Rcdm Package Demo

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Installation

To install the package from the source code, Rcpp and RcppArmadillo are re- quired. If you have not installed Rcpp and RcppArmadillo packages, run:

```
install.packages(c("Rcpp", "RcppArmadillo"))
```

Then, install the package either by the command:

```
install.packages("Rcdm_0.1-0.tar.gz", repos = NULL, type = "source")
```

or if you are using RStudio go to ”Packages - Install - Install from” and choose ”Package Archive File” then Browse the File and klick Install. Alternatively your can install Rcdm directly from GitHub:

```
install.packages("devtools") # if you have not installed devools
devtools::install_github("mphili/cdm")
```

Rcdm currently depends on Rcpp, Matrix, limSolve and gtools packages, that need to be installed on your system.

```
install.packages(c("Rcpp", "Matrix", "limSolve", "gtools"))
```

Fitting a GDINA model

```
library("Rcdm")
```

Load your own data or use the data example from the pks package:

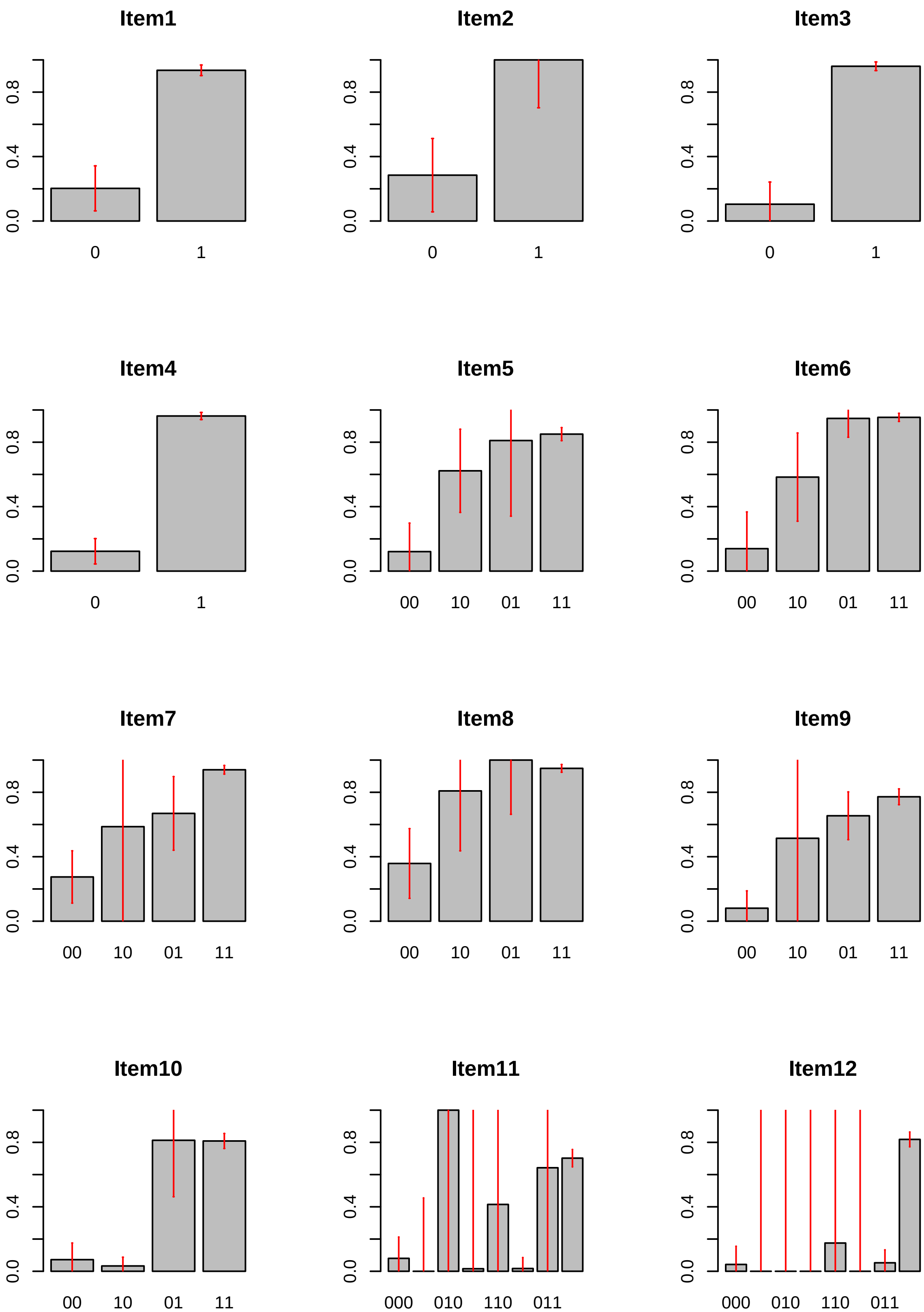
```
# install.packages("pks")
data("probability", package = "pks")

# reduce to 12 items from the first test
items <- sprintf("b1%.2i", 1:12)
resp <- probability[, items]
resp <- resp[complete.cases(resp),]

qmat <- t(read.table(header = FALSE, text = "
  0    1    0    0    1    1    0    0    0    1    1    0
  0    0    0    1    0    0    0    0    1    1    1    1
  1    0    0    0    1    1    1    1    1    0    1    1
  0    0    1    0    0    0    1    1    0    0    0    1
"))

colnames(qmat) <- c("cp", "id", "pb", "un")
rownames(qmat) <- colnames(resp)
```

