Association Rule Mining with R*

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Outline

Association Rule Mining with R [†]

- basic concepts of association rules
- association rules mining with R
- pruning redundant rules
- interpreting and visualizing association rules
- recommended readings

[†] Chapter 9: Association Rules, *R and Data Mining: Examples and Case Studies*. http://www.rdatamining.com/docs/RDataMining.pdf

Association Rules

Association rules are rules presenting association or correlation between itemsets.

$$
\begin{aligned}
\text{support}(A \Rightarrow B) &= P(A \cup B) \\
\text{confidence}(A \Rightarrow B) &= P(B|A) \\
&= \frac{P(A \cup B)}{P(A)} \\
\text{lift}(A \Rightarrow B) &= \frac{\text{confidence}(A \Rightarrow B)}{P(B)} \\
&= \frac{P(A \cup B)}{P(A)P(B)}
\end{aligned}
$$

where $P(A)$ is the percentage (or probability) of cases containing A.

Association Rule Mining Algorithms in R

- APRIORI
  - a level-wise, breadth-first algorithm which counts transactions to find frequent itemsets and then derive association rules from them
  - apriori() in package arules
- ECLAT
  - finds frequent itemsets with equivalence classes, depth-first search and set intersection instead of counting
  - eclat() in the same package

Outline

The Titanic Dataset

- The Titanic dataset in the *datasets* package is a 4-dimensional table with summarized information on the fate of passengers on the Titanic according to social class, sex, age and survival.
- To make it suitable for association rule mining, we reconstruct the raw data as `titanic.raw`, where each row represents a person.
- The reconstructed raw data can also be downloaded at `http://www.rdatamining.com/data/titanic.raw.rdata`.

```r
load("./data/titanic.raw.rdata")
## draw a sample of 5 records
idx <- sample(1:nrow(titanic.raw), 5)
titanic.raw[idx, ]

##       Class    Sex   Age Survived
## 383     3rd   Male Adult       No
## 2188   Crew Female Adult      Yes
## 481     3rd   Male Adult       No
## 1671    3rd   Male Adult      Yes
## 1634    3rd   Male Adult      Yes

summary(titanic.raw)

##   Class         Sex          Age       Survived
##  1st :325   Female: 470   Adult:2092   No :1490
##  2nd :285   Male  :1731   Child: 109   Yes: 711
##  3rd :706
##  Crew:885
```

Function apriori()

Mine frequent itemsets, association rules or association hyperedges using the Apriori algorithm. The Apriori algorithm employs level-wise search for frequent itemsets.

Default settings:

