Package ‘caMST’

May 18, 2021

Type Package
Title Mixed Computerized Adaptive Multistage Testing
Version 0.1.4
Date 2021-05-18
Description Provides functions to more easily analyze computerized adaptive tests. Currently, functions for computerized adaptive tests (CAT), computer adaptive multistage tests (CMT), and mixed computer adaptive multistage tests (McaMST) utilizing CAT item-level adaptation for the initial stage and traditional MST module-level adaptation for the subsequent stages have been created, and a variation of Hybrid computer adaptive MST is planned as well. For an in-depth look at CAT and MST, see Weiss & Kingsbury (1984) <doi:10.1111/j.1745-3984.1984.tb01040.x> and Luecht & Nungester (2000) <doi:10.1007/0-306-47531-6_6> respectively.
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Encoding UTF-8
LazyData true
Depends R (&ge; 3.5.0)
Imports catR, mstR, diagram, methods
Suggests testthat, knitr, rmarkdown
RoxygenNote 7.1.1
NeedsCompilation no
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Repository CRAN
Date/Publication 2021-05-18 16:10:03 UTC
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Description

Hook triggered when package attached.

Usage

.onAttach(lib, pkg)

Arguments

lib a character string giving the library directory where the package defining the namespace was found

pkg a character string giving the name of the package

Details


Examples

camst:::.onAttach(.libPaths()[1], "caMST")
caMST

caMST caMST package

Description

Computer Adaptive Mutistage Test Analysis

Details

See the README on GitHub for more information.

caMSTStartup

Create Package Startup Message

Description

Makes package startup message.

Usage

caMSTStartup()

Details


Examples

caMST:::caMSTStartup()

CAT-class

An S4 class for computerized adaptive tests

Description

An S4 class for computerized adaptive tests

Value

An S4 object of class ‘CAT’.
Slots

function.call The original function call.
final.theta.estimate Numeric vector of theta estimates calculated by the provided 'method'.
eap.theta Numeric vector of theta estimates calculated by 'catR::eapEst'.
final.theta.Baker Numeric vector of theta estimates calculated by the internal 'iterative.theta.estimate' function.
final.theta.SEM Numeric vector of SEM estimates calculated by the internal 'iterative.theta.estimate' function.
final.items.seen Character matrix of the final items seen by each individual.
final.responses Numeric matrix of the response patterns observed.
runtime A 'difftime' object of the total run time of the function.

cat_items

Example items for the CAT stage of an example adaptive test.

Description

A data frame formatted in the style required by mstR for item data. Represents items to be used in an item-level adaptation portion of a computerized adaptive test.

Usage

cat_items

Format

A data frame with 564 rows (items) and 6 columns (item parameters):

a item discrimination
b item difficulty
c item guessing
u item carelessness
content_ID what content area the item comes from
stage which stage the item belongs to
Computerized Adaptive Test

Description

Computerized Adaptive Test

Usage

computerized_adaptive_test(
  cat_item_bank,
  response_matrix,
  initial_theta = 0,
  model = NULL,
  randomesque = 1,
  maxItems = 50,
  method = "BM",
  nextItemControl = list(criterion = "MFI", method = method, priorDist = "norm",
    priorPar = c(0, 1), D = 1, range = c(-4, 4), parInt = c(-4, 4, 33), infoType = "Fisher",
    random.seed = NULL, rule = "precision", thr = 0.3, SETH = NULL, AP = 1,
    nAvailable = NULL, cbControl = NULL, cbGroup = NULL),
  ...
)

Arguments

cat_item_bank          A data frame with the items on the rows and their item parameters on the columns. These should be in the catR package format for item banks.
response_matrix        A matrix of the person responses, with individuals as rows and items as columns.
initial_theta          The initial theta estimate for all individuals. Default is 0.
model                  Either NULL (default) for dichotomous models or a character value indicating the polytomous model used. See the mstR package for more details.
randomesque            An integer value that indicates the number of items from which the selection rule should choose from randomly for administration. See the help documentation for catR::nextItem for more details.
maxItems               An integer value indicating the maximum number of items to administer, regardless of other stopping rules.
method                 A character value indicating method for the provisional theta estimate. Defaults to "BM" (Bayes Modal). See the catR package for more details.
nextItemControl        A list of control values passed to catR::nextItem. See that function for more details.
...                   Further arguments to be passed to internal functions. Currently unimplemented.
Value

