R-code for Chapter 8: Selection of regular vine copula models

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Contents

Required R-packages

- VineCopula
- rafalib
- TSP

Section 8.3 The Dissmann algorithm for sequential top-down.

Example 8.4 WINE7: Illustration of the Dissmann Algorithm.

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")
reddata7<-reddata[,c(1,2,3,5,7,8,9)]
```

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])
}
udata7<-udata[,c(1,2,3,5,7,8,9)]
```

Table 8.2: WINE7: Ordered weights (pairwise absolute empirical Kendall's τ values of copula data) for all pairs of variables.

```
options(digits=3)
temp<-abs(cor(reddata7,method = "kendall"))
cor.names<-outer(names(reddata7),names(reddata7),paste)
cor.vec<-as.vector(temp)
names(cor.vec)<-as.vector(cor.names)
names.cor.vec<-as.vector(cor.names)
sort.cor.vec<-sort(cor.vec,decreasing=TRUE)
names.sort.cor.vec<-names.cor.vec[sort.list(cor.vec,decreasing=TRUE)]
names(sort.cor.vec)<-names(names.sort.cor.vec)
dup.list<-duplicated(sort.cor.vec)
unique.sort.cor<-sort.cor.vec[dup.list==FALSE]
names(unique.sort.cor)<-names.sort.cor.vec[dup.list==FALSE]
unique.sort.cor[-1]
```

```
##   ph acf  acc acf  den acf  acc acv   ph acc den clor  den acc   ph den
##   0.5278   0.4843   0.4575   0.4284   0.3898   0.2879   0.2457   0.2172
##  acv acf clor acf  ph clor   ph acv clor acv  st clor   den st clor acc
##   0.1852   0.1760   0.1627   0.1587   0.1096   0.0916   0.0877   0.0767
##   st acv   st acf  den acv   st acc    ph st
##   0.0637   0.0569   0.0159   0.0116   0.0068
```