Fit a GDINA model using the Rcdm package:

```
mGDINA <- gdina(resp, qmat)
```

Plot the estimated conditional response probabilities:

```
plot(mGDINA)
```


Item1
0.0
0.4
0.8
0
1
Item2
0.0
0.4
0.8
0
1
Item3
0.0
0.4
0.8
0
1
Item4
0.0
0.4
0.8
0
1
Item5
0.0
0.4
0.8
00
10
01
11
Item6
0.0
0.4
0.8
00
10
01
11
Item7
0.0
0.4
0.8
00
10
01
11
Item8
0.0
0.4
0.8
00
10
01
11
Item9
0.0
0.4
0.8
00
10
01
11
Item10
0.0
0.4
0.8
00
10
01
11
Item11
0.0
0.4
0.8
000
010
110
011
Item12
0.0
0.4
0.8
000
010
110
011

Analyzing the Result

Parameter Estimates

Extract the estimates of the item parameters:

```
mGDINA$dj
```

```
## $b101
##       d_0       d_1
## 0.2026237 0.7328790
##
## $b102
##       d_0       d_1
## 0.2845926 0.7154054
##
## $b103
##       d_0       d_1
## 0.1043282 0.8561985
##
## $b104
##       d_0       d_1
## 0.1231026 0.8395613
##
## $b105
##        d_0        d_1        d_2       d_12
##  0.1209243  0.5015454  0.6894077 -0.4617671
##
## $b106
##        d_0        d_1        d_2       d_12
##  0.1392815  0.4441071  0.8083905 -0.4376127
##
## $b107
##         d_0         d_1         d_2        d_12
##  0.27455117  0.31206864  0.39445421 -0.04133606
##
## $b108
##        d_0        d_1        d_2       d_12
##  0.3582082  0.4501938  0.6417898 -0.5016836
##
## $b109
##         d_0         d_1         d_2        d_12
##  0.08063802  0.43401073  0.57355589 -0.31613747
##
## $b110
##         d_0         d_1         d_2        d_12
##  0.07219741 -0.03921185  0.74069189  0.03489225
##
## $b111
##         d_0         d_1         d_2         d_3        d_12        d_13
##  0.08022087 -0.08021887  0.91977713 -0.06451234 -0.50500065  0.08168869
##        d_23       d_123
## -0.29302834  0.56309866
##
```

```
## $b112
##         d_0         d_1         d_2         d_3        d_12        d_13
##  0.04242436 -0.04242236 -0.04242236 -0.04242236  0.21772990  0.04242236
##        d_23       d_123
##  0.09498799  0.54806811
```

Extract the estimates of the latent class distribution

```
mGDINA$pa
```

```
##         0000         1000         0100         0010         0001
## 8.118021e-02 1.222217e-02 5.123528e-03 1.949008e-02 1.064277e-02
##         1100         1010         1001         0110         0101
## 9.999996e-07 9.999996e-07 4.669068e-02 9.999996e-07 1.821362e-03
##         0011         1110         1101         1011         0111
## 3.593686e-03 2.728925e-03 1.150701e-02 1.149323e-01 3.068450e-02
##         1111
## 6.593798e-01
```

