Translating lme4 models to sommer

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The sommer package was developed to provide R users a powerful and reliable multivariate mixed model solver. The package is focused on problems of the type p > n (more effects to estimate than observations) and its core algorithm is coded in C++ using the Armadillo library. This package allows the user to fit mixed models with the advantage of specifying the variance-covariance structure for the random effects, and specifying heterogeneous variances, and obtaining other parameters such as BLUPs, BLUEs, residuals, fitted values, variances for fixed and random effects, etc.

The purpose of this vignette is to show how to translate the syntax formula from lme4 models to sommer models. Feel free to remove the comment marks from the lme4 code so you can compare the results.

1) Random slopes with same intercept
2) Random slopes and random intercepts (without correlation)
3) Random slopes and random intercepts (with correlation)
4) Random slopes with a different intercept
5) Other models not available in lme4

1) Random slopes

This is the simplest model people use when a random effect is desired and the levels of the random effect are considered to have the same intercept.

```r
# install.packages("lme4")
# library(lme4)
library(sommer)
data(DT_sleepstudy)
DT <- DT_sleepstudy

###########
## lme4
###########
fm1 <- lmer(Reaction ~ Days + (1 | Subject), data=DT)
summary(fm1) # or vc <- VarCorr(fm1); print(vc, comp="Variance")

Random effects:
   Groups   Name     Variance Std.Dev.
   Subject (Intercept) 1378.2    37.12
   Residual            960.5    30.99
Number of obs: 180, groups: Subject, 18

###########
## sommer
###########
fm2 <- mmer(Reaction ~ Days,
  random = ~ Subject,
  data=DT, tolParInv = 1e-6, verbose = FALSE)
summary(fm2)$varcomp
```
## VarComp VarCompSE Zratio Constraint
## Subject.Reaction-Reaction 1377.9758 505.0776 2.728246 Positive
## units.Reaction-Reaction 960.4705 107.0638 8.971013 Positive

# fm2 <- mmec(Reaction ~ Days,
# random= ~ Subject,
# data=DT, tolParInv = 1e-6, verbose = FALSE)
# summary(fm2)$varcomp

2) Random slopes and random intercepts (without correlation)

This is the a model where you assume that the random effect has different intercepts based on the levels of another variable. In addition the || in lme4 assumes that slopes and intercepts have no correlation.

### lme4

# fm1 <- lmer(Reaction ~ Days + (Days || Subject), data=DT)
# summary(fm1) # or vc <- VarCorr(fm1); print(vc,comp=c("Variance"))
# Random effects:
# Groups Name Variance Std.Dev.
# Subject (Intercept) 627.57 25.051
# Subject.1 Days 35.86 5.988
# Residual 653.58 25.565
# Number of obs: 180, groups: Subject, 18

### sommer

### fm2 <- mmer(Reaction ~ Days,
# random= ~ Subject + vsr(Days, Subject),
# data=DT, tolParInv = 1e-6, verbose = FALSE)
# summary(fm2)$varcomp

Notice that Days is a numerical (not factor) variable.

3) Random slopes and random intercepts (with correlation)

This is the a model where you assume that the random effect has different intercepts based on the levels of another variable. In addition a single | in lme4 assumes that slopes and intercepts have a correlation to be estimated.

### lme4

### fm2 <- mmer(Reaction ~ Days,
# fm1 <- lmer(Reaction ~ Days + (Days | Subject), data=DT)
# summary(fm1) # or # vc <- VarCorr(fm1); print(vc,comp=c("Variance"))
# Random effects:
# Groups  Name   Variance Std.Dev. Corr
# Subject  (Intercept) 612.10   24.741
#          Days          35.07    5.922  0.07
# Residual           654.94   25.592
# Number of obs: 180, groups: Subject, 18

# sommer
# no equivalence in sommer to find the correlation between the 2 vc
# this is the most similar which is equivalent to (intercept || slope)
fm2 <- mmer(Reaction ~ Days,
             random= ~ Subject + vsr(Days, Subject),
             data=DT, tolParInv = 1e-6, verbose = FALSE)
summary(fm2)$varcomp

## VarComp  VarCompSE   Zratio  Constraint
## Subject.Reaction-Reaction  627.54087  283.52939  2.213319  Positive
## Days:Subject.Reaction-Reaction 35.86008  14.53187  2.467686  Positive
## units.Reaction-Reaction     653.58305   76.72711  8.518281  Positive

4) Random slopes with a different intercept

This is the a model where you assume that the random effect has different intercepts based on the levels of another variable but there’s not a main effect. The 0 in the intercept in lme4 assumes that random slopes interact with an intercept but without a main effect.