Example 8.5 WINE7 Fitted R-vine, C- and D-vine copulas

Fitting R-vines and Gauss R-vines using sequential estimation with restricted pair copula family set

```
fit.rv=RVineStructureSelect(udata7, familyset=c(1,5,6,4),
selectioncrit="AIC",
indeptest=FALSE, level=0.05)
fit.rv.ind=RVineStructureSelect(udata7, familyset=c(1,5,6,4),
 selectioncrit="AIC",
indeptest=TRUE, level=0.05)
fit.Gauss=RVineStructureSelect(udata7, familyset=1, selectioncrit="AIC",
                               indeptest=FALSE, level=0.05)
fit.Gauss.ind=RVineStructureSelect(udata7, familyset=1, selectioncrit="AIC",
                              indeptest=TRUE, level=0.05)
summary(fit.rv)
```

```
## tree           edge | family   cop    par  par2 |   tau   utd   ltd
## ---------------------------------------------------------------------
##    1            3,2 |      5     F  -4.44  0.00 | -0.42     -     -
##                 1,3 |      4     G   1.80  0.00 |  0.44  0.53     -
##                 4,5 |     14    SG   1.09  0.00 |  0.09     -  0.12
##                 6,4 |     16    SJ   1.64  0.00 |  0.26     -  0.48
##                 1,6 |      4     G   1.82  0.00 |  0.45  0.54     -
##                 7,1 |     34  G270  -1.99  0.00 | -0.50     -     -
##    2          1,2;3 |      5     F   1.15  0.00 |  0.13     -     -
##               7,3;1 |     24   G90  -1.10  0.00 | -0.09     -     -
##               6,5;4 |     16    SJ   1.08  0.00 |  0.04     -  0.10
##               1,4;6 |     36  J270  -1.06  0.00 | -0.03     -     -
##               7,6;1 |      4     G   1.24  0.00 |  0.19  0.25     -
##    3        7,2;1,3 |      6     J   1.03  0.00 |  0.01  0.03     -
##             6,3;7,1 |      5     F  -0.59  0.00 | -0.07     -     -
##             1,5;6,4 |     34  G270  -1.16  0.00 | -0.14     -     -
##             7,4;1,6 |     26   J90  -1.26  0.00 | -0.13     -     -
##    4      6,2;7,1,3 |     16    SJ   1.33  0.00 |  0.16     -  0.32
##           4,3;6,7,1 |      5     F  -0.08  0.00 | -0.01     -     -
##           7,5;1,6,4 |     24   G90  -1.14  0.00 | -0.12     -     -
##    5    4,2;6,7,1,3 |     14    SG   1.10  0.00 |  0.09     -  0.12
##         5,3;4,6,7,1 |      5     F   0.81  0.00 |  0.09     -     -
##    6  5,2;4,6,7,1,3 |      6     J   1.06  0.00 |  0.03  0.08     -
## ---
## type: R-vine    logLik: 2525    AIC: -5009    BIC: -4896
## ---
## 1 <-> acf,   2 <-> acv,   3 <-> acc,   4 <-> clor,   5 <-> st,   6 <-> den,
## 7 <-> ph
```

```
summary(fit.rv.ind)
```

```
## tree           edge | family   cop    par  par2 |   tau   utd   ltd
## ---------------------------------------------------------------------
##    1            3,2 |      5     F  -4.44  0.00 | -0.42     -     -
##                 1,3 |      4     G   1.80  0.00 |  0.44  0.53     -
##                 4,5 |     14    SG   1.09  0.00 |  0.09     -  0.12
##                 6,4 |     16    SJ   1.64  0.00 |  0.26     -  0.48
##                 1,6 |      4     G   1.82  0.00 |  0.45  0.54     -
##                 7,1 |     34  G270  -1.99  0.00 | -0.50     -     -
##    2          1,2;3 |      5     F   1.15  0.00 |  0.13     -     -
##               7,3;1 |     24   G90  -1.10  0.00 | -0.09     -     -
##               6,5;4 |     16    SJ   1.08  0.00 |  0.04     -  0.10
##               1,4;6 |      0     I      -     - |  0.00     -     -
##               7,6;1 |      4     G   1.24  0.00 |  0.19  0.25     -
##    3        7,2;1,3 |      0     I      -     - |  0.00     -     -
##             6,3;7,1 |      5     F  -0.59  0.00 | -0.07     -     -
##             1,5;6,4 |     34  G270  -1.16  0.00 | -0.14     -     -
##             7,4;1,6 |     26   J90  -1.26  0.00 | -0.13     -     -
##    4      6,2;7,1,3 |     16    SJ   1.33  0.00 |  0.16     -  0.32
##           4,3;6,7,1 |      0     I      -     - |  0.00     -     -
##           7,5;1,6,4 |     24   G90  -1.14  0.00 | -0.12     -     -
##    5    4,2;6,7,1,3 |     14    SG   1.10  0.00 |  0.09     -  0.12
##         5,3;4,6,7,1 |      5     F   0.82  0.00 |  0.09     -     -
```

```
##    6  5,2;4,6,7,1,3 |      6     J   1.06  0.00 |  0.03  0.08     -
## ---
## type: R-vine    logLik: 2519    AIC: -5003    BIC: -4906
## ---
## 1 <-> acf,   2 <-> acv,   3 <-> acc,   4 <-> clor,   5 <-> st,   6 <-> den,
## 7 <-> ph
```

```
summary(fit.Gauss)
```

```
## tree           edge | family  cop    par  par2 |   tau   utd   ltd
## ------------------------------------------------------------------
##    1            3,2 |      1    N  -0.56  0.00 | -0.37     -     -
##                 1,3 |      1    N   0.65  0.00 |  0.45     -     -
##                 4,5 |      1    N   0.11  0.00 |  0.07     -     -
##                 6,4 |      1    N   0.44  0.00 |  0.29     -     -
##                 1,6 |      1    N   0.67  0.00 |  0.47     -     -
##                 7,1 |      1    N  -0.72  0.00 | -0.51     -     -
##    2          1,2;3 |      1    N   0.15  0.00 |  0.10     -     -
##               7,3;1 |      1    N  -0.18  0.00 | -0.11     -     -
##               6,5;4 |      1    N   0.08  0.00 |  0.05     -     -
##               1,4;6 |      1    N  -0.03  0.00 | -0.02     -     -
##               7,6;1 |      1    N   0.28  0.00 |  0.18     -     -
##    3        7,2;1,3 |      1    N  -0.02  0.00 | -0.02     -     -
##             6,3;7,1 |      1    N  -0.07  0.00 | -0.04     -     -
##             1,5;6,4 |      1    N  -0.24  0.00 | -0.15     -     -
##             7,4;1,6 |      1    N  -0.23  0.00 | -0.15     -     -
##    4      6,2;7,1,3 |      1    N   0.28  0.00 |  0.18     -     -
##           4,3;6,7,1 |      1    N  -0.03  0.00 | -0.02     -     -
##           7,5;1,6,4 |      1    N  -0.21  0.00 | -0.14     -     -
##    5    4,2;6,7,1,3 |      1    N   0.17  0.00 |  0.11     -     -
##         5,3;4,6,7,1 |      1    N   0.12  0.00 |  0.07     -     -
##    6  5,2;4,6,7,1,3 |      1    N   0.07  0.00 |  0.04     -     -
## ---
## type: R-vine    logLik: 2272    AIC: -4502    BIC: -4389
## ---
## 1 <-> acf,   2 <-> acv,   3 <-> acc,   4 <-> clor,   5 <-> st,   6 <-> den,
## 7 <-> ph
```

```
summary(fit.Gauss.ind)
```

```
## tree           edge | family  cop    par  par2 |   tau   utd   ltd
## ------------------------------------------------------------------
##    1            3,2 |      1    N  -0.56  0.00 | -0.37     -     -
##                 1,3 |      1    N   0.65  0.00 |  0.45     -     -
##                 4,5 |      1    N   0.11  0.00 |  0.07     -     -
##                 6,4 |      1    N   0.44  0.00 |  0.29     -     -
##                 1,6 |      1    N   0.67  0.00 |  0.47     -     -
##                 7,1 |      1    N  -0.72  0.00 | -0.51     -     -
##    2          1,2;3 |      1    N   0.15  0.00 |  0.10     -     -
##               7,3;1 |      1    N  -0.18  0.00 | -0.11     -     -
##               6,5;4 |      1    N   0.08  0.00 |  0.05     -     -
##               1,4;6 |      0    I      -     - |  0.00     -     -
##               7,6;1 |      1    N   0.28  0.00 |  0.18     -     -
##    3        7,2;1,3 |      0    I      -     - |  0.00     -     -
##             6,3;7,1 |      1    N  -0.07  0.00 | -0.04     -     -
```

```
##             1,5;6,4 |      1    N  -0.24  0.00 | -0.15     -     -
##             7,4;1,6 |      1    N  -0.23  0.00 | -0.15     -     -
##    4      6,2;7,1,3 |      1    N   0.28  0.00 |  0.18     -     -
##           4,3;6,7,1 |      1    N  -0.03  0.00 | -0.02     -     -
##           7,5;1,6,4 |      1    N  -0.21  0.00 | -0.14     -     -
##    5    4,2;6,7,1,3 |      1    N   0.17  0.00 |  0.11     -     -
##         5,3;4,6,7,1 |      1    N   0.12  0.00 |  0.07     -     -
##    6  5,2;4,6,7,1,3 |      0    I      -     - |  0.00     -     -
## ---
## type: R-vine    logLik: 2267    AIC: -4498    BIC: -4401
## ---
## 1 <-> acf,   2 <-> acv,   3 <-> acc,   4 <-> clor,   5 <-> st,   6 <-> den,
## 7 <-> ph
```

