

Multivariate, RRM, and RNM using BLUPF90

Daniela Lourenco

BLUPF90 TEAM – 08/2024



**UNIVERSITY OF
GEORGIA**

**College of Agricultural &
Environmental Sciences**

*Animal Breeding and
Genetics Group*



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RENUMF90 parameter file: multi-trait

```
# Parameter file for program renf90; it is translated to parameter
# file for BLUPF90 family f programs.
# ## Columns in example10.ped ##
# # 1 2 3 4
# # animal sire dam yob
#
# ## Columns in example10.dat ##
# # 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
# # animal CG_BW CG_WW CG_YW BW WW YW sire dam herd age_BW age_WW age_YW AOD sireXherd YOB
#
DATAFILE
example10.dat
TRAITS
5 6 7
FIELDS_PASSED TO OUTPUT

WEIGHT(S)

RESIDUAL_VARIANCE
22.92 28.79 85.95
28.79 207.58 180.90
85.95 180.90 488.42
EFFECT
2 3 4 cross alpha
EFFECT
14 14 14 cov
EFFECT
1 1 1 cross alpha
RANDOM
animal
OPTIONAL
mat
FILE
example10.ped
FILE_POS
1 2 3 0 4
PED_DEPTH
3
```

RENUMF90 parameter file: multi-trait

```
(CO)VARIANCES
 32.79      -7.22      -11.07      -8.59      -0.35      -0.68
-7.22      258.06      87.66      4.55      21.57      29.92
-11.07     87.66     194.34      4.54      23.12      26.67
-8.59      4.55      4.54      46.91      0.60      -0.08
-0.35      21.57      23.12      0.60     132.24      29.95
-0.68      29.92      26.67     -0.08      29.95     132.65
EFFECT
15 15 15 cross alpha
RANDOM
diagonal
(CO)VARIANCES
 9.61      3.42      2.36
 3.42     224.03     148.26
 2.36     148.26     242.12
OPTION blksize 3
OPTION sol se
OPTION use_yams
```

renf90.par: multi-trait

```
# BLUPF90 parameter file created by RENUMF90
DATAFILE
  renf90.dat
NUMBER_OF_TRAITS
  3
NUMBER_OF_EFFECTS
  5
OBSERVATION(S)
  1 2 3
WEIGHT(S)

EFFECTS: POSITIONS_IN_DATAFILE NUMBER_OF_LEVELS TYPE_OF_EFFECT[EFFECT NESTED]
  4 5 6      3130 cross
  7 7 7 1 cov
  8 8 8      43299 cross
  9 9 9      43299 cross
 10 10 10     3098 cross
RANDOM_RESIDUAL VALUES
  22.920      28.790      85.950
  28.790      207.58      180.90
  85.950      180.90      488.42
RANDOM_GROUP
  3 4
RANDOM_TYPE
  add_an_upginb
FILE
  renadd03.ped
(CO)VARIANCES
  32.790      -7.2200      -11.070      -8.5900      -0.35000      -0.68000
  -7.2200      258.06      87.660      4.5500      21.570      29.920
  -11.070      87.660      194.34      4.5400      23.120      26.670
  -8.5900      4.5500      4.5400      46.910      0.60000      -0.80000E-01
  -0.35000      21.570      23.120      0.60000      132.24      29.950
  -0.68000      29.920      26.670      -0.80000E-01      29.950      132.65
RANDOM_GROUP
  5
RANDOM_TYPE
  diagonal
```

renf90.par: multi-trait

(CO)VARIANCES

9.6100	3.4200	2.3600
3.4200	224.03	148.26
2.3600	148.26	242.12

OPTION blksize 3

OPTION sol se

OPTION use_yams

Problems with multi-trait models

- Poor convergence
 - Some traits have lots of missing records
 - Lots of genotyped animals with no records
- Example – Computing GEBV
 - American Angus Association
 - ww, rib, cwt, uswt, urib_b, urib_c, fat, ufat_b, ufat_c
 - Some traits with >2M and some with 100k records

Traits	Rounds	Time (h)	Time (s)/round
9	4313	39	28.11
7	2835	23	22.72

(No rib and fat - 348 animals with gen/phen)

Random regression models





Journal of Dairy Science

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Review

Invited review: Advances and applications of random regression models: From quantitative genetics to genomics

