
n_units(d)
```

npbbb_efficiency *A-Efficiency of an NPBBB Design*

Description

Evaluates the A-efficiency of a nested partially balanced bipartite block design separately for its block and sub-block classifications. For each classification the A-efficiency is

$$E = A^{\mathrm{opt}}/A,$$

the ratio of the A-value of the A-optimal completely symmetric reference design to the A-value of the design under study. A value of 1 means the design is A-optimal for that classification. For more details see Vinayaka et al. (2026).

Usage

```
npbbb_efficiency(block_design, subblock_design, v1, v2)
```

Arguments

block_design	A matrix whose rows are the blocks (each block being the concatenation of its sub-blocks) and whose entries are treatment labels `1, ..., v1` (test) and `v1 + 1, ..., v1 + v2` (control).
subblock_design	A matrix whose rows are the sub-blocks, with the same labelling convention.
v1	Number of test treatments.
v2	Number of control treatments.

Value

An object of class `"npbbb_efficiency"`: a list with the following components:

- **E1**: block-classification A-efficiency.
- **E2**: sub-block-classification A-efficiency.
- **A1**, **A2**: A-values of the design under study (block and sub-block classifications, respectively).
- **A1_opt**, **A2_opt**: A-values of the corresponding A-optimal completely symmetric reference designs.
- **v1**, **v2**: numbers of test and control treatments.

References

Hedayat AS, Majumdar D (1984) A-optimal incomplete block designs for test treatment-control comparisons. *Technometrics*, 26, 363–370.

Stufken J (1988) On bounds for the efficiency of block designs for comparing test treatments with a control. *Journal of Statistical Planning and Inference*, 19, 361–372.

Vinayaka, Parsad R, Mandal BN, LN Vinaykumar (2026) Nested partially balanced bipartite block designs for comparing test treatments with multiple controls. Journal of Statistical Theory and Practice. (In press).

Examples

```
d <- construct_method4(m = 3, n = 2, v2 = 2)
npbbb_efficiency(d$block_design, d$subblock_design, v1 = d$v1, v2 = d$v2)
```

---

print.npbbb *Print Method for NPBBB Designs*

Description

Prints a nested partially balanced bipartite block design: its construction method, design parameters, block and sub-block A-efficiencies and, optionally, the full block layout with controls displayed as `0_1, 0_2, ...`.

Usage

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

Arguments

`x`	An object of class `"npbbb"`, as returned by the `construct_method*` functions.
`digits`	Number of significant digits used when printing the A-efficiencies.
`show_layout`	Logical; if `TRUE` the block and sub-block layouts are printed.
`...`	Further arguments passed to or from other methods.

Value

The object `x`, invisibly.

Examples

```
d <- construct_method4(m = 3, n = 2, v2 = 2)
print(d)
print(d, show_layout = FALSE)
```

print.npbbb_efficiency

Print Method for NPBBB Efficiency Objects

Description

Prints the block and sub-block A-efficiencies of a nested partially balanced bipartite block design held in an object of class "npbbb_efficiency".

Usage

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

Arguments

x	An object of class "npbbb_efficiency", as returned by npbbb_efficiency.
digits	Number of significant digits used when printing the A-values and A-efficiencies.
...	Further arguments passed to or from other methods.

Value

The object x, invisibly.

Examples

```
d <- construct_method4(m = 3, n = 2, v2 = 2)
print(d$efficiency)
```

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