Fitting C-vines using sequential estimation with restricted pair copula family set

```
fit.cv=RVineStructureSelect(udata7, familyset=c(1,5,6,4), selectioncrit="AIC",
                            indeptest=FALSE, level=0.05,type="CVine")
fit.cv.ind=RVineStructureSelect(udata7, familyset=c(1,5,6,4), selectioncrit="AIC",
                                indeptest=TRUE, level=0.05,type ="CVine")
summary(fit.cv)
```

```
## tree           edge | family   cop    par  par2 |   tau   utd   ltd
## ------------------------------------------------------------------
##    1            1,4 |     16    SJ   1.34  0.00 |  0.16     -  0.32
##                 1,2 |      5     F  -1.69  0.00 | -0.18     -     -
##                 1,5 |      1     N  -0.10  0.00 | -0.06     -     -
##                 1,3 |      4     G   1.80  0.00 |  0.44  0.53     -
##                 1,6 |      4     G   1.82  0.00 |  0.45  0.54     -
##                 7,1 |     34  G270  -1.99  0.00 | -0.50     -     -
##    2          6,4;1 |     16    SJ   1.46  0.00 |  0.21     -  0.39
##               6,2;1 |     14    SG   1.23  0.00 |  0.18     -  0.24
##               6,5;1 |     14    SG   1.19  0.00 |  0.16     -  0.21
##               6,3;1 |      5     F  -0.78  0.00 | -0.09     -     -
##               7,6;1 |      4     G   1.24  0.00 |  0.19  0.25     -
##    3        3,4;6,1 |      6     J   1.11  0.00 |  0.06  0.13     -
##             3,2;6,1 |      5     F  -3.84  0.00 | -0.38     -     -
##             3,5;6,1 |      1     N   0.15  0.00 |  0.10     -     -
##             7,3;6,1 |     24   G90  -1.08  0.00 | -0.08     -     -
##    4      7,4;3,6,1 |     26   J90  -1.24  0.00 | -0.12     -     -
##           7,2;3,6,1 |     36  J270  -1.06  0.00 | -0.04     -     -
##           7,5;3,6,1 |     26   J90  -1.21  0.00 | -0.11     -     -
##    5    2,4;7,3,6,1 |     14    SG   1.09  0.00 |  0.08     -  0.11
##         5,2;7,3,6,1 |      6     J   1.05  0.00 |  0.03  0.07     -
##    6  5,4;2,7,3,6,1 |     16    SJ   1.06  0.00 |  0.03     -  0.07
## ---
## type: C-vine    logLik: 2489    AIC: -4937    BIC: -4824
## ---
## 1 <-> acf,   2 <-> acv,   3 <-> acc,   4 <-> clor,   5 <-> st,   6 <-> den,
## 7 <-> ph
```

```
summary(fit.cv.ind)
```

```
## tree           edge | family   cop    par  par2 |   tau   utd   ltd
```

```
## ------------------------------------------------------------------
##    1            1,4 |     16    SJ   1.34  0.00 |  0.16     -  0.32
##                 1,2 |      5     F  -1.69  0.00 | -0.18     -     -
##                 1,5 |      1     N  -0.10  0.00 | -0.06     -     -
##                 1,3 |      4     G   1.80  0.00 |  0.44  0.53     -
##                 1,6 |      4     G   1.82  0.00 |  0.45  0.54     -
##                 7,1 |     34  G270  -1.99  0.00 | -0.50     -     -
##    2          6,4;1 |     16    SJ   1.46  0.00 |  0.21     -  0.39
##               6,2;1 |     14    SG   1.23  0.00 |  0.18     -  0.24
##               6,5;1 |     14    SG   1.19  0.00 |  0.16     -  0.21
##               6,3;1 |      5     F  -0.78  0.00 | -0.09     -     -
##               7,6;1 |      4     G   1.24  0.00 |  0.19  0.25     -
##    3        3,4;6,1 |      0     I      -     - |  0.00     -     -
##             3,2;6,1 |      5     F  -3.84  0.00 | -0.38     -     -
##             3,5;6,1 |      1     N   0.15  0.00 |  0.10     -     -
##             7,3;6,1 |     24   G90  -1.08  0.00 | -0.08     -     -
##    4      7,4;3,6,1 |     24   G90  -1.14  0.00 | -0.12     -     -
##           7,2;3,6,1 |     36  J270  -1.06  0.00 | -0.04     -     -
##           7,5;3,6,1 |     26   J90  -1.21  0.00 | -0.11     -     -
##    5    2,4;7,3,6,1 |      4     G   1.09  0.00 |  0.09  0.11     -
##         5,2;7,3,6,1 |      6     J   1.05  0.00 |  0.03  0.07     -
##    6  5,4;2,7,3,6,1 |      0     I      -     - |  0.00     -     -
## ---
## type: C-vine    logLik: 2447    AIC: -4855    BIC: -4753
## ---
## 1 <-> acf,   2 <-> acv,   3 <-> acc,   4 <-> clor,   5 <-> st,   6 <-> den,
## 7 <-> ph
```

Fitting D-vines using sequential estimation with restricted pair copula family set

