

R-code for Chapter 7: Parameter estimation in simplified regular vine copulas

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Required R-packages

- VineCopula
- rafalib

Section 7.2 Sequential and maximum likelihood estimation in simplified regular vine copulas

Example 7.4: WINE3: Parameter estimates and log likelihood

Read in data and set column names

```
reddata<-read.csv(file="winequality-red.csv",sep=";")
n<-length(reddata[,1])
colnames(reddata)<-c("acf","acv","acc","sugar","clor","sf","st","den","ph","sp","alc","quality")
acf<-reddata[,1]
acv<-reddata[,2]
acc<-reddata[,3]
```

Transform original data to copula data (udata) using ranks and then to marginal normalized data (zdata)

```

udata<-reddata
zdata<-reddata
for(i in 1:12){
udata[,i]<-rank(reddata[,i])/(n+1)
zdata[,i]<-qnorm(udata[,i])
}
wine3<-udata[,1:3]

```

Setting copula parameters using empirical pairwise Kendall's τ 's and the copula families chosen in Example 4.3

```

theta.acfacv<-BiCopTau2Par(34,cor(acf,acv,method="kendall"))
theta.acfacc<-BiCopTau2Par(4,cor(acf,acc,method="kendall"))
theta.acvacc<-BiCopTau2Par(5,cor(acv,acc,method="kendall"))
theta<-c(theta.acfacv,theta.acfacc,theta.acvacc)

```

Sequential estimation of PCC1 (C-vine with root order 312)

- 1,2,3=acf,acv,acc
- want to fit vine with pair copulas c13,c23,c12;3
- c13 Gumbel (family=4) using original data
- c23 Frank (family=5) using original data
- 12;3 Gaussian (family=1) using pseudo obs.
- corresponds to D-vine with order 132 (acf-acc-acv)

Create pseudo observations for c12;3 and find copula parameter using inversion of Kendall's τ

```

options(digits=2)
h13<-BiCopHfunc(udata[,1],udata[,3],family=4,par=theta.acfacc)$hfunc2
h23<-BiCopHfunc(udata[,2],udata[,3],family=5,par=theta.acvacc)$hfunc2
theta.12.3<-BiCopTau2Par(1,cor(h13,h23,method="kendall"))
h12<-BiCopHfunc(udata[,1],udata[,2],family=34,par=theta.acfacv)$hfunc2
h32<-BiCopHfunc(udata[,3],udata[,2],family=5,par=theta.acvacc)$hfunc2
theta.13.2<-BiCopTau2Par(4,cor(h12,h32,method="kendall"))
h21<-BiCopHfunc(udata[,2],udata[,1],family=34,par=theta.acfacv)$hfunc2
h31<-BiCopHfunc(udata[,3],udata[,1],family=4,par=theta.acfacc)$hfunc2
theta.23.1<-BiCopTau2Par(5,cor(h21,h31,method="kendall"))

```

Table 7.1: WINE3: Sequential (inversion of Kendall's τ , MLE) as well as associated Kendall's τ estimate together with the log likelihoods for PCC1

```

options(digits=2)
fam=c(4,5,1)
theta12=theta[1]
theta13=theta[2]

```

```

theta23=theta[3]
theta312<-c(theta13,theta23,theta.12.3)
RVM1<-C2RVine(order=c(3,1,2),family = fam,par=theta312)
fam.name<-c(BiCopName(4),BiCopName(5),BiCopName(1))
#pair.name<-c("(acf,acc)","(acv,acc)","(acf,acv;acc)")
r3.itau.seq.pcc1<-RVineSeqEst(wine3,RVM1,method="itau")
r3.mle.seq.pcc1<-RVineSeqEst(wine3,RVM1,method="mle")
options(digits=5)
summary(r3.itau.seq.pcc1)