An S4 object of class 'CAT' with the following slots:

function.call  The function and arguments called to create this object.
final.theta.estimate  A numeric vector of the final theta estimates using the method provided in function.call.
eap.theta  A numeric vector of the final theta estimates using the expected a posteriori (EAP) theta estimate from catR::eapEst.
final.items.seen  A matrix of the final items seen by each individual using the supplied item names. NA values indicate that an individual wasn’t given any items to answer after the last specified item in their row.
final.responses  A matrix of the responses to the items seen in final.items.seen. NA values indicate that the individual didn’t answer the question in the supplied response file or wasn’t given any more items to answer.
runtime  A difftime object recording how long the function took to complete.

References


See Also

[mixed_adaptive_test] for a multistage test with a routing module using item-level adaptation.

Examples

data(example_thetas) # 5 simulated abilities
data(example_responses) # 5 simulated responses
data(cat_items) # using just the CAT routing stage items
catResults <- computerized_adaptive_test(cat_item_bank = cat_items,
response_matrix = example_responses, randomesque = 1, maxItems = 3,
nextItemControl = list(criterion = "MFI",
priorDist = "norm", priorPar = c(0, 1), D = 1, range = c(-4, 4),
parInt = c(-4, 4, 33), infoType = "Fisher", randomesque = 1, random.seed = NULL,
rule = "precision", thr = .3, nAvailable = NULL,
cbControl = NULL, cbGroup = NULL))
Description

A matrix with items on the rows and modules on the columns, where 0 indicates the item and module are unrelated and 1 indicates that the item is a part of that module. Used in combination with a transition matrix to describe a multistage adaptive test.

Usage

example_module_items

Format

An object of class matrix (inherits from array) with 42 rows and 7 columns.

Description

Responses to all of the example items by the five individuals represented in the "example_thetas" data.

Usage

example_responses

Format

An object of class data.frame with 5 rows and 600 columns.
example_thetas

Theta values used in the examples.

Description

A numeric vector with five simulated theta values.

Usage

example_thetas

Format

An object of class numeric of length 5.

description

Example transition matrix showing how individuals traverse the multistage test.

Description

A matrix with modules on the rows and columns. A 0 indicates that an individual cannot move from the row module to the column module, while a 1 indicates that an individual who has completed the row module can potentially transition into the column module.

Usage

example_transition_matrix

Format

An object of class matrix (inherits from array) with 7 rows and 7 columns.
MAT-class

An S4 method for mixed adaptive tests.

Description

An S4 method for mixed adaptive tests.

Value

An S4 object of class ‘MAT’.

Slots

function.call The original function call.
final.theta.estimate Numeric vector of theta estimates calculated by the provided ‘method’.
eap.theta Numeric vector of theta estimates calculated by ‘catR::eapEst’.
final.theta.SEM Numeric vector of SEM estimates calculated by the internal ‘iterative.theta.estimate’ function.
final.items.seen Character matrix of the final items seen by each individual.
modules.seen Numeric matrix of the modules seen by each individual.
final.responses Numeric matrix of the response patterns observed.
transition.matrix Numeric matrix; the transition matrix entered into the function.
n.stages Numeric; the number of stages specified.
runtime A ‘difftime’ object of the total run time of the function.

mixed_adaptive_test Mixed Computerized Adaptive Multistage Test

Description

Mixed Computerized Adaptive Multistage Test
Usage

mixed_adaptive_test(
  response_matrix,
  cat_item_bank,
  initial_theta = 0,
  method = "BM",
  item_method = "MFI",
  cat_length,
  nAvailable_cat = NULL,
  cbControl = NULL,
  cbGroup = NULL,
  randomesque = 1,
  mst_item_bank,
  modules,
  transition_matrix,
  n_stages
)

Arguments

response_matrix
A matrix of the person responses, with individuals as rows and items as columns.

cat_item_bank
A data frame with the first stage items on the rows and their item parameters on the columns. These should be in the mstR package format for item banks.

initial_theta
The initial theta estimate for all individuals.

method
A character value indicating method for the provisional theta estimate. Defaults to "BM" (Bayes Modal). See the catR and mstR packages for more details.