### lme4

# fm1 <- lmer(Reaction ~ Days + (0 + Days | Subject), data=DT)
# summary(fm1) # or vc <- VarCorr(fm1); print(vc,comp=c("Variance"))
# Random effects:
# Groups  Name   Variance Std.Dev.
# Subject  Days          52.71    7.26
# Residual           842.03   29.02
# Number of obs: 180, groups: Subject, 18

# sommer

# mmec(Reaction ~ Days,
#      random= ~ vsr(Days, Subject),
#      data=DT, tolParInv = 1e-6, verbose = FALSE)

## VarComp  VarCompSE   Zratio  Constraint
## Days:Subject.Reaction-Reaction 52.70946  19.09984  2.759681  Positive
## units.Reaction-Reaction     842.02736  93.84640  8.972399  Positive
4) Other models available in sommer but not in lme4

One of the strengths of sommer is the availability of other variance covariance structures. In this section we show 4 models available in sommer that are not available in lme4 and might be useful.

```r
library(orthopolynom)

### diagonal model
fm2 <- mmer(Reaction ~ Days,
            random = ~ vsr(dsr(Daysf), Subject),
            data=DT, tolParInv = 1e-6, verbose = FALSE)
summary(fm2)$varcomp
```

```
## VarComp  VarCompSE  Zratio Constraint
## 0:Subject.Reaction-Reaction 139.5473 399.5095 0.3492967 Positive
## 1:Subject.Reaction-Reaction 196.8544 411.8262 0.4780037 Positive
## 2:Subject.Reaction-Reaction 0.0000 365.3178 0.0000000 Positive
## 3:Subject.Reaction-Reaction 556.0773 501.2665 1.1093445 Positive
## 4:Subject.Reaction-Reaction 855.2104 581.8190 1.4698910 Positive
## 5:Subject.Reaction-Reaction 1699.4269 820.4561 2.0713197 Positive
## 6:Subject.Reaction-Reaction 2910.8975 1175.7872 2.4757011 Positive
## 7:Subject.Reaction-Reaction 1539.6201 779.1437 1.9760413 Positive
## 8:Subject.Reaction-Reaction 2597.5337 1089.4522 2.3842568 Positive
## 9:Subject.Reaction-Reaction 3472.7108 1351.5702 2.5693899 Positive
## units.Reaction-Reaction 879.6958 247.4680 3.5547862 Positive
```

