Minimal Surface Area Problem

25 Conjugate Gradient Algorithms
Comparison between conjugate gradient algorithms and their accelerated variants

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1. Conjugate Gradient Algorithms

```
   *-----------------------------------------------------
   | Fastest Conjugate Gradient Algorithm Project
   |                                      April 2, 2009
   | stoptest =     1
   | maxiter  = 10000
   | Conjugate Gradient with Powell restart.
   *-----------------------------------------------------

     1    CG-HS Algorithm. Function:Minimal Surface Area
          Hestenes and Stiefel.  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    326    92    505   178       962  .1000000130278E+01  .4626278704131E-04
-------------------------------------------------------------------------------
TOTAL     326    92    505   178      9.62 (seconds)    proc=  28.22%


     2    CG-FR Algorithm. Function:Minimal Surface Area
          Fletcher and Reeves.  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    399   127    625   225      1146  .1000000335667E+01  .5439062174767E-04
-------------------------------------------------------------------------------
TOTAL     399   127    625   225     11.46 (seconds)    proc=  31.83%


     3    CG-PRP Algorithm. Function:Minimal Surface Area
          Polak-Ribiere and Polyak.  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    374   120    590   215      1089  .1000000193002E+01  .5192877567106E-04
-------------------------------------------------------------------------------
TOTAL     374   120    590   215     10.89 (seconds)    proc=  32.09%


     4    CG-PRP+ Algorithm. Function:Minimal Surface Area
          Polak-Ribiere and Polyak plus.  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    374   120    590   215      1092  .1000000193002E+01  .5192877567106E-04
-------------------------------------------------------------------------------
TOTAL     374   120    590   215     10.92 (seconds)    proc=  32.09%
```

```
     5    CG-CD Algorithm. Function:Minimal Surface Area
          Conjugate Descent - Fletcher. stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    419   131    646   226      1185  .1000000017491E+01  .4266705007384E-04
-------------------------------------------------------------------------------
TOTAL     419   131    646   226     11.85 (seconds)    proc=  31.26%


     6    CG-LS Algorithm. Function:Minimal Surface Area
          Liu and Storey.  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    443   138    699   254      1290  .1000000128729E+01  .4284170537791E-04
-------------------------------------------------------------------------------
TOTAL     443   138    699   254     12.90 (seconds)    proc=  31.15%


     7    CG-DY Algorithm. Function:Minimal Surface Area
          Dai and Yuan.  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    347    97    528   180       975  .1000000005925E+01  .4098356585345E-04
-------------------------------------------------------------------------------
TOTAL     347    97    528   180      9.75 (seconds)    proc=  27.95%


     8    CG-DL Algorithm. Function:Minimal Surface Area
          Dai and Liao (t=1).  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    353   109    544   190      1009  .1000000190415E+01  .4627745244128E-04
-------------------------------------------------------------------------------
TOTAL     353   109    544   190     10.09 (seconds)    proc=  30.88%


     9    CG-DL+ Algorithm. Function:Minimal Surface Area
          Dai and Liao plus (t=1).  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    365   113    555   189      1027  .1000000100002E+01  .4577992976737E-04
-------------------------------------------------------------------------------
TOTAL     365   113    555   189     10.27 (seconds)    proc=  30.96%


    10    CG-SDC Algorithm. Function:Minimal Surface Area
          Andrei - Sufficient Descent Condition.  stoptest= 1
    aCGSD: beta = gtg/yts - ytg*stg/(yts*yts)
     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000  10001  9929  10047    45     19290  .1029312446165E+01  .2885091620876E-01
-------------------------------------------------------------------------------
TOTAL   10001  9929  10047    45    192.90 (seconds)    proc=  99.28%


    11    CG-hDY Algorithm. Function:Minimal Surface Area
          hDY:Hybrid Dai and Yuan. max(c*DY,min(HS,DY)). stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    606   187    979   372      1807  .1000000210534E+01  .4926958688630E-04
-------------------------------------------------------------------------------
TOTAL     606   187    979   372     18.07 (seconds)    proc=  30.86%


    12    CG-hDYz Algorithm. Function:Minimal Surface Area
          hDYz: Hybrid Dai and Yuan zero. max(0,min(HS,DY)). stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
```

```
 40000    606   187    979   372      1810  .1000000210534E+01  .4926958688630E-04
-------------------------------------------------------------------------------------
TOTAL     606   187    979   372     18.10 (seconds)    proc=  30.86%


    13    CG-GN Algorithm. Function:Minimal Surface Area
          Gilbert and Nocedal.  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------------
 40000    362   113    558   195      1029  .1000000204381E+01  .4292767752622E-04
-------------------------------------------------------------------------------------
TOTAL     362   113    558   195     10.29 (seconds)    proc=  31.22%


    14    CG-HuS Algorithm. Function:Minimal Surface Area