H.R. Oliveira^{1,2}, L.F. Brito^{1,3}, D.A.L. Lourenco⁴, F.F. Silva², J. Jamrozik^{1,5}, L.R. Schaeffer¹, F.S. Schenkel¹  

Random regression models

Animal model with PE: $y = b + a + p + e$

*Animal model with Random regression: $y = (b_0 + b_1*x) + (a_0 + a_1*x) + (p_0 + p_1*x) + e$*



Random Regression vs. Reaction Norm

RRM: uses temporal covariables

RNM: uses environmental covariables

RENUMF90: Random regression options

Keyword	possible value	description
RANDOM_REGRESSION		Specifies that random regression should be applied to the random* effects
	data	If covariables are in the data
	legendre	If the program will compute Legendre polynomials

Keyword	possible value	description
RR_POSITON	Integer	Specifies positions of covariables in the data if RANDOM_REGRESSION type is data
	r1 ... rq	Positions of covariables if “data”
	r1 r2	r1 is the order of the polynomial and r2 is the position of covariable if “legendre”

RENUMF90: Reaction norm options

Keyword	possible value	description
RANDOM_REGRESSION	data	Specifies that random regression should be applied to the random* effects If covariables are in the data

Keyword	possible value	description
RR_POSITON	Integer r1 ... rq	Specifies positions of covariables in the data if RANDOM_REGRESSION type is data Positions of covariables if “data”

RENUMF90 parameter file: RRM

Covariables are in the data

```
DATAFILE
datrr.leg
TRAITS
4
FIELDS_PASSED TO OUTPUT
 2 # dim
WEIGHT(S)

RESIDUAL_VARIANCE
3.710
EFFECT
3 cross alpha          #cg
EFFECT
5 cross alpha # mu column of ones
RANDOM_REGRESSION
data
RR_POSITION
6 7 8 9 10
EFFECT
1 cross cross          #cow
RANDOM
animal
OPTIONAL
pe
FILE
pedrr
RANDOM_REGRESSION
data
RR_POSITION
6 7 8
(CO)VARIANCES
 3.297  0.594 -1.381
 0.594  0.921 -0.289
-1.381 -0.289  1.005
(CO)VARIANCES_PE
 6.872 -0.254 -1.101
-0.254  3.171  0.167
-1.101  0.167  2.457
```

4	4	1	17.0	1	.707107	-1.224745	1.581139	-1.870829	2.121320
4	38	2	18.6	1	.707107	-.952579	.644168	-.017964	-.620456
4	72	3	24.0	1	.707107	-.680414	-.058561	.757057	-.775651
4	106	4	20.0	1	.707107	-.408248	-.527046	.762189	.026189
4	140	5	20.0	1	.707107	-.136083	-.761289	.305389	.698700
4	174	6	15.5	1	.707107	.136083	-.761289	-.305389	.698700
4	208	7	16.0	1	.707107	.408248	-.527046	-.762189	.026189
4	242	8	13.0	1	.707107	.680414	-.058561	-.757057	-.775651
4	276	9	8.2	1	.707107	.952579	.644168	.017964	-.620456
4	310	10	8.0	1	.707107	1.224745	1.581139	1.870829	2.121320

RENUMF90 parameter file: RRM

```
# Parameter file for Random regression model
DATAFILE
datrr.leg
TRAITS
4
FIELDS_PASSED TO OUTPUT
 2 # dim
WEIGHT(S)

RESIDUAL_VARIANCE
3.710
EFFECT
3 cross alpha #cg
EFFECT
5 cross alpha # mu column of ones
FIXED_REGRESSION
legendre
RR_POSITION
5 2
EFFECT
1 cross alpha #cow
RANDOM
animal
OPTIONAL
pe
FILE
pedrr
RANDOM_REGRESSION
legendre
RR_POSITION
3 2
(CO)VARIANCES
3.297 0.594 -1.381
0.594 0.921 -0.289
-1.381 -0.289 1.005
(CO)VARIANCES_PE
6.872 -0.254 -1.101
-0.254 3.171 0.167
-1.101 0.167 2.457
```