```

```

## tree   edge | family cop   par  par2 |   tau   utd   ltd
## -----
##    1    3,2 |     5   F -4.57  0.00 | -0.43   -   -
##          3,1 |     4   G  1.94  0.00 |  0.48  0.57   -
##    2    1,2;3 |     1   N  0.20  0.00 |  0.13   -   -
## ---
## type: C-vine   logLik: 807.88   AIC: -1609.8   BIC: -1593.6
## ---
## 1 <-> acf,   2 <-> acv,   3 <-> acc

```

```
summary(r3.mle.seq.pcc1)
```

```

## tree   edge | family cop   par  par2 |   tau   utd   ltd
## -----
##    1    3,2 |     5   F -4.44  0.00 | -0.42   -   -
##          3,1 |     4   G  1.80  0.00 |  0.44  0.53   -
##    2    1,2;3 |     1   N  0.17  0.00 |  0.11   -   -
## ---
## type: C-vine   logLik: 816.83   AIC: -1627.7   BIC: -1611.5
## ---
## 1 <-> acf,   2 <-> acv,   3 <-> acc

```

Table 7.1: WINE3: Joint ML estimates as well as associated Kendall's τ estimate together with the log likelihoods for PCC1

This is also reported in Table 7.2 for PCC1

```

options(digits=5)
r3.mle.pcc1<-RVineMLE(wine3,RVM1,se=TRUE)

```

```

## iter   10 value -816.862869
## final  value -816.915732
## converged

```

```
summary(r3.mle.pcc1$RVM)
```

```

## tree   edge | family cop   par  par2 |   tau   utd   ltd
## -----
##    1    3,2 |     5   F -4.51 (0.18)   - | -0.42   -   -
##          3,1 |     4   G  1.80 (0.04)   - |  0.44  0.53   -
##    2    1,2;3 |     1   N  0.17 (0.02)   - |  0.11   -   -
## ---
## type: C-vine   logLik: 816.92   AIC: -1627.8   BIC: -1611.7

```

Sequential estimation of PCC2 (C-vine with root order 213)

D-vine with order 123 (acf-acv-acc) 1=acf 2=acv 3=acc pair copulas: c12, c23, c13;2 want to fit vine with pair copulas c12,c23,c13;2 + c13 rotated 270 degree Gumbel (family=34) using original data + c23 Frank (family=5) using original data + c12;3 Gumbel (family=4) using pseudo obs.

Table 7.1: WINE3: Sequential (inversion of Kendall's τ , MLE) as well as associated Kendall's τ estimate together with the log likelihoods for PCC2

```
fam=c(34,5,4)
theta213<-c(theta12,theta23,theta.13.2)
RVM2=C2RVine(order=c(2,1,3),family = fam,par=theta213)
r3.itau.seq.pcc2<-RVineSeqEst(wine3,RVM2,method="itau")
r3.mle.seq.pcc2<-RVineSeqEst(wine3,RVM2,method="mle")
options(digits=5)
summary(r3.itau.seq.pcc2)
```

## tree	edge	family	cop	par	par2	tau	utd	ltd
## 1	2,3	5	F	-4.57	0.00	-0.43	-	-
##	2,1	34	G270	-1.23	0.00	-0.19	-	-
## 2	1,3;2	4	G	1.82	0.00	0.45	0.54	-

```
## ---
## type: C-vine    logLik: 763.93    AIC: -1521.9    BIC: -1505.7
## ---
## 1 <-> acf,    2 <-> acv,    3 <-> acc
```

```
summary(r3.mle.seq.pcc2)
```

## tree	edge	family	cop	par	par2	tau	utd	ltd
## 1	2,3	5	F	-4.44	0.00	-0.42	-	-
##	2,1	34	G270	-1.15	0.00	-0.13	-	-
## 2	1,3;2	4	G	1.70	0.00	0.41	0.50	-

```
## ---
## type: C-vine    logLik: 763.43    AIC: -1520.9    BIC: -1504.7
## ---
## 1 <-> acf,    2 <-> acv,    3 <-> acc
```