- minimum support: supp=0.1
- minimum confidence: conf=0.8
- maximum length of rules: maxlen=10

```r
library(arules)
rules.all <- apriori(titanic.raw)

##
## parameter specification:
##  confidence minval smax arem  aval originalSupport support
##         0.8    0.1    1 none FALSE            TRUE     0.1
##  minlen maxlen target   ext
##       1     10  rules FALSE
##
## algorithmic control:
##  filter tree heap memopt load sort verbose
##     0.1 TRUE TRUE  FALSE TRUE    2    TRUE
##
## apriori - find association rules with the apriori algorithm
## version 4.21 (2004.05.09)        (c) 1996-2004   Christian ...
## set item appearances ...[0 item(s)] done [0.00s].
## set transactions ...[10 item(s), 2201 transaction(s)] done ...
## sorting and recoding items ... [9 item(s)] done [0.00s].
## creating transaction tree ... done [0.00s].
## checking subsets of size 1 2 3 4 done [0.00s].
## writing ... [27 rule(s)] done [0.00s].
## creating S4 object  ... done [0.00s].
```

```r
inspect(rules.all)

##    lhs               rhs            support confidence   lift
## 1  {}             => {Age=Adult}     0.9505     0.9505 1.0000
## 2  {Class=2nd}    => {Age=Adult}     0.1186     0.9158 0.9635
## 3  {Class=1st}    => {Age=Adult}     0.1449     0.9815 1.0327
## 4  {Sex=Female}   => {Age=Adult}     0.1931     0.9043 0.9514
## 5  {Class=3rd}    => {Age=Adult}     0.2849     0.8881 0.9344
## 6  {Survived=Yes} => {Age=Adult}     0.2971     0.9198 0.9678
## 7  {Class=Crew}   => {Sex=Male}      0.3916     0.9740 1.2385
## 8  {Class=Crew}   => {Age=Adult}     0.4021     1.0000 1.0521
## 9  {Survived=No}  => {Sex=Male}      0.6197     0.9154 1.1640
## 10 {Survived=No}  => {Age=Adult}     0.6533     0.9651 1.0154
## 11 {Sex=Male}     => {Age=Adult}     0.7574     0.9630 1.0132
## 12 {Sex=Female,
##     Survived=Yes} => {Age=Adult}     0.1436     0.9186 0.9665
## 13 {Class=3rd,
##     Sex=Male}     => {Survived=No}   0.1917     0.8275 1.2223
## 14 {Class=3rd,
##     Survived=No}  => {Age=Adult}     0.2163     0.9015 0.9485
## 15 {Class=3rd,
##     Sex=Male}     => {Age=Adult}     0.2099     0.9059 0.9531
## 16 {Sex=Male,
##     Survived=Yes} => {Age=Adult}     0.1536     0.9210 0.9690
```

```r
# rules with rhs containing "Survived" only
rules <- apriori(titanic.raw,
                 control = list(verbose=F),
                 parameter = list(minlen=2, supp=0.005, conf=0.8),
                 appearance = list(rhs=c("Survived=No",
                                         "Survived=Yes"),
                                   default="lhs"))
## keep three decimal places
quality(rules) <- round(quality(rules), digits=3)
## order rules by lift
rules.sorted <- sort(rules, by="lift")
```

```r
inspect(rules.sorted)
```

```
##    lhs                rhs             support confidence  lift
## 1  {Class=2nd,
##     Age=Child}  => {Survived=Yes}   0.011      1.000 3.096
## 2  {Class=2nd,
##     Sex=Female,
##     Age=Child}  => {Survived=Yes}   0.006      1.000 3.096
## 3  {Class=1st,
##     Sex=Female} => {Survived=Yes}   0.064      0.972 3.010
## 4  {Class=1st,
##     Sex=Female,
##     Age=Adult}  => {Survived=Yes}   0.064      0.972 3.010
## 5  {Class=2nd,
##     Sex=Female} => {Survived=Yes}   0.042      0.877 2.716
## 6  {Class=Crew,
##     Sex=Female} => {Survived=Yes}   0.009      0.870 2.692
## 7  {Class=Crew,
##     Sex=Female,
##     Age=Adult}  => {Survived=Yes}   0.009      0.870 2.692
## 8  {Class=2nd,
##     Sex=Female,
##     Age=Adult}  => {Survived=Yes}   0.036      0.860 2.663
## 9  {Class=2nd,
```

Outline

Redundant Rules

```
inspect(rules.sorted[1:2])

##   lhs                rhs            support confidence  lift
## 1 {Class=2nd,
##    Age=Child}  => {Survived=Yes}   0.011          1 3.096
## 2 {Class=2nd,
##    Sex=Female,
##    Age=Child}  => {Survived=Yes}   0.006          1 3.096
```

- Rule #2 provides no extra knowledge in addition to rule #1, since rules #1 tells us that all 2nd-class children survived.
- When a rule (such as #2) is a super rule of another rule (#1) and the former has the same or a lower lift, the former rule (#2) is considered to be redundant.
- Other redundant rules in the above result are rules #4, #7 and #8, compared respectively with #3, #6 and #5.

Remove Redundant Rules

```r
## find redundant rules
subset.matrix <- is.subset(rules.sorted, rules.sorted)
subset.matrix[lower.tri(subset.matrix, diag = T)] <- NA
redundant <- colSums(subset.matrix, na.rm = T) >= 1
```

```r
## which rules are redundant
which(redundant)

## [1] 2 4 7 8

## remove redundant rules
rules.pruned <- rules.sorted[!redundant]
```