          PRP-FR: Hu and Storey. max(0,min(PRP,FR)). stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------------
 40000    362   113    558   195      1032  .1000000204381E+01  .4292767752622E-04
-------------------------------------------------------------------------------------
TOTAL     362   113    558   195     10.32 (seconds)    proc=  31.22%


    15    CG-TAS Algorithm. Function:Minimal Surface Area
          Touat-Ahmed and Storey. (PRP <= FR). stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------------
 40000    362   113    558   195      1030  .1000000204381E+01  .4292767752622E-04
-------------------------------------------------------------------------------------
TOTAL     362   113    558   195     10.30 (seconds)    proc=  31.22%


    16    LS-CD Algorithm. Function:Minimal Surface Area
          Hybrid Liu&Storey-Conjugate Descent. max(0,min(LS,CD)) stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------------
 40000    343   115    544   199      1004  .1000000060617E+01  .4344730257501E-04
-------------------------------------------------------------------------------------
TOTAL     343   115    544   199     10.04 (seconds)    proc=  33.53%


    17    CG-BM Algorithm. Function:Minimal Surface Area
          Birgin and Martinez (scaled Perry). Theta spectral. stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------------
 40000    401   123    617   215      1144  .1000000003082E+01  .2315798552546E-04
-------------------------------------------------------------------------------------
TOTAL     401   123    617   215     11.44 (seconds)    proc=  30.67%


    18    CG-BM+ Algorithm. Function:Minimal Surface Area
          Birgin and Martinez plus (scaled Perry). Theta spectral. stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------------
 40000    369   112    569   199      1059  .1000000051201E+01  .3258700728285E-04
-------------------------------------------------------------------------------------
TOTAL     369   112    569   199     10.59 (seconds)    proc=  30.35%


    19    CG-sPRP Algorithm. Function:Minimal Surface Area
          Scaled Polak-Ribiere and Polyak. Theta spectral. stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------------
 40000    363   111    568   204      1053  .1000000160861E+01  .4814374374548E-04
-------------------------------------------------------------------------------------
TOTAL     363   111    568   204     10.53 (seconds)    proc=  30.58%


    20    CG-sFR Algorithm. Function:Minimal Surface Area
          Scaled Fletcher and Revees. Theta spectral. stoptest= 1
```

```
     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
--------------------------------------------------------------------------------
 40000    412   131    646   233      1193  .1000000100958E+01  .4180151393785E-04
--------------------------------------------------------------------------------
TOTAL     412   131    646   233     11.93 (seconds)    proc=  31.80%


    21    New CG Algorithm. Function:Minimal Surface Area
          Andrei New Sufficient Descent from PRP. stoptest= 1
    PRP-SDC: beta = (ytg-yty*stg/gtgprev)/yts
     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
--------------------------------------------------------------------------------
 40000    632   194   1026   393      1898  .1000000294875E+01  .5321155872259E-04
--------------------------------------------------------------------------------
TOTAL     632   194   1026   393     18.98 (seconds)    proc=  30.70%


    22    New CG Algorithm. Function:Minimal Surface Area
          Andrei New Sufficient Descent from DY. stoptest= 1
          ACGSD: beta=ytg/yts-ytg*stg/(yts**2)

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
--------------------------------------------------------------------------------
 40000    359   106    550   190      1019  .1000000067436E+01  .3067793134027E-04
--------------------------------------------------------------------------------
TOTAL     359   106    550   190     10.19 (seconds)    proc=  29.53%


    23    New CG Algorithm. Function:Minimal Surface Area
          Andrei Sufficient Descent from DY (max). stoptest= 1
          ACGSDz: beta=max(0,ytg/yts)*(1-stg/yts)

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
--------------------------------------------------------------------------------
 40000    358   108    549   190      1018  .1000000090341E+01  .3926705350975E-04
--------------------------------------------------------------------------------
TOTAL     358   108    549   190     10.18 (seconds)    proc=  30.17%


    24    New CG Algorithm. Function:Minimal Surface Area
          PRP - DY with Newton direction. (NDOMB) stoptest= 1
     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
--------------------------------------------------------------------------------
 40000    339    87    504   164       934  .1000000073097E+01  .3677357393504E-04
--------------------------------------------------------------------------------
TOTAL     339    87    504   164      9.34 (seconds)    proc=  25.66%


    25    New CG Algorithm. Function:Minimal Surface Area
          PRP - DY with Conjugacy Condition. (CCOMB) stoptest= 1
     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
--------------------------------------------------------------------------------
 40000    361   105    547   185      1016  .1000000068635E+01  .4429164579067E-04
--------------------------------------------------------------------------------
TOTAL     361   105    547   185     10.16 (seconds)    proc=  29.09%
```