Since the traveling salesman problem is a NP hard problem, the package TSP provides different choices as solution. To be consistent with the book we fix the order to the one utilized there, which is given by

den acf ph acc acv st clor

6 1 7 3 2 5 4

```
d = dim(udata7)[2]
M = 1 - abs(TauMatrix(udata7))
hamilton = insert_dummy(TSP(M),label="cut")
sol = solve_TSP(hamilton,method="repetitive_nn")
order = cut_tour(sol,"cut")
order<-c(6,1,7,3,2,5,4)
names(order)<-c("den","acf","ph","acc","acv","st","clor")
DVM= D2RVine(order,family=rep(0,d*(d-1)/2),par=rep(0,d*(d-1)/2))
fit.dv=RVineCopSelect(data=udata7,familyset=c(1,5,6,4),indeptest=FALSE,
                      level=0.05,Matrix=DVM$Matrix,selectioncrit="AIC")
fit.dv.ind=RVineCopSelect(data=udata7,familyset=c(1,5,6,4),indeptest=TRUE,
                          level=0.05,Matrix=DVM$Matrix,selectioncrit="AIC")
summary(fit.dv)
```

```
## tree           edge | family   cop    par  par2 |   tau   utd   ltd
## ------------------------------------------------------------------
##    1            5,4 |     14    SG   1.09  0.00 |  0.09     -  0.12
##                 2,5 |     14    SG   1.06  0.00 |  0.06     -  0.08
```

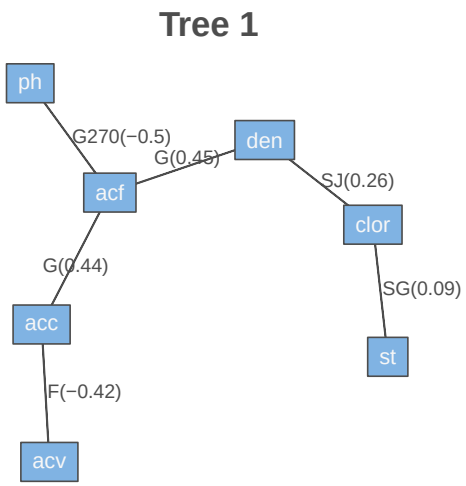
```
##                 3,2 |      5     F  -4.44  0.00 | -0.42     -     -
##                 7,3 |      1     N  -0.56  0.00 | -0.38     -     -
##                 1,7 |     24   G90  -1.99  0.00 | -0.50     -     -
##                 6,1 |      4     G   1.82  0.00 |  0.45  0.54     -
##    2          2,4;5 |     14    SG   1.11  0.00 |  0.10     -  0.13
##               3,5;2 |      1     N   0.10  0.00 |  0.07     -     -
##               7,2;3 |      5     F  -0.80  0.00 | -0.09     -     -
##               1,3;7 |      4     G   1.40  0.00 |  0.28  0.36     -
##               6,7;1 |      4     G   1.24  0.00 |  0.19  0.25     -
##    3        3,4;2,5 |      4     G   1.19  0.00 |  0.16  0.21     -
##             7,5;3,2 |      5     F   0.16  0.00 |  0.02     -     -
##             1,2;7,3 |      4     G   1.11  0.00 |  0.10  0.13     -
##             6,3;1,7 |      5     F  -0.65  0.00 | -0.07     -     -
##    4      7,4;3,2,5 |     34  G270  -1.12  0.00 | -0.11     -     -
##           1,5;7,3,2 |     26   J90  -1.15  0.00 | -0.08     -     -
##           6,2;1,7,3 |     16    SJ   1.33  0.00 |  0.16     -  0.32
##    5    1,4;7,3,2,5 |     14    SG   1.08  0.00 |  0.07     -  0.10
##         6,5;1,7,3,2 |      1     N   0.29  0.00 |  0.18     -     -
##    6  6,4;1,7,3,2,5 |     14    SG   1.25  0.00 |  0.20     -  0.26
## ---
## type: D-vine    logLik: 2451    AIC: -4860    BIC: -4747
## ---
## 1 <-> acf,   2 <-> acv,   3 <-> acc,   4 <-> clor,   5 <-> st,   6 <-> den,
## 7 <-> ph
```