item_method
A character value indicating the method for the item-level selection in the first stage. Defaults to "MFI" (Maximum Fisher Information). See the catR and mstR packages for more details.

cat_length
A numeric value indicating the number of items in the first stage.

nAvailable_cat
Defaults to ‘NULL’. See the catR package for more information on how to use this option.

cbControl
A list of the appropriate format used to control for content balancing in the first stage. See the Details in the nextItem function in catR.

cbGroup
A factor vector of the appropriate format used to control for content balancing in the first stage. See the Details in the nextItem function in catR.

randomesque
An integer indicating the number of items from which to select the next item to administer in the first stage. Default value is 1.

mst_item_bank
A data frame with the second stage and beyond items on the rows and their item parameters on the columns. These should be in the mstR package format for item banks.

modules
A matrix describing the relationship between the items and the modules they belong to. See Details.
transition_matrix
A matrix describing how individuals can transition from one stage to the next.
n_stages A numerical value indicating the number of stages in the test.

Details
To be filled in later.

Value
A list of all individuals with the following elements: the vector of final theta estimates based on "method", the vector of final theta estimates based on EAP, the vector of final theta estimates based on the iterative estimate from Baker 2004, a matrix of the final items taken, a matrix of the modules seen, and a matrix of the final responses.

An S4 object of class 'MST' with the following slots:

function.call The function and arguments called to create this object.
final.theta.estimate A numeric vector of the final theta estimates using the method provided in function.call.
eap.theta A numeric vector of the final theta estimates using the expected a posteriori (EAP) theta estimate from catR::eapEst.
final.theta.SEM A numeric vector of the final standard error of measurement (SEM) estimates using an iterative maximum likelihood estimation procedure as described in chapter 5 of Baker (2001).
final.items.seen A matrix of the final items seen by each individual using the supplied item names. ‘NA’ values indicate that an individual wasn’t given any items to answer after the last specified item in their row.
final.responses A matrix of the responses to the items seen in final.items.seen. NA values indicate that the individual didn’t answer the question in the supplied response file or wasn’t given any more items to answer.
transition.matrix The transition_matrix originally supplied to the function.
n_stages The n_stages originally supplied to the function.
runtime A difftime object recording how long the function took to complete.

References
See Also


Examples

```r
# using simulated test data
data(example_thetas) # 5 simulated abilities
data(example_responses) # 5 simulated response vectors
# the transition matrix for an 18 item 1-3-3 balanced design
data(example_transition_matrix)
# the items designated for use in the routing module with item-level
# adaptation
data(cat_items)
# the items designated for use in the second and third modules with
# module-level adaptation
data(mst_items)
# the matrix specifying how the item data frame relates to the modules
data(example_module_items)

# run the Mca-MST model
results <- mixed_adaptive_test(response_matrix = example_responses[1:2,],
cat_item_bank = cat_items, initial_theta = 0,
method = "EAP", item_method = "MFI",
cat_length = 6, cbControl = NULL, cbGroup = NULL,
randomesque = 1, mst_item_bank = mst_items,
modules = example_module_items,
transition_matrix = example_transition_matrix,
n_stages = 3)
```

MST-class

An S4 method for multistage adaptive tests.

Description

An S4 method for multistage adaptive tests.

Value

An S4 object of class ‘MST’.

Slots

function.call The original function call.
final.theta.estimates Numeric vector of theta estimates calculated by the provided ‘method’.
**mst_items**

- **eap.theta**: Numeric vector of theta estimates calculated by `catR::eapEst`.
- **final.theta.Baker**: Numeric vector of theta estimates calculated by the internal `iterative.theta.estimate` function.
- **final.theta.SEM**: Numeric vector of SEM estimates calculated by the internal `iterative.theta.estimate` function.
- **final.items.seen**: Character matrix of the final items seen by each individual.
- **modules.seen**: Numeric matrix of the modules seen by each individual.
- **final.responses**: Numeric matrix of the response patterns observed.
- **transition.matrix**: Numeric matrix; the transition matrix entered into the function.
- **n.stages**: Numeric; the number of stages specified.
- **nc.list**: A list of the number correct scoring logic and method, if applicable. Defaults to 'NULL'.
- **runtime**: A ‘difftime’ object of the total run time of the function.