2. Accelerated Conjugate Gradient Algorithms

```
*-------------------------------------------------
| Fastest Conjugate Gradient Algorithm Project
|                                      April 2, 2009
| stoptest =     1
| maxiter  = 10000
| Accelerated Conjugate Gradient with Powell restart.
*-------------------------------------------------

  1    CG-HS Algorithm. Function:Minimal Surface Area
       Hestenes and Stiefel.  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    281     1    582    19      1099  .1000000005314E+01  .3701995084726E-04
-------------------------------------------------------------------------------
TOTAL     281     1    582    19     10.99 (seconds)    proc=    .36%


  2    CG-FR Algorithm. Function:Minimal Surface Area
       Fletcher and Reeves.  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    260     8    564    43      1025  .1000000011108E+01  .3987712387393E-04
-------------------------------------------------------------------------------
TOTAL     260     8    564    43     10.25 (seconds)    proc=   3.08%


  3    CG-PRP Algorithm. Function:Minimal Surface Area
       Polak-Ribiere and Polyak.  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    281     1    582    19      1065  .1000000005317E+01  .3737157318242E-04
-------------------------------------------------------------------------------
TOTAL     281     1    582    19     10.65 (seconds)    proc=    .36%


  4    CG-PRP+ Algorithm. Function:Minimal Surface Area
       Polak-Ribiere and Polyak plus.  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    281     1    582    19      1068  .1000000005317E+01  .3737157318242E-04
-------------------------------------------------------------------------------
TOTAL     281     1    582    19     10.68 (seconds)    proc=    .36%


  5    CG-CD Algorithm. Function:Minimal Surface Area
       Conjugate Descent - Fletcher. stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    273     8    586    39      1066  .1000000002750E+01  .3695187166514E-04
-------------------------------------------------------------------------------
TOTAL     273     8    586    39     10.66 (seconds)    proc=   2.93%


  6    CG-LS Algorithm. Function:Minimal Surface Area
       Liu and Storey.  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    284     1    589    20      1077  .1000000003712E+01  .3295901606242E-04
-------------------------------------------------------------------------------
TOTAL     284     1    589    20     10.77 (seconds)    proc=    .35%


  7    CG-DY Algorithm. Function:Minimal Surface Area
       Dai and Yuan.  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
```

```
 40000    277     8    596    41      1089  .1000000002324E+01  .3761157252916E-04
-------------------------------------------------------------------------------------
TOTAL     277     8    596    41     10.89 (seconds)    proc=   2.89%


     8    CG-DL Algorithm. Function:Minimal Surface Area
          Dai and Liao (t=1).  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------------
 40000    281     1    582    19      1069  .1000000004679E+01  .3595009223815E-04
-------------------------------------------------------------------------------------
TOTAL     281     1    582    19     10.69 (seconds)    proc=    .36%


     9    CG-DL+ Algorithm. Function:Minimal Surface Area
          Dai and Liao plus (t=1).  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------------
 40000    281     1    582    19      1067  .1000000004679E+01  .3595009225661E-04
-------------------------------------------------------------------------------------
TOTAL     281     1    582    19     10.67 (seconds)    proc=    .36%


    10    CG-SDC Algorithm. Function:Minimal Surface Area
          Andrei - Sufficient Descent Condition.  stoptest= 1
    aCGSD: beta = gtg/yts - ytg*stg/(yts*yts)
     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------------
 40000    288     0    597    20      1097  .1000000003972E+01  .3406736062801E-04
-------------------------------------------------------------------------------------
TOTAL     288     0    597    20     10.97 (seconds)    proc=    .00%


    11    CG-hDY Algorithm. Function:Minimal Surface Area
          hDY:Hybrid Dai and Yuan. max(c*DY,min(HS,DY)). stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------------
 40000    385    76    973   202      1770  .1000000280960E+01  .5039454638956E-04
-------------------------------------------------------------------------------------
TOTAL     385    76    973   202     17.70 (seconds)    proc=  19.74%


    12    CG-hDYz Algorithm. Function:Minimal Surface Area
          hDYz: Hybrid Dai and Yuan zero. max(0,min(HS,DY)). stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------------
 40000    385    76    973   202      1770  .1000000280960E+01  .5039454638956E-04
-------------------------------------------------------------------------------------
TOTAL     385    76    973   202     17.70 (seconds)    proc=  19.74%


    13    CG-GN Algorithm. Function:Minimal Surface Area
          Gilbert and Nocedal.  stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------------
 40000    284     1    588    19      1074  .1000000004303E+01  .3511433288743E-04
-------------------------------------------------------------------------------------
TOTAL     284     1    588    19     10.74 (seconds)    proc=    .35%


    14    CG-HuS Algorithm. Function:Minimal Surface Area