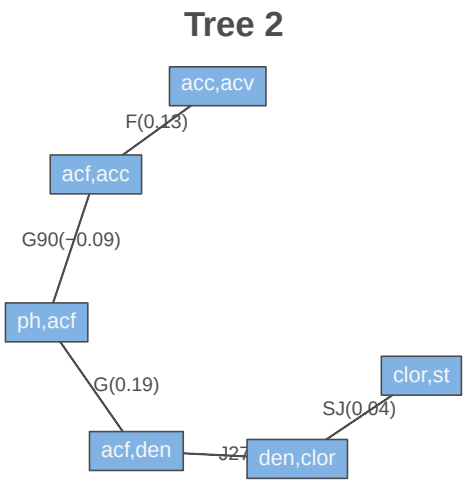
```
summary(fit.dv.ind)
```

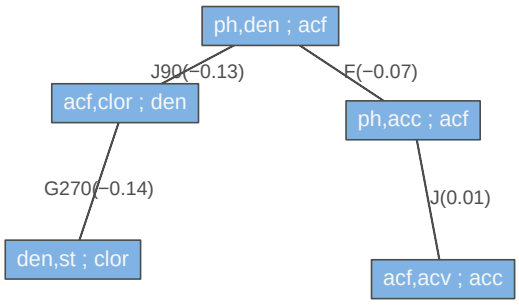
```
## tree           edge | family   cop    par  par2 |   tau   utd   ltd
## ------------------------------------------------------------------
##    1            5,4 |     14    SG   1.09  0.00 |  0.09     -  0.12
##                 2,5 |     14    SG   1.06  0.00 |  0.06     -  0.08
##                 3,2 |      5     F  -4.44  0.00 | -0.42     -     -
##                 7,3 |      1     N  -0.56  0.00 | -0.38     -     -
##                 1,7 |     24   G90  -1.99  0.00 | -0.50     -     -
##                 6,1 |      4     G   1.82  0.00 |  0.45  0.54     -
##    2          2,4;5 |     14    SG   1.11  0.00 |  0.10     -  0.13
##               3,5;2 |      1     N   0.10  0.00 |  0.07     -     -
##               7,2;3 |      5     F  -0.80  0.00 | -0.09     -     -
##               1,3;7 |      4     G   1.40  0.00 |  0.28  0.36     -
##               6,7;1 |      4     G   1.24  0.00 |  0.19  0.25     -
##    3        3,4;2,5 |      4     G   1.19  0.00 |  0.16  0.21     -
##             7,5;3,2 |      0     I      -     - |  0.00     -     -
##             1,2;7,3 |      4     G   1.11  0.00 |  0.10  0.13     -
##             6,3;1,7 |      5     F  -0.65  0.00 | -0.07     -     -
##    4      7,4;3,2,5 |     34  G270  -1.12  0.00 | -0.11     -     -
##           1,5;7,3,2 |     26   J90  -1.15  0.00 | -0.08     -     -
##           6,2;1,7,3 |     16    SJ   1.33  0.00 |  0.16     -  0.32
##    5    1,4;7,3,2,5 |     14    SG   1.08  0.00 |  0.07     -  0.10
##         6,5;1,7,3,2 |      1     N   0.28  0.00 |  0.18     -     -
##    6  6,4;1,7,3,2,5 |     14    SG   1.25  0.00 |  0.20     -  0.26
## ---
## type: D-vine    logLik: 2451    AIC: -4861    BIC: -4754
## ---
## 1 <-> acf,   2 <-> acv,   3 <-> acc,   4 <-> clor,   5 <-> st,   6 <-> den,
## 7 <-> ph
```

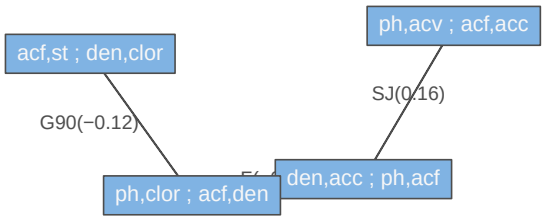
Figure 8.8: WINE7: Selected R-vine tree plots based on the Dissmann Algorithm 8.2.

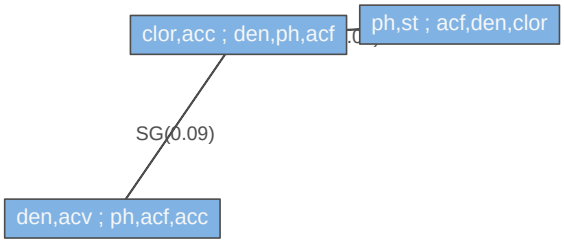
```
bigpar(3,2)
plot(fit.rv,edge.labels = "family-tau",type=1 )
```


Tree 1
ph
G270(−0.5)
G(0.45)
den
SJ(0.26)
acf
clor
G(0.44)
SG(0.09)
acc
st
F(−0.42)
acv


Tree 2
acc,acv
F(0.13)
acf,acc
G90(−0.09)
ph,acf
clor,st
G(0.19)
SJ(0.04)
acf,den
den,clor


Tree 3
ph,den ; acf
J90(−0.13)
F(−0.07)
acf,clor ; den
ph,acc ; acf
G270(−0.14)
J(0.01)
den,st ; clor
acf,acv ; acc


Tree 4
ph,acv ; acf,acc
acf,st ; den,clor
SJ(0.16)
G90(−0.12)
den,acc ; ph,acf
ph,clor ; acf,den


Tree 5
clor,acc ; den,ph,acf
ph,st ; acf,den,clor
SG(0.09)
den,acv ; ph,acf,acc

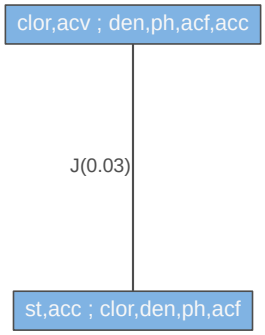
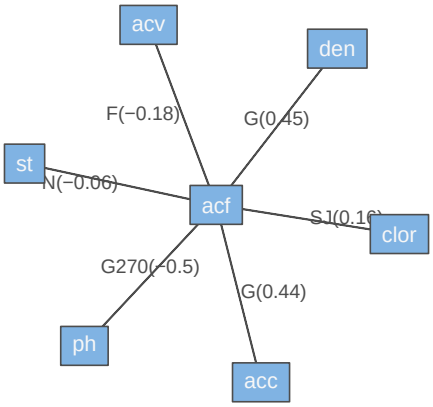