Extract the estimates of the response probabilities:

```
mGDINA$pj
```

```
## $b101
##         0         1
## 0.2026237 0.9355027
##
## $b102
##         0         1
## 0.2845926 0.9999990
##
## $b103
##         0         1
## 0.1043282 0.9605268
##
## $b104
##         0         1
## 0.1231026 0.9626639
##
## $b105
##        00        10        01        11
## 0.1209243 0.6224697 0.8103320 0.8501103
##
## $b106
##        00        10        01        11
## 0.1392815 0.5833885 0.9476719 0.9541663
##
## $b107
##        00        10        01        11
## 0.2745512 0.5866198 0.6690054 0.9397380
##
## $b108
```

```
##        00        10        01        11
## 0.3582082 0.8084021 0.9999990 0.9485082
##
## $b109
##         00         10         01         11
## 0.08063802 0.51464876 0.65419391 0.77206717
##
## $b110
##         00         10         01         11
## 0.07219741 0.03298556 0.81288930 0.80856969
##
## $b111
##        000        100        010        001        110        101
## 0.08022087 0.00000100 0.99999900 0.01570852 0.41477848 0.01717834
##        011        111
## 0.64245732 0.70202515
##
## $b112
##        000        100        010        001        110        101
## 0.04242436 0.00000100 0.00000100 0.00000100 0.17530953 0.00000100
##        011        111
## 0.05256762 0.81836563
```

Get a nice table that contains the estimates of the item parameters:

```r
coef(mGDINA)
```

```
##        item itemno   rule         est
## d_0    b101      1 G-DINA  0.20262371
## d_1    b101      1 G-DINA  0.73287898
## d_01   b102      2 G-DINA  0.28459258
## d_11   b102      2 G-DINA  0.71540542
## d_02   b103      3 G-DINA  0.10432823
## d_14   b103      3 G-DINA  0.85619854
## d_03   b104      4 G-DINA  0.12310264
## d_15   b104      4 G-DINA  0.83956128
## d_04   b105      5 G-DINA  0.12092427
## d_16   b105      5 G-DINA  0.50154544
## d_2    b105      5 G-DINA  0.68940769
## d_12   b105      5 G-DINA -0.46176715
## d_05   b106      6 G-DINA  0.13928146
## d_17   b106      6 G-DINA  0.44410707
## d_21   b106      6 G-DINA  0.80839046
## d_121  b106      6 G-DINA -0.43761267
## d_06   b107      7 G-DINA  0.27455117
## d_18   b107      7 G-DINA  0.31206864
## d_22   b107      7 G-DINA  0.39445421
## d_122  b107      7 G-DINA -0.04133606
## d_07   b108      8 G-DINA  0.35820825
## d_19   b108      8 G-DINA  0.45019381
## d_24   b108      8 G-DINA  0.64178975
## d_124  b108      8 G-DINA -0.50168364
## d_08   b109      9 G-DINA  0.08063802
```

```
## d_110  b109      9 G-DINA  0.43401073
## d_25   b109      9 G-DINA  0.57355589
## d_125  b109      9 G-DINA -0.31613747
## d_09   b110     10 G-DINA  0.07219741
## d_111  b110     10 G-DINA -0.03921185
## d_26   b110     10 G-DINA  0.74069189
## d_126  b110     10 G-DINA  0.03489225
## d_010  b111     11 G-DINA  0.08022087
## d_112  b111     11 G-DINA -0.08021887
## d_27   b111     11 G-DINA  0.91977713
## d_3    b111     11 G-DINA -0.06451234
## d_127  b111     11 G-DINA -0.50500065
## d_13   b111     11 G-DINA  0.08168869
## d_23   b111     11 G-DINA -0.29302834
## d_123  b111     11 G-DINA  0.56309866
## d_011  b112     12 G-DINA  0.04242436
## d_113  b112     12 G-DINA -0.04242236
## d_28   b112     12 G-DINA -0.04242236
## d_31   b112     12 G-DINA -0.04242236
## d_128  b112     12 G-DINA  0.21772990
## d_131  b112     12 G-DINA  0.04242236
## d_231  b112     12 G-DINA  0.09498799
## d_1231 b112     12 G-DINA  0.54806811
```

Standard Errors

Compute the (correct) variance covariance matrix of all model parameters:

```
v0 <- vcov(mGDINA)
```

Compute the (incorrect) variance covariance matrix by ignoring the skill parameters:

```
v1 <- vcov(mGDINA, type = "partial")
```

Compute the (incorrect) variance covariance matrix by item-wise computation of the information matrix:

```
v2 <- vcov(mGDINA, type = "itemwise")
```