          PRP-FR: Hu and Storey. max(0,min(PRP,FR)). stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------------
 40000    284     1    588    19      1076  .1000000004303E+01  .3511433288743E-04
-------------------------------------------------------------------------------------
TOTAL     284     1    588    19     10.76 (seconds)    proc=    .35%


    15    CG-TAS Algorithm. Function:Minimal Surface Area
          Touat-Ahmed and Storey. (PRP <= FR). stoptest= 1
```

```
     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    284     1    588    19      1076  .1000000004303E+01  .3511433288743E-04
-------------------------------------------------------------------------------
TOTAL     284     1    588    19     10.76 (seconds)    proc=    .35%


    16    LS-CD Algorithm. Function:Minimal Surface Area
          Hybrid Liu&Storey-Conjugate Descent. max(0,min(LS,CD)) stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    279     1    578    19      1058  .1000000005438E+01  .3658167056494E-04
-------------------------------------------------------------------------------
TOTAL     279     1    578    19     10.58 (seconds)    proc=    .36%


    17    CG-BM Algorithm. Function:Minimal Surface Area
          Birgin and Martinez (scaled Perry). Theta spectral. stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    285     1    590    19      1085  .1000000003885E+01  .3450575324852E-04
-------------------------------------------------------------------------------
TOTAL     285     1    590    19     10.85 (seconds)    proc=    .35%


    18    CG-BM+ Algorithm. Function:Minimal Surface Area
          Birgin and Martinez plus (scaled Perry). Theta spectral. stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    285     1    590    19      1085  .1000000003885E+01  .3450575352871E-04
-------------------------------------------------------------------------------
TOTAL     285     1    590    19     10.85 (seconds)    proc=    .35%


    19    CG-sPRP Algorithm. Function:Minimal Surface Area
          Scaled Polak-Ribiere and Polyak. Theta spectral. stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    368    75    912   175      1661  .1000000207170E+01  .5194581054124E-04
-------------------------------------------------------------------------------
TOTAL     368    75    912   175     16.61 (seconds)    proc=  20.38%


    20    CG-sFR Algorithm. Function:Minimal Surface Area
          Scaled Fletcher and Revees. Theta spectral. stoptest= 1

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    324    66    804   155      1463  .1000000043960E+01  .3525609273337E-04
-------------------------------------------------------------------------------
TOTAL     324    66    804   155     14.63 (seconds)    proc=  20.37%


    21    New CG Algorithm. Function:Minimal Surface Area
          Andrei New Sufficient Descent from PRP. stoptest= 1
    PRP-SDC: beta = (ytg-yty*stg/gtgprev)/yts
     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    436    86   1116   243      2032  .1000000023691E+01  .4277468083321E-04
-------------------------------------------------------------------------------
TOTAL     436    86   1116   243     20.32 (seconds)    proc=  19.72%


    22    New CG Algorithm. Function:Minimal Surface Area
          Andrei New Sufficient Descent from DY. stoptest= 1
          ACGSD: beta=ytg/yts-ytg*stg/(yts**2)

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    282     0    585    20      1075  .1000000005489E+01  .3712331804413E-04
-------------------------------------------------------------------------------
TOTAL     282     0    585    20     10.75 (seconds)    proc=    .00%
```

```
    23    New CG Algorithm. Function:Minimal Surface Area
          Andrei Sufficient Descent from DY (max). stoptest= 1
          ACGSDz: beta=max(0,ytg/yts)*(1-stg/yts)

     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    282     0    585    20      1072  .1000000005489E+01  .3712331805512E-04
-------------------------------------------------------------------------------
TOTAL     282     0    585    20     10.72 (seconds)    proc=    .00%


    24    New CG Algorithm. Function:Minimal Surface Area
          PRP - DY with Newton direction. (NDOMB) stoptest= 1
     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    278     1    576    19      1059  .1000000006139E+01  .3864510871461E-04
-------------------------------------------------------------------------------
TOTAL     278     1    576    19     10.59 (seconds)    proc=    .36%


    25    New CG Algorithm. Function:Minimal Surface Area
          PRP - DY with Conjugacy Condition. (CCOMB) stoptest= 1
     n   iter   irs  fgcnt lscnt   time(c)        fxnew              gnorm
-------------------------------------------------------------------------------
 40000    283     1    587    20      1076  .1000000004466E+01  .3557583723444E-04
-------------------------------------------------------------------------------
TOTAL     283     1    587    20     10.76 (seconds)    proc=    .35%
```

Remarks.

This problem belongs to the MINPACK2 collection.

These results have been obtained with APPL7.FOR package which implements 25 conjugate gradient algorithms in classical and accelerated versions. To use the accelerated version of these algorithms the value of the logical parameter accel must be set to .true.

Observe the differences between cpu time corresponding to the conjugate gradient algorithms and their accelerated versions.

References

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