Remaining Rules

```
inspect(rules.pruned)

##   lhs                rhs              support confidence  lift
## 1 {Class=2nd,
##    Age=Child}   => {Survived=Yes}   0.011      1.000 3.096
## 2 {Class=1st,
##    Sex=Female} => {Survived=Yes}   0.064      0.972 3.010
## 3 {Class=2nd,
##    Sex=Female} => {Survived=Yes}   0.042      0.877 2.716
## 4 {Class=Crew,
##    Sex=Female} => {Survived=Yes}   0.009      0.870 2.692
## 5 {Class=2nd,
##    Sex=Male,
##    Age=Adult}   => {Survived=No}    0.070      0.917 1.354
## 6 {Class=2nd,
##    Sex=Male}    => {Survived=No}    0.070      0.860 1.271
## 7 {Class=3rd,
##    Sex=Male,
##    Age=Adult}   => {Survived=No}    0.176      0.838 1.237
## 8 {Class=3rd,
##    Sex=Male}    => {Survived=No}    0.192      0.827 1.222
```

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```r
inspect(rules.pruned[1])

##   lhs                rhs            support confidence  lift
## 1 {Class=2nd,
##    Age=Child} => {Survived=Yes}   0.011          1 3.096
```

Did children of the 2nd class have a higher survival rate than other children?

```r
inspect(rules.pruned[1])

##   lhs              rhs            support confidence  lift
## 1 {Class=2nd,
##    Age=Child} => {Survived=Yes}   0.011          1 3.096
```

Did children of the 2nd class have a higher survival rate than other children?

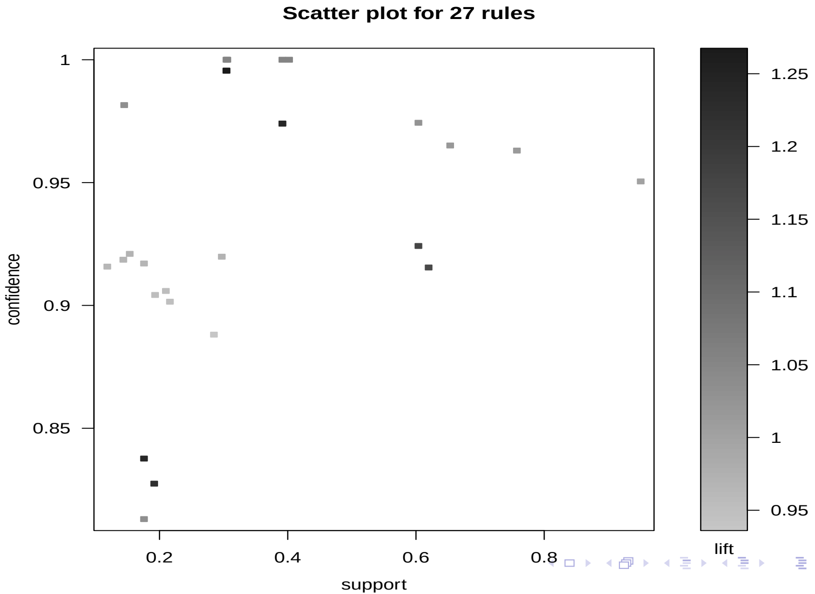
The rule states only that all children of class 2 survived, but provides no information at all to compare the survival rates of different classes.

Rules about Children

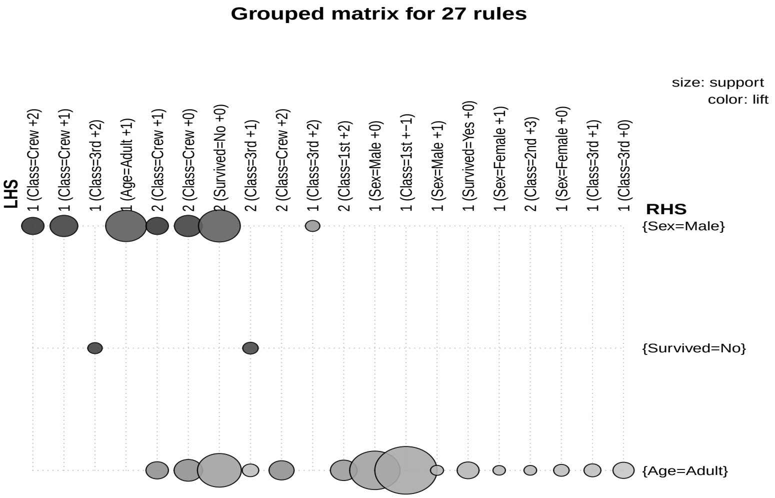
```
rules <- apriori(titanic.raw, control = list(verbose=F),
     parameter = list(minlen=3, supp=0.002, conf=0.2),
     appearance = list(default="none", rhs=c("Survived=Yes"),
                       lhs=c("Class=1st", "Class=2nd", "Class=3rd",
                             "Age=Child", "Age=Adult")))
rules.sorted <- sort(rules, by="confidence")
inspect(rules.sorted)