Standard errors for the item parameters

```
cbind("full (correct)"       = sqrt(diag(v0))[seq(1, 2*nrow(qmat))],
      "partial (incorrect)"  = sqrt(diag(v1)),
      "itemwise (incorrect)" = sqrt(diag(v2)))
```

```
##       full (correct) partial (incorrect) itemwise (incorrect)
##  [1,]     0.07121171          0.06518312           0.05217388
##  [2,]     0.07279614          0.06718363           0.05464946
##  [3,]     0.11612098          0.08626799           0.06796940
##  [4,]     0.17182358          0.09082291           0.07200665
##  [5,]     0.07021230          0.05737784           0.04947524
##  [6,]     0.07127242          0.05879708           0.05108984
```

```
##  [7,]     0.04012112          0.03712668          0.03196255
##  [8,]     0.04161989          0.03877674          0.03398180
##  [9,]     0.09022412          0.08127162          0.05204203
## [10,]     0.15288442          0.14595823          0.11984529
## [11,]     0.24267117          0.17271489          0.10754958
## [12,]     0.30099310          0.21197154          0.15516515
## [13,]     0.11624850          0.07362337          0.05860907
## [14,]     0.18365387          0.15544856          0.12465630
## [15,]     0.13378764          0.09471415          0.08028801
## [16,]     0.19781948          0.16807885          0.13786396
## [17,]     0.08273508          0.07972691          0.06892772
## [18,]     0.38165644          0.23151316          0.19463657
## [19,]     0.14913728          0.14203399          0.12228028
## [20,]     0.40243539          0.26098010          0.22077888
## [21,]     0.11027818          0.10202863          0.07466451
## [22,]     0.23194382          0.21088713          0.17283776
## [23,]     0.21392272          0.13561825          0.10649104
## [24,]     0.31876822          0.23353762          0.18993072
## [25,]     0.07121171          0.05117352          0.03965984
## [26,]     0.07279614          0.33093551          0.21983244
## [27,]     0.11612098          0.09225305          0.08007924
## [28,]     0.17182358          0.34467225          0.23263022
## [29,]     0.07021230          0.04495428          0.03709611
## [30,]     0.07127242          0.05504762          0.04790852
## [31,]     0.04012112          0.17987668          0.11732563
## [32,]     0.04161989          0.18640738          0.12498224
## [33,]     0.09022412          0.05686949          0.04556542
## [34,]     0.15288442          0.16883727          0.14127159
## [35,]     0.24267117          1.17855729          0.58522110
## [36,]     0.30099310          0.17203164          0.13230816
## [37,]     0.11624850          1.34215412          0.73703531
## [38,]     0.18365387          0.26305703          0.20132970
## [39,]     0.13378764          1.18352783          0.59909999
## [40,]     0.19781948          1.34629442          0.75301474
## [41,]     0.08273508          0.04349507          0.03255495
## [42,]     0.38165644          1.28860960          0.66098386
## [43,]     0.14913728          0.47840854          0.37345415
## [44,]     0.40243539          0.27081987          0.21384399
## [45,]     0.11027818          1.81386396          1.28479053
## [46,]     0.23194382          1.51520043          0.93376039
## [47,]     0.21392272          0.55708288          0.43506161
## [48,]     0.31876822          1.98297735          1.44835048
```

Standard errors for the parameter estimates of the latent class distribution

```
sqrt(diag(v1))[-seq(1, 2*nrow(qmat))]
```

```
##  [1] 0.05117352 0.33093551 0.09225305 0.34467225 0.04495428 0.05504762
##  [7] 0.17987668 0.18640738 0.05686949 0.16883727 1.17855729 0.17203164
## [13] 1.34215412 0.26305703 1.18352783 1.34629442 0.04349507 1.28860960
## [19] 0.47840854 0.27081987 1.81386396 1.51520043 0.55708288 1.98297735
```