---

### mst_items

**Example items for the MST stages of an example adaptive test.**

---

**Description**

A data frame formatted in the style required by **mstR** for item data. Represents items to be used in module-level adaptation portions of a computerized adaptive test.

**Usage**

```r
mst_items
```

**Format**

A data frame with 564 rows (items) and 6 columns (item parameters):

- **a**: item discrimination
- **b**: item difficulty
- **c**: item guessing
- **u**: item carelessness
- **content_ID**: what content area the item comes from
- **stage**: which stage the item belongs to
### mst_only_items

The matrix of items used in the “multistage_test” example.

#### Description

A data frame formatted in the style required by mstR for item data. Represents items to be used in an item-level adaptation portion of a computerized adaptive test.

#### Usage

mst_only_items

#### Format

A data frame with 564 rows (items) and 6 columns (item parameters):

- **a** item discrimination
- **b** item difficulty
- **c** item guessing
- **u** item carelessness
- **content_ID** what content area the item comes from

### mst_only_matrix

Example “item-to-module” map matrix for the “multistage_test” example.

#### Description

A matrix with items on the rows and modules on the columns, where 0 indicates the item and module are unrelated and 1 indicates that the item is a part of that module. Used in combination with a transition matrix to describe a multistage adaptive test.

#### Usage

mst_only_matrix

#### Format

An object of class matrix (inherits from array) with 42 rows and 7 columns.
**multistage_test**

Computer Adaptive Multistage Test

**Description**

Computer Adaptive Multistage Test

**Usage**

```r
multistage_test(
  mst_item_bank,
  modules,
  transition_matrix,
  method = "BM",
  response_matrix,
  initial_theta = 0,
  model = NULL,
  n_stages = 3,
  test_length = 18,
  nc_list = NULL
)
```

**Arguments**

- **mst_item_bank**  
  A data frame with the items on the rows and their item parameters on the columns. These should be in the mstR package format for item banks.

- **modules**  
  A matrix describing the relationship between the items and the modules they belong to. See Details.

- **transition_matrix**  
  A matrix describing how individuals can transition from one stage to the next.

- **method**  
  A character value indicating method for the provisional theta estimate. Defaults to "BM" (Bayes Modal). See the mstR package for more details.

- **response_matrix**  
  A matrix of the person responses, with individuals as rows and items as columns.

- **initial_theta**  
  The initial theta estimate for all individuals. Default is 0.

- **model**  
  Either NULL (default) for dichotomous models or a character value indicating the polytomous model used. See the mstR package for more details.

- **n_stages**  
  A numeric value indicating the number of stages in the test.

- **test_length**  
  A numeric value indicating the total number of items each individual answers.

- **nc_list**  
  This parameter controls whether or not to use number correct ("NC") scoring to select modules. Defaults to ‘NULL’, using module information. Otherwise, this should be a list where the elements of the list correspond to each module which routes to other modules by number correct. If no ‘method’ argument is provided in this list, or if an invalid entry is given, the method will default to ‘cumulative_sum’, meaning the values provided are a running tally of the number of
items correctly answered on the test. If 'method' is set to 'module_sum', then
the sum of the number correct within the current module will be used to select
the next module. See 'details' for more information.

Details

When using (cumulative) number correct module selection, the input list should contain one element
for each module that needs to route to other modules. For example, in a 1-3-3 design the first module
can route to any module in the second stage, so the first element of 'nc_list' would be a numeric
vector with three values indicating the *maximum* number of correct items needed in order to be
routed to the second, third, or fourth module respectively. When the design is not crossed (e.g., a
person routed to the easy module in the second stage **cannot** be routed to the hard module in
the third stage), '-Inf' and 'Inf' need to be used within 'nc_list' to indicate this. Continuing the
example, let's assume the 1-3-3 design is not crossed and will be balanced so that each stage has
the same number of items (10 each) for a total of 30 items administered. The 'nc_list' object could
be specified like so: nc_list = list(module1 = c(4, 5, 7), module2 = c(8, 14, Inf), module3 = c(8, 14,
20), module4 = c(-Inf, 14, 20), method = "cumulative_sum").

As it is the most common method of number correct scoring, "cumulative_sum" is the default. Any
value included in the 'method' argument of 'nc_list' that does _not_ equal "module_sum" will cause
the default "cumulative_sum" to be used. _This is intentional and will not be changed unless I am
given a good argument to change it_.