Covariables created by renumf90

4	4	1	17.0	1	.707107	-1.224745	1.581139	-1.870829	2.121320
4	38	2	18.6	1	.707107	-.952579	.644168	-.017964	-.620456
4	72	3	24.0	1	.707107	-.680414	-.058561	.757057	-.775651
4	106	4	20.0	1	.707107	-.408248	-.527046	.762189	.026189
4	140	5	20.0	1	.707107	-.136083	-.761289	.305389	.698700
4	174	6	15.5	1	.707107	.136083	-.761289	-.305389	.698700
4	208	7	16.0	1	.707107	.408248	-.527046	-.762189	.026189
4	242	8	13.0	1	.707107	.680414	-.058561	-.757057	-.775651
4	276	9	8.2	1	.707107	.952579	.644168	.017964	-.620456
4	310	10	8.0	1	.707107	1.224745	1.581139	1.870829	2.121320

renf90.par: RRM

```
# BLUPF90 parameter file created by RENUMF90
DATAFILE
renf90.dat
NUMBER_OF_TRAITS
1 # covariables are in the data
NUMBER_OF_EFFECTS
12
OBSERVATION(S)
1
WEIGHT(S)

EFFECTS: POSITIONS_IN_DATAFILE NUMBER_OF_LEVELS TYPE_OF_EFFECT[EFFECT NESTED]
7 10 cross
2 1 cov 8
3 1 cov 8
4 1 cov 8
5 1 cov 8
6 1 cov 8
2 8 cov 9
3 8 cov 9
4 8 cov 9
2 8 cov 9
3 8 cov 9
4 8 cov 9
RANDOM_RESIDUAL_VALUES
3.7100
RANDOM_GROUP
7 8 9
RANDOM_TYPE
add_an_upginb
FILE
renadd03.ped
(CO)VARIANCES
3.2970 0.59400 -1.3810
0.59400 0.92100 -0.28900
-1.3810 -0.28900 1.0050
RANDOM_GROUP
10 11 12
RANDOM_TYPE
diagonal
FILE
(CO)VARIANCES
6.8720 -0.25400 -1.1010
-0.25400 3.1710 0.16700
-1.1010 0.16700 2.4570
```

```
# BLUPF90 parameter file created by RENUMF90
DATAFILE
renf90.dat
NUMBER_OF_TRAITS
1 # covariables created by renumf90
NUMBER_OF_EFFECTS
12
OBSERVATION(S)
1
WEIGHT(S)

EFFECTS: POSITIONS_IN_DATAFILE NUMBER_OF_LEVELS TYPE_OF_EFFECT[EFFECT NESTED]
7 10 cross
2 1 cov 8
3 1 cov 8
4 1 cov 8
5 1 cov 8
6 1 cov 8
2 8 cov 9
3 8 cov 9
4 8 cov 9
2 8 cov 9
3 8 cov 9
4 8 cov 9
RANDOM_RESIDUAL_VALUES
3.7100
RANDOM_GROUP
7 8 9
RANDOM_TYPE
add_an_upginb
FILE
renadd03.ped
(CO)VARIANCES
3.2970 0.59400 -1.3810
0.59400 0.92100 -0.28900
-1.3810 -0.28900 1.0050
RANDOM_GROUP
10 11 12
RANDOM_TYPE
diagonal
FILE
(CO)VARIANCES
6.8720 -0.25400 -1.1010
-0.25400 3.1710 0.16700
-1.1010 0.16700 2.4570
```

RENUMF90 parameter file: multi-trait RRM

```
# DATA FILE = HO.dat
# 1 2 3 4 5 6 7 8 9 10 11 12
# ID17_COW HerdID-by-TDAT_grp DIM*season LACT State MILK FAT_lb PROT_lb ageCALVmon_grp mean b0 HL=f(THI)

# PED FILE = HO.ped
# 1 2 3 4
# animal sire dam YOB
```