Confidence intervals

Confidence intervals for the intem parameters using the correct computation of the standard errors:

```
confint(mGDINA, alpha = 0.05)
```

```
##             itemno        lower       upper
## b101.d_0         1   0.063051317  0.34219611
## b101.d_1         1   0.590201164  0.87555680
## b102.d_0         2   0.056999643  0.51218552
## b102.d_1         2   0.378637393  1.05217344
## b103.d_0         3  -0.033285348  0.24194181
## b103.d_1         3   0.716507162  0.99588991
## b104.d_0         4   0.044466697  0.20173858
## b104.d_1         4   0.757987789  0.92113478
## b105.d_0         5  -0.055911749  0.29776029
## b105.d_1         5   0.201897496  0.80119339
## b105.d_2         5   0.213780936  1.16503445
## b105.d_12        5  -1.051702786  0.12816849
## b106.d_0         6  -0.088561417  0.36712434
## b106.d_1         6   0.084152099  0.80406205
## b106.d_2         6   0.546171496  1.07060942
## b106.d_12        6  -0.825331729 -0.04989362
## b107.d_0         7   0.112393391  0.43670894
## b107.d_1         7  -0.435964239  1.06010151
## b107.d_2         7   0.102150511  0.68675791
## b107.d_12        7  -0.830094927  0.74742281
## b108.d_0         8   0.142066992  0.57434950
## b108.d_1         8  -0.004407718  0.90479533
## b108.d_2         8   0.222508928  1.06107058
## b108.d_12        8  -1.126457865  0.12309059
## b109.d_0         9  -0.026767989  0.18804404
## b109.d_1         9  -0.361300942  1.22932240
## b109.d_2         9   0.378491204  0.76862057
## b109.d_12        9  -1.136093436  0.50381850
## b110.d_0        10  -0.030869172  0.17526400
## b110.d_1        10  -0.162227099  0.08380339
## b110.d_2        10   0.375569476  1.10581429
## b110.d_12       10  -0.342500140  0.41228464
## b111.d_0        11  -0.052037188  0.21247892
## b111.d_1        11  -0.555819291  0.39538156
## b111.d_2        11  -9.697870384 11.53742465
## b111.d_3        11  -3.266888533  3.13786385
## b111.d_12       11 -11.345357072 10.33535576
## b111.d_13       11  -3.225420402  3.38879778
## b111.d_23       11 -11.487323073 10.90126640
## b111.d_123      11 -10.845750188 11.97194751
## b112.d_0        12  -0.070306683  0.15515541
## b112.d_1        12  -4.311337857  4.22649313
## b112.d_2        12  -4.198409819  4.11356509
## b112.d_3        12  -1.256776158  1.17193143
## b112.d_12       12  -7.043770998  7.47923079
## b112.d_13       12  -6.107679782  6.19252451
## b112.d_23       12  -3.859605176  4.04958115
```

```
## b112.d_123     12  -7.982720942  9.07885715
```

Item-level fit

Item-level comparison of saturated and reduced models (de la Torre, 2013):

```r
gdina_wald(mGDINA)
```

```
##              Kj   W value df     Pr(>W)
## b101  1.000000        NA NA         NA
## b102  1.000000        NA NA         NA
## b103  1.000000        NA NA         NA
## b104  1.000000        NA NA         NA
## b105  2.000000 14.529871  2 0.0006996 ***
## b106  2.000000 38.464606  2 4.441e-09 ***
## b107  2.000000  7.259821  2 0.0265186 *
## b108  2.000000  9.369927  2 0.0092331 **
## b109  2.000000 33.230430  2 6.083e-08 ***
## b110  2.000000 18.538968  2 9.426e-05 ***
## b111  3.000000  7.210987  6 0.3017754
## b112  3.000000  0.046081  6 0.9999980
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Fit indices

```r
logLik(mGDINA)
```

```
## 'log Lik.' -2425.988 (df=63)
```

```r
BIC(mGDINA)
```

```
## [1] 5243.999
```

```r
AIC(mGDINA)
```

```
## [1] 4977.977
```

Fitting Reduced Models

Fit the reduced DINA model

```r
mDINA <- gdina(resp, qmat, rule = "DINA")
```

Fit the reduced DINO model

```r
mDINO <- gdina(resp, qmat, rule = "DINO")
```

Fit the reduced ACDM

```r
mACDM <- gdina(resp, qmat, rule = "ACDM")
```

Model comparisons

Compare (non-nested) models

```r
AIC(mDINA, mDINO, mACDM, mGDINA)
```

```
##        df      AIC
## mDINA  39 5035.778
## mDINO  39 5204.394
## mACDM  49 4949.977
## mGDINA 63 4977.977
```

```r
BIC(mDINA, mDINO, mACDM, mGDINA)
```

```
##        df      BIC
## mDINA  39 5200.459
## mDINO  39 5369.075
## mACDM  49 5156.883
## mGDINA 63 5243.999
```

compare (nested) models

```r
anova(mDINA, mACDM, mGDINA)
```

```
## Analysis of Variance Table
##
##    Npar  logLik    AIC    BIC Df Deviance Pr(>Chi)
## m1   39 -2478.9 5035.8 5200.5
## m2   49 -2426.0 4950.0 5156.9 10    105.8   <2e-16 ***
## m3   63 -2426.0 4978.0 5244.0 14      0.0        1
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
anova(mDINO, mACDM, mGDINA)
```

```
## Analysis of Variance Table
##
##    Npar  logLik    AIC    BIC Df Deviance Pr(>Chi)
## m1   39 -2563.2 5204.4 5369.1
## m2   49 -2426.0 4950.0 5156.9 10   274.42   <2e-16 ***
## m3   63 -2426.0 4978.0 5244.0 14     0.00        1
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```