Tree 6
clor,acv ; den,ph,acf,acc
J(0.03)
st,acc ; clor,den,ph,acf

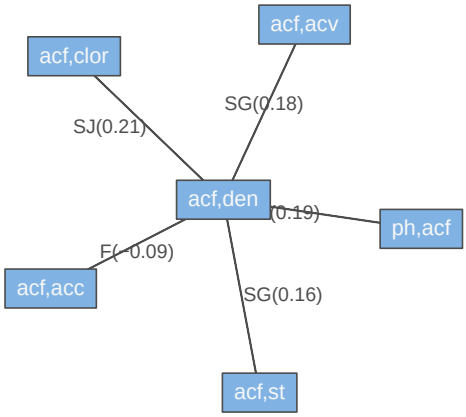
Figure 8.9: WINE7: Selected C-vine tree plots based on Dissmann Algorithm 8.2.

```
bigpar(3,2)
plot(fit.cv,edge.labels = "family-tau",type=1 )
```

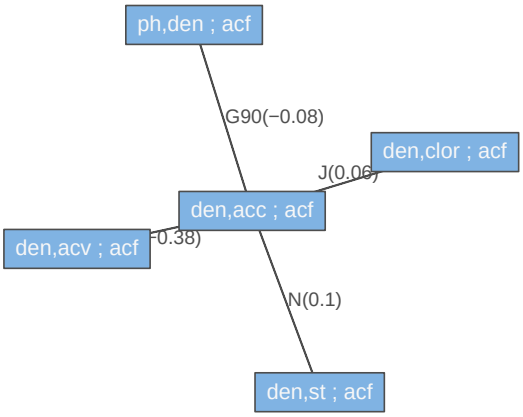
Tree 1



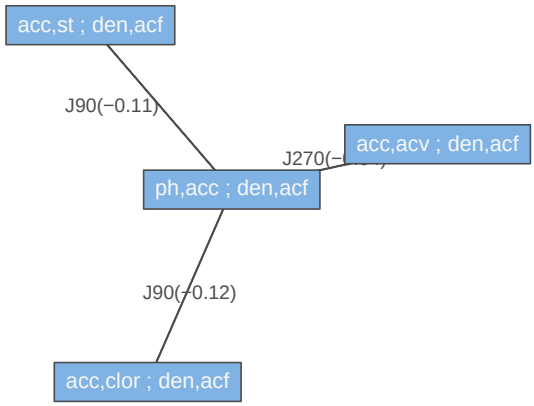
Tree 2



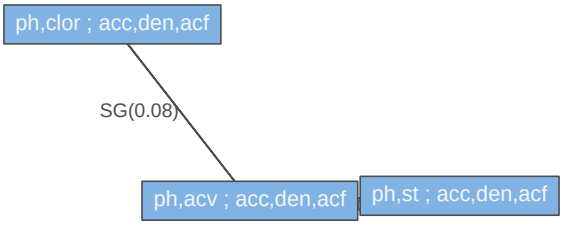
Tree 3



Tree 4



Tree 5



Tree 6

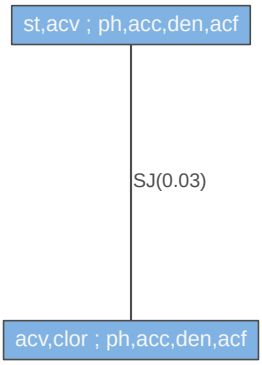
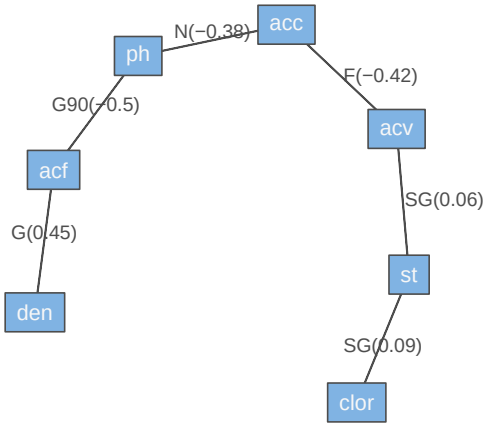


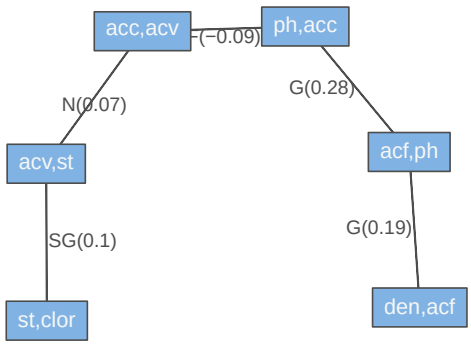
Figure 8.10: WINE7: Selected D-vine tree plots based on a solution of the traveling salesman problem

```
bigpar(3,2)
plot(fit.dv,edge.labels = "family-tau",type=1 )
```