RENUMF90 parameter file: multi-trait RRM

```
DATAFILE
H0.phen
TRAITS
6 7 8
FIELDS_PASSED TO OUTPUT
1 # animID
WEIGHT(S)

RESIDUAL_VARIANCE
#3x3 structure
EFFECT
2 2 2 cross alpha # HTD
EFFECT
3 3 3 cross alpha # DIM*season grp
# EFFECT - NO LACT EFFECT FOR LACT1 MODEL
# 4 4 4 cross alpha # lact
EFFECT
5 5 5 cross alpha # state
EFFECT
9 9 9 cross alpha # ageCALV grp
EFFECT
10 10 10 cov # fixed regression (pop. mean = THI threshold = 69)
EFFECT
1 1 1 cross alpha # animID
RANDOM
animal
OPTIONAL
pe
FILE
H0.ped
FILE_POS
1 2 3 0 4
SNP_FILE
H0.geno
```

```
PED_DEPTH
3
REC_SEX
2
INBREEDING
pedigree
RANDOM_REGRESSION
data
RR_POSITION # RR HL=f(THI) applied to anim and pe
11 12
(CO)VARIANCES
#6x6 structure
(CO)VARIANCES_PE
#6x6 structure
OPTION use_yams
```


renf90.par: multi-trait RRM

```
DATAFILE
renf90.dat
NUMBER_OF_TRAITS
3
NUMBER_OF_EFFECTS
8 # 9
OBSERVATION(S)
1 2 3
WEIGHT(S)

EFFECTS: POSITIONS_IN_DATAFILE NUMBER_OF_LEVELS TYPE_OF_EFFECT[EFFECT NESTED]
6 6 6 1000 cross # HTD
7 7 7 10 cross # DIM*season
8 8 8 20 cross # State
9 9 9 10 cross # ageCALVmon
# 10 10 10 1 cov # fixed_reg THI threshold
4 4 4 80000 cov 11 11 11 # intercept_1s - by - anim
5 5 5 80000 cov 11 11 11 # HL[f(THI)] - by - anim
4 4 4 00000 cov 11 11 11 # intercept_1s - by - pe
5 5 5 80000 cov 11 11 11 # HL[f(THI)] - by - pe
RANDOM_RESIDUAL_VALUES
#3x3 structure
RANDOM_GROUP # anim regressions (intercept and slope)
5 6
RANDOM_TYPE
add_an_upginb
FILE
renadd06.ped
(CO)VARIANCES
#6x6 structure
RANDOM_GROUP # pe regressions (intercept and slope)
7 8
RANDOM_TYPE
diagonal
```

```
(CO)VARIANCES
#6x6 structure
OPTION SNP_file H0.geno_clean
OPTION use_yams
OPTION no_quality_control
OPTION conv_crit 1e-14
OPTION blksize 3
```

(CO)VARIANCES structure

b0

b1

		E1			E2		
		T1	T2	T3	T1	T2	T3
E1	T1						
	T2						
	T3						
E2	T1						
	T2						
	T3						

Computing (G)EBV



BLUPF90

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RRMEBF90

Summary

This program is a post-processor tool for solutions obtained with blupf90+ or gibbsf90+ for random-regression models. The program outputs solutions, variances, and reliabilities for a specific point of the longitudinal scale (e.g., days in milk), for a cumulative interval of the longitudinal scale, or with a user-specified vector of coefficients. The program can calculate solutions, variances, and reliabilities for a weighted average of different traits. Additionally, (co)variances and heritabilities for each value of the longitudinal scale can be calculated.

readme.rrmebv90

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Computing (G)EBV

- blupf90+ gives solutions for random regression coefficients
- How?
 - rrmebv90
 - Post-process solutions from blupf90+
 - Combine effects and traits into indices
 - Provide daily variances and h^2

rrmebv90

1. Run your random-regression model with blupf90+
2. Optionally, calculate or approximate prediction error variances
3. Run rrmebv90 with proper options and the same parameter file

rrmebv90

- `OPTION include_effects e1 e2 e3`
 - Calculates indexes for effects e1, e2, and e3
- `OPTION include_pev`
 - Calculates accuracies based on a pev_pec file
- `OPTION minmaxrr min max`
 - Min and max values to standardize longitudinal variable
- `OPTION timepoint t1 t2`
 - Calculates index for timepoint t1 and t2

rrmebv90

- `OPTION cumulative min max`
 - Calculates cumulative index between min and max
- `OPTION user_coef x`
 - `x` is a vector of user-supplied coefficients
- `OPTION trait_group t1,t2,t3 0.333 0.333 0.333`
 - Combine indexes for traits `t1`, `t2`, and `t3` using weights `0.333`
- `OPTION daily_var e1 e4`
 - Stores daily co-variances and `h2` for effects (and their correlated) `e1` and `e4`