Table 7.1: WINE3: Joint ML estimates as well as associated Kendall's τ estimate together with the log likelihoods for PCC2

This is also reported in Table 7.2 for PCC2

```
options(digits=5)
r3.mle.pcc2<-RVineMLE(wine3,RVM2,se=TRUE)
```

```
## final value -772.584081
## converged
```

```
summary(r3.mle.pcc2$RVM)
```

## tree	edge	family	cop	par	par2	tau	utd	ltd
##	-----							

```
##      1      2,3 |      5      F -4.14 (0.17)      - | -0.40      -      -
##              2,1 |      34 G270 -1.20 (0.02)      - | -0.16      -      -
##      2      1,3;2 |      4      G  1.73 (0.04)      - |  0.42  0.51      -
## ---
## type: C-vine      logLik: 772.58      AIC: -1539.2      BIC: -1523
```

Sequential estimation of PCC3 (C-vine with root order 123)

- D-vine with order 123 (acf-acv-acc)
- 1=acf 2=acv 3=acc
- pair copulas: c12, c13, c23;1
- want to fit vine with pair copulas c12,c13,c23;1
- c12 rotated 270 degree Gumbel (family=34) using original data
- c13 Gumbel (family=4) using original data
- c23;1 Frank (family=5) using pseudo obs.

Table 7.1: WINE3: Sequential (inversion of Kendall's τ , MLE) as well as associated Kendall's τ estimate together with the log likelihoods for PCC3

```
fam=c(34,4,5)
fam.name<-c(BiCopName(34),BiCopName(5),BiCopName(4))
theta123<-c(theta12,theta13,theta.23.1)
RVM3<-C2RVine(order=c(1,2,3),family = fam,par=theta123)
r3.itau.seq.pcc3<-RVineSeqEst(wine3,RVM3,method="itau")
r3.mle.seq.pcc3<-RVineSeqEst(wine3,RVM3,method="mle")
options(digits=5)
summary(r3.itau.seq.pcc3)

## tree   edge | family   cop   par  par2 |   tau   utd   ltd
## -----
##      1   1,3 |      4     G  1.94  0.00 |  0.48  0.57   -
##              1,2 |      34 G270 -1.23  0.00 | -0.19   -   -
##      2   2,3;1 |      5     F -4.01  0.00 | -0.39   -   -
## ---
## type: C-vine      logLik: 770.27      AIC: -1534.5      BIC: -1518.4
## ---
## 1 <-> acf,      2 <-> acv,      3 <-> acc

summary(r3.mle.seq.pcc3)

## tree   edge | family   cop   par  par2 |   tau   utd   ltd
## -----
##      1   1,3 |      4     G  1.80  0.00 |  0.44  0.53   -
##              1,2 |      34 G270 -1.18  0.00 | -0.15   -   -
##      2   2,3;1 |      5     F -4.11  0.00 | -0.40   -   -
## ---
## type: C-vine      logLik: 784.05      AIC: -1562.1      BIC: -1546
## ---
## 1 <-> acf,      2 <-> acv,      3 <-> acc
```

Table 7.1: WINE3: Joint ML estimates as well as associated Kendall's τ estimate together with the log likelihoods for PCC3.

This is also reported in Table 7.2 for PCC3

```
options(digits=5)
r3.mle.pcc3<-RVineMLE(wine3,RVM3,se=TRUE)
```

```
## iter    10 value -785.719881
## final  value -785.719919
## converged
```

```
summary(r3.mle.pcc3$RVM)
```

```
## tree  edge | family  cop          par  par2 |  tau  utd  ltd
## -----|-----|-----|-----|-----|-----
##    1   1,3 |     4    G   1.74 (0.04)   - |  0.42  0.51  -
##         1,2 |    34  G270 -1.17 (0.02)   - | -0.14   -   -
##    2   2,3;1 |     5    F  -4.20 (0.18)   - | -0.40   -   -
## ---
## type: C-vine    logLik: 785.72    AIC: -1565.4    BIC: -1549.3
```