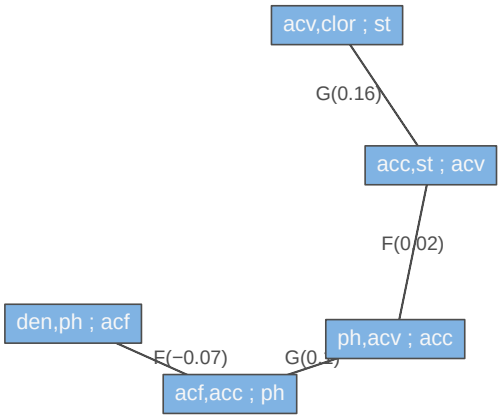
Tree 1



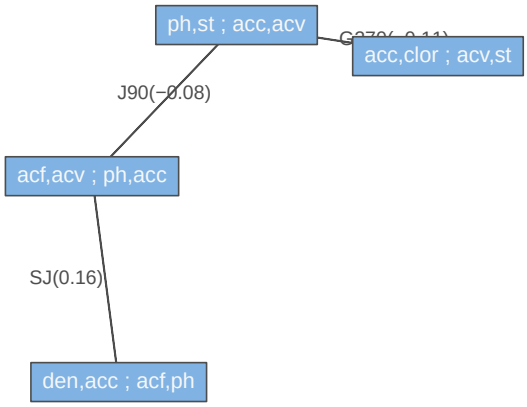
Tree 2



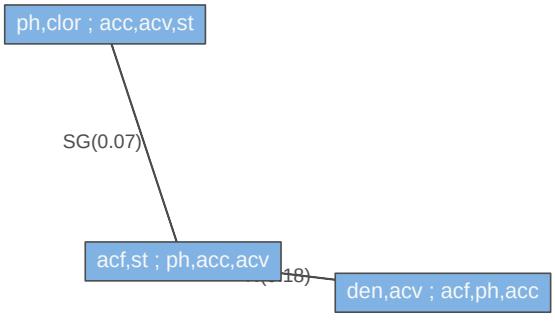
Tree 3



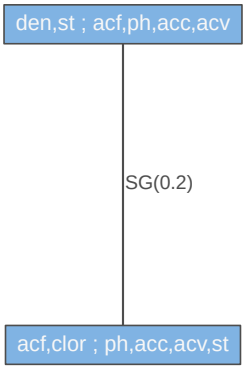
Tree 4



Tree 5



Tree 6



Analysis of chosen pair copula families for each tree

```
vine.fam<-function(fit=fit.rv.sum,familyset=c(1,2,5,6,4,14,24,34))
{
d<-ncol(fit$family)
sum.fam<-matrix(0,d-1,length(familyset))
rownames(sum.fam)<-paste("tree",2:d-1)
colnames(sum.fam)<-as.character(familyset)
for(i in d:2){
temp<-factor(as.character(fit$family[i,1:i-1]),levels=familyset)
temp
table(temp)
sum.fam[d-i+1,]<-table(temp)
}
sum.fam
}
fam.rv<-vine.fam(fit=fit.rv,familyset=c(1,5,6,4,16,26,36,14,24,34))
fam.rv.ind<-vine.fam(fit=fit.rv.ind,familyset=c(1,5,6,4,16,26,36,14,24,34,0))
fam.cv<-vine.fam(fit=fit.cv,familyset=c(1,5,6,4,16,26,36,14,24,34))
fam.cv.ind<-vine.fam(fit=fit.cv.ind,familyset=c(1,5,6,4,16,26,36,14,24,34,0))
fam.dv<-vine.fam(fit=fit.dv,familyset=c(1,5,6,4,16,26,36,14,24,34))
fam.dv.ind<-vine.fam(fit=fit.dv.ind,familyset=c(1,5,6,4,16,26,36,14,24,34,0))
```

Table 8.4: WINE7: Chosen pair copula families for different vine copula models. Modelswith ind at the ending denote a selection with an independence test performed for each pair copula in the Dissmann Algorithm 8.2

```
fam.out<-rbind(
c(apply(fam.rv,2,sum),0),
apply(fam.rv.ind,2,sum),
c(apply(fam.cv,2,sum),0),
apply(fam.cv.ind,2,sum),
c(apply(fam.dv,2,sum),0),
apply(fam.dv.ind,2,sum))
rownames(fam.out)<-
c("rvine","rvine-ind","cvine","cvine-ind","dvine","dvine-ind")
n.fam<-length(c(1,5,6,4,16,26,36,14,24,34,0))
familyset<-c(1,5,6,4,16,26,36,14,24,34,0)
for(i in (1:n.fam)){colnames(fam.out)[i]<-BiCopName(familyset[i])}
fam.out
```

```
##           N F J G SJ J90 J270 SG G90 G270 I
## rvine     0 5 2 3  3   1    1  2   2    2 0
## rvine-ind 0 4 1 3  3   1    0  2   2    2 3
## cvine     2 3 2 3  3   2    1  3   1    1 0
## cvine-ind 2 3 1 4  2   1    1  2   2    1 2
## dvine     3 4 0 5  1   1    0  5   1    1 0
## dvine-ind 3 3 0 5  1   1    0  5   1    1 1
```

Table 8.5: WINE7: Range of estimated (conditional) Kendall's τ values per tree for MLEestimated R-vine model (top left), Gaussian R-vine model (top right), C-vinemodel (bottom left) and D-vine model (bottom right)

Fitting R-vines, Gaussian R-vines, C-vines and D-vines using joint MLE

```
fit.mle=RVineMLE(udata7, fit.rv)
```

```
## iter   10 value -2527.262525
## iter   20 value -2527.296219
## final  value -2527.297156
## converged
```

```
fit.mle.ind=RVineMLE(udata7, fit.rv.ind)
```

```
## iter   10 value -2521.146096
## final  value -2521.169311
## converged
```

```
fit.mle.Gauss=RVineMLE(udata7, fit.Gauss)
```

```
## final  value -2271.796370
## converged
```

```
fit.mle.Gauss.ind=RVineMLE(udata7, fit.Gauss.ind)
```

```
## final  value -2267.147957
## converged
```

```
fit.cv.mle=RVineMLE(udata7, fit.cv)
```

```
## iter   10 value -2496.333280
## iter   20 value -2496.413547
## iter   30 value -2496.428978
## iter   40 value -2496.522471
## iter   50 value -2496.642744
## final  value -2496.644184
## converged
```

```
fit.cv.mle.ind=RVineMLE(udata7, fit.cv.ind)
```

```
## iter   10 value -2453.953098
## iter   20 value -2454.161703
## iter   30 value -2454.169972
## iter   40 value -2454.194084
## iter   50 value -2454.391382
## iter   60 value -2454.452796
## iter   70 value -2454.457012
## final  value -2454.457049
## converged
```

```
fit.dv.mle=RVineMLE(udata7, fit.dv)
```

```
## iter   10 value -2456.004582
## iter   20 value -2456.220726
## iter   30 value -2457.494929
## iter   40 value -2459.702427
## iter   50 value -2459.758492
```

```
## final  value -2459.761101
## converged
```

```
fit.dv.mle.ind=RVineMLE(udata7, fit.dv.ind)
```

```
## iter   10 value -2455.790869
## iter   20 value -2456.197239
## iter   30 value -2459.090227
## iter   40 value -2459.536363
## iter   50 value -2459.541593
## final  value -2459.541626
## converged
```