### unstructured model

```r
fm2 <- mmer(Reaction ~ Days,
            random = ~ vsr(usr(Daysf), Subject),
            data=DT, tolParInv = 1e-6, verbose = FALSE)
summary(fm2)$varcomp
```

```
## VarComp  VarCompSE  Zratio Constraint
## 0:Subject.Reaction-Reaction 402.6286 572.0867 0.7037894 Positive
## 1:Subject.Reaction-Reaction 1022.5098 393.6922 2.5972314 Unconstr
## 2:Subject.Reaction-Reaction 417.6460 521.3722 0.8010515 Positive
## 3:Subject.Reaction-Reaction 540.3746 287.1704 1.8817210 Unconstr
## 4:Subject.Reaction-Reaction 828.5156 325.7576 2.5433499 Unconstr
## 5:Subject.Reaction-Reaction 760.2469 436.7463 1.7407060 Positive
## 6:Subject.Reaction-Reaction 757.8909 411.2464 1.8429119 Unconstr
## 7:Subject.Reaction-Reaction 1137.3863 443.9056 2.5622566 Unconstr
## 8:Subject.Reaction-Reaction 1057.0708 385.9026 2.7392162 Unconstr
## 9:Subject.Reaction-Reaction 760.2469 436.7463 1.7407060 Positive
## 10:Subject.Reaction-Reaction 757.8909 411.2464 1.8429119 Unconstr
## 11:Subject.Reaction-Reaction 1039.6832 447.5192 2.3232148 Unconstr
## 12:Subject.Reaction-Reaction 911.1369 377.9651 2.4106377 Unconstr
## 13:Subject.Reaction-Reaction 1590.6778 566.5376 2.8077180 Unconstr
## 14:Subject.Reaction-Reaction 957.1797 364.0599 2.6291817 Positive
## 15:Subject.Reaction-Reaction 932.5247 516.7169 1.8047110 Unconstr
## 16:Subject.Reaction-Reaction 1179.5219 547.9498 2.1526095 Unconstr
## 17:Subject.Reaction-Reaction 859.1635 440.5250 1.9503173 Unconstr
## 18:Subject.Reaction-Reaction 1672.9989 664.0846 2.5192556 Unconstr
## 19:Subject.Reaction-Reaction 2003.0167 738.6399 2.7117633 Unconstr
```
## 5: Subject.Reaction-Reaction 2067.9299 553.3254 3.7372765 Positive
## 6: 0: Subject.Reaction-Reaction 666.1077 565.7589 1.1773702 Unconstr
## 6: 1: Subject.Reaction-Reaction 850.9395 583.6190 1.4580394 Unconstr
## 6: 2: Subject.Reaction-Reaction 916.2375 504.0273 1.8178333 Unconstr
## 6: 3: Subject.Reaction-Reaction 1785.8432 750.7274 2.3788171 Unconstr
## 6: 4: Subject.Reaction-Reaction 2077.5064 822.0777 2.5271412 Unconstr
## 6: 5: Subject.Reaction-Reaction 2603.2823 1035.1406 2.5149070 Unconstr
## 6: 6: Subject.Reaction-Reaction 3123.2005 1049.0352 2.9772123 Positive
## 7: 0: Subject.Reaction-Reaction 932.8190 490.4744 1.9018709 Unconstr
## 7: 1: Subject.Reaction-Reaction 927.3416 492.7764 1.8818709 Unconstr
## 7: 2: Subject.Reaction-Reaction 924.7079 426.2387 2.1694602 Unconstr
## 7: 3: Subject.Reaction-Reaction 1282.8637 583.3415 2.1991642 Unconstr
## 7: 4: Subject.Reaction-Reaction 1549.9053 643.7083 2.4077757 Unconstr
## 7: 5: Subject.Reaction-Reaction 1669.8274 612.0081 2.7284398 Positive
## 8: 0: Subject.Reaction-Reaction 920.3110 576.8500 1.5954079 Unconstr
## 8: 1: Subject.Reaction-Reaction 1044.9313 592.5243 1.7635247 Unconstr
## 8: 2: Subject.Reaction-Reaction 831.4993 486.9625 1.7075221 Unconstr
## 8: 3: Subject.Reaction-Reaction 1607.0156 717.6871 2.2391591 Unconstr
## 8: 4: Subject.Reaction-Reaction 2029.1022 805.6724 2.5185201 Unconstr
## 8: 5: Subject.Reaction-Reaction 2927.6051 1177.5589 2.4861644 Unconstr
## 8: 6: Subject.Reaction-Reaction 2927.6051 1177.5589 2.4861644 Unconstr
## 8: 7: Subject.Reaction-Reaction 2433.2427 957.7103 2.5408786 Unconstr
## 8: 8: Subject.Reaction-Reaction 2947.1635 844.8113 3.4885466 Positive
## 8: 9: Subject.Reaction-Reaction 1440.6886 690.1726 2.0463876 Unconstr
## 9: 0: Subject.Reaction-Reaction 927.4539 567.8500 1.6720144 Unconstr
## 9: 1: Subject.Reaction-Reaction 1044.9313 592.5243 1.7635247 Unconstr
## 9: 2: Subject.Reaction-Reaction 967.8504 550.1628 1.7592073 Unconstr
## 9: 3: Subject.Reaction-Reaction 1742.6866 797.5934 2.1849310 Unconstr
## 9: 4: Subject.Reaction-Reaction 2198.3504 892.7701 2.4623924 Unconstr
## 9: 5: Subject.Reaction-Reaction 3236.8715 1196.2341 2.7058847 Unconstr
## 9: 6: Subject.Reaction-Reaction 2198.3504 892.7701 2.4623924 Unconstr
## 9: 7: Subject.Reaction-Reaction 2210.6321 1185.1233 1.8653182 Unconstr
## 9: 8: Subject.Reaction-Reaction 2399.5130 1027.8125 2.3345824 Unconstr
## 9: 9: Subject.Reaction-Reaction 3847.0132 1391.5584 2.7645359 Unconstr
## 9: 10: Subject.Reaction-Reaction 3946.2369 1228.6678 3.2118013 Positive
## units.Reaction-Reaction 883.2477 577.9203 1.5283210 Positive

```r
## random regression (legendre polynomials)
fm2 <- mmer(Reaction ~ Days,
            random = ~ vsr(leg(Days, 1), Subject),
            data=DT, tolParInv = 1e-6, verbose = FALSE)
summary(fm2)$varcomp

## unstructured random regression (legendre)
fm2 <- mmer(Reaction ~ Days,
            random = ~ vsr(usr(leg(Days, 1)), Subject),
            data=DT, tolParInv = 1e-6, verbose = FALSE)
summary(fm2)$varcomp
```
## leg0:Subject.Reaction-Reaction 2817.4056 1011.24156 2.786086 Positive
## leg1:leg0:Subject.Reaction-Reaction 869.9590 381.02481 2.283208 Unconstr
## leg1:Subject.Reaction-Reaction 473.4608 199.53612 2.372807 Positive
## units.Reaction-Reaction 654.9428 77.18763 8.485075 Positive

# same can be done with the mmec function

### Literature


Covarrubias-Pazaran G. 2018. Software update: Moving the R package sommer to multivariate mixed models for genome-assisted prediction. doi: https://doi.org/10.1101/354639