Value

A list of all individuals with the following elements: the vector of final theta estimates based on
"method", the vector of final theta estimates based on EAP, the vector of final theta estimates based
on the iterative estimate from Baker 2004, a matrix of the final items taken, a matrix of the modules
seen, and a matrix of the final responses.

An S4 object of class 'MST' with the following slots:

function.call  The function and arguments called to create this object.

final.theta.estimate
   A numeric vector of the final theta estimates using the method provided in
   function.call.

eap.theta
   A numeric vector of the final theta estimates using the expected a posteriori
   (EAP) theta estimate from catR::eapEst.

final.theta.Baker
   A numeric vector of the final theta estimates using an iterative maximum likeli-
  hood estimation procedure as described in chapter 5 of Baker (2001).

final.theta.SEM
   A numeric vector of the final standard error of measurement (SEM) estimates us-
   ing an iterative maximum likelihood estimation procedure as described in chap-

final.items.seen
   A matrix of the final items seen by each individual using the supplied item
   names. 'NA' values indicate that an individual wasn’t given any items to an-
   swer after the last specified item in their row.
multistage_test

final.responses
A matrix of the responses to the items seen in final.items.seen. NA values indicate that the individual didn’t answer the question in the supplied response file or wasn’t given any more items to answer.

transition.matrix
The transition_matrix originally supplied to the function.

n.stages
The n_stages originally supplied to the function.

nc.list
The nc_list originally supplied to the function.

runtime
A difftime object recording how long the function took to complete.

References

See Also
[mixed_adaptive_test] for a multistage test with a routing module using item-level adaptation.

Examples

```r
# using simulated test data
data(example_thetas)  # 5 simulated abilities
data(example_responses)  # 5 simulated response vectors
# the transition matrix for an 18 item 1-3-3 design
data(example_transition_matrix)
# the MST item bank
data(mst_only_items)
# the MST module matrix
data(example_module_items)
# run the MST model
results <- multistage_test(mst_item_bank = mst_only_items,
modules = example_module_items, transition_matrix = example_transition_matrix,
method = "BM", response_matrix = example_responses, initial_theta = 0,
model = NULL, n_stages = 3, test_length = 18)

# using number correct scoring for the same data
# create nc_list as explained in 'details'
nc_list = list(module1 = c(4, 5, 7),
module2 = c(8, 14, Inf),
module3 = c(8, 14, 18),
module4 = c(-Inf, 14, 18),
method = 3)  # the method here will default to "cumulative_sum" as described in 'details'
# this is the ONLY difference currently! Everything else remains the same
# run the example
nc.results <- multistage_test(mst_item_bank = mst_only_items,
modules = example_module_items, transition_matrix = example_transition_matrix,
method = "BM", response_matrix = example_responses, initial_theta = 0,
model = NULL, n_stages = 3, test_length = 18, nc_list = nc_list)
```
transition_matrix_plot

Transition Matrix Plot

Description

Given a transition matrix and the number of modules at each stage, produces a plot that demonstrates the potential paths through a (mixed) multistage test.

Usage

transition_matrix_plot(object = NULL, n_stages = NULL)

Arguments

object Either an S4 object of class "MST" or class "MAT", or a matrix describing how individuals can transition from one stage to the next. If an S4 object is provided, the 'transition.matrix' slot is used to create the plot.

n_stages A numeric value indicating how many stages are used in the (mixed) multistage test. If an S4 object is provided, this value is taken from the object and the input value is ignored.

Value

A plot using the current graphic device.

Examples

# Create a plot for a multistage test with a 1-3-3 design
data("example_transition_matrix")
transition_matrix_plot(example_transition_matrix, n_stages = 3)

## Not run:
# Save the plot as a png file.
png("Example 1-3-3 Transition Matrix Plot.png")
transition_matrix_plot(example_transition_matrix, n_stages = 3)
title("Transition Matrix for a 1-3-3 Design MST")
dev.off()

# Use the 'results' object from the 'mixed_adaptive_test()' example to create
# a transition matrix plot and save as a .pdf file.
pdf("MAT Transition Matrix.pdf")
transition_matrix_plot(results)
title("Transition Matrix from the mixed_adaptive_test Example")
dev.off()

## End(Not run)
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