Table 8.5: WINE7: Range of estimated (conditional) Kendall's τ values per tree for MLE estimated R-vine model (top left), Gaussian R-vine model (top right), C-vine model (bottom left) and D-vine model (bottom right)

```
round(RVinePar2Tau(fit.mle$RVM),digits=2)
```

```
##       [,1]  [,2]  [,3]  [,4] [,5] [,6] [,7]
## [1,]  0.00  0.00  0.00  0.00 0.00  0.0    0
## [2,]  0.03  0.00  0.00  0.00 0.00  0.0    0
## [3,]  0.09  0.09  0.00  0.00 0.00  0.0    0
## [4,]  0.16 -0.01 -0.13  0.00 0.00  0.0    0
## [5,]  0.01 -0.06 -0.13 -0.13 0.00  0.0    0
## [6,]  0.11 -0.09  0.04 -0.03 0.20  0.0    0
## [7,] -0.41  0.44  0.09  0.26 0.46 -0.5    0
```

```
round(RVinePar2Tau(fit.mle.Gauss$RVM),digits=2)
```

```
##       [,1]  [,2]  [,3]  [,4] [,5]  [,6] [,7]
## [1,]  0.00  0.00  0.00  0.00 0.00  0.00    0
## [2,]  0.04  0.00  0.00  0.00 0.00  0.00    0
## [3,]  0.11  0.07  0.00  0.00 0.00  0.00    0
## [4,]  0.18 -0.02 -0.14  0.00 0.00  0.00    0
## [5,] -0.02 -0.04 -0.15 -0.15 0.00  0.00    0
## [6,]  0.10 -0.11  0.05 -0.02 0.18  0.00    0
## [7,] -0.37  0.45  0.07  0.29 0.46 -0.51    0
```

```
round(RVinePar2Tau(fit.cv.mle$RVM),digits=2)
```

```
##       [,1]  [,2]  [,3]  [,4] [,5]  [,6] [,7]
## [1,]  0.00  0.00  0.00  0.00 0.00  0.00    0
## [2,]  0.04  0.00  0.00  0.00 0.00  0.00    0
## [3,]  0.08  0.03  0.00  0.00 0.00  0.00    0
## [4,] -0.12 -0.03 -0.11  0.00 0.00  0.00    0
## [5,]  0.06 -0.38  0.10 -0.07 0.00  0.00    0
## [6,]  0.20  0.17  0.15 -0.08 0.20  0.00    0
## [7,]  0.14 -0.16 -0.05  0.42 0.46 -0.49    0
```

```
round(RVinePar2Tau(fit.dv.mle$RVM),digits=2)
```

```
##       [,1]  [,2]  [,3]  [,4]  [,5] [,6] [,7]
## [1,]  0.00  0.00  0.00  0.00  0.00 0.00    0
## [2,]  0.20  0.00  0.00  0.00  0.00 0.00    0
```

```
## [3,]  0.08  0.19  0.00  0.00  0.00 0.00    0
## [4,] -0.11 -0.07  0.15  0.00  0.00 0.00    0
## [5,]  0.14  0.01  0.10 -0.06  0.00 0.00    0
## [6,]  0.09  0.06 -0.09  0.29  0.19 0.00    0
## [7,]  0.10  0.05 -0.40 -0.35 -0.49 0.46    0
```

```
tree.kendall.range<-function(RVM=fit.mle$RVM){
temp<-round(RVinePar2Tau(RVM),digits=2)
d<-ncol(temp)
treerange<-matrix(0,d-1,2)
rownames(treerange)<-paste("tree",1:(d-1))
colnames(treerange)<-c("min","max")
for(i in 1:(d-1)){
treerange[i,]<-range(temp[d-i+1,1:(d-i)])
}
treerange
}
tree.kendall.range(fit.mle$RVM)
```

```
##          min  max
## tree 1 -0.50 0.46
## tree 2 -0.09 0.20
## tree 3 -0.13 0.01
## tree 4 -0.13 0.16
## tree 5  0.09 0.09
## tree 6  0.03 0.03
```

```
tree.kendall.range(fit.mle.Gauss$RVM)
```

```
##          min   max
## tree 1 -0.51  0.46
## tree 2 -0.11  0.18
## tree 3 -0.15 -0.02
## tree 4 -0.14  0.18
## tree 5  0.07  0.11
## tree 6  0.04  0.04
```

```
tree.kendall.range(fit.cv.mle$RVM)
```

```
##          min   max
## tree 1 -0.49  0.46
## tree 2 -0.08  0.20
## tree 3 -0.38  0.10
## tree 4 -0.12 -0.03
## tree 5  0.03  0.08
## tree 6  0.04  0.04
```

```
tree.kendall.range(fit.dv.mle$RVM)
```

```
##          min  max
## tree 1 -0.49 0.46
## tree 2 -0.09 0.29
## tree 3 -0.06 0.14
## tree 4 -0.11 0.15
## tree 5  0.08 0.19
## tree 6  0.20 0.20
```