##   lhs               rhs             support confidence   lift
## 1 {Class=2nd,
##    Age=Child} => {Survived=Yes} 0.010904     1.0000 3.0956
## 2 {Class=1st,
##    Age=Child} => {Survived=Yes} 0.002726     1.0000 3.0956
## 3 {Class=1st,
##    Age=Adult} => {Survived=Yes} 0.089505     0.6176 1.9117
## 4 {Class=2nd,
##    Age=Adult} => {Survived=Yes} 0.042708     0.3602 1.1149
## 5 {Class=3rd,
##    Age=Child} => {Survived=Yes} 0.012267     0.3418 1.0580
## 6 {Class=3rd,
##    Age=Adult} => {Survived=Yes} 0.068605     0.2408 0.7455
```

Outline

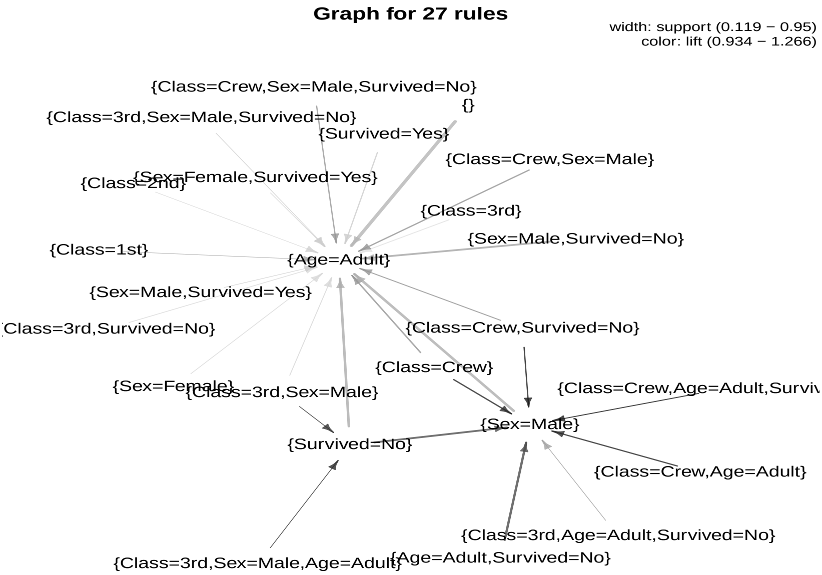
```r
library(arulesViz)
plot(rules.all)
```



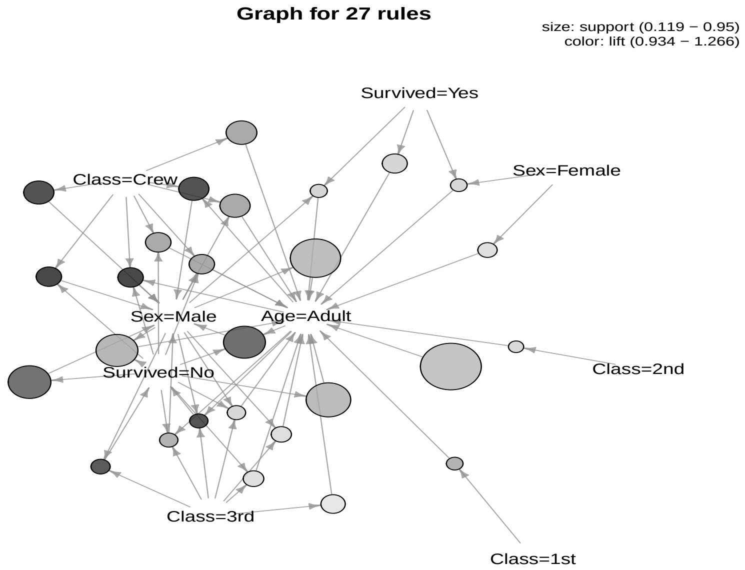
```r
plot(rules.all, method = "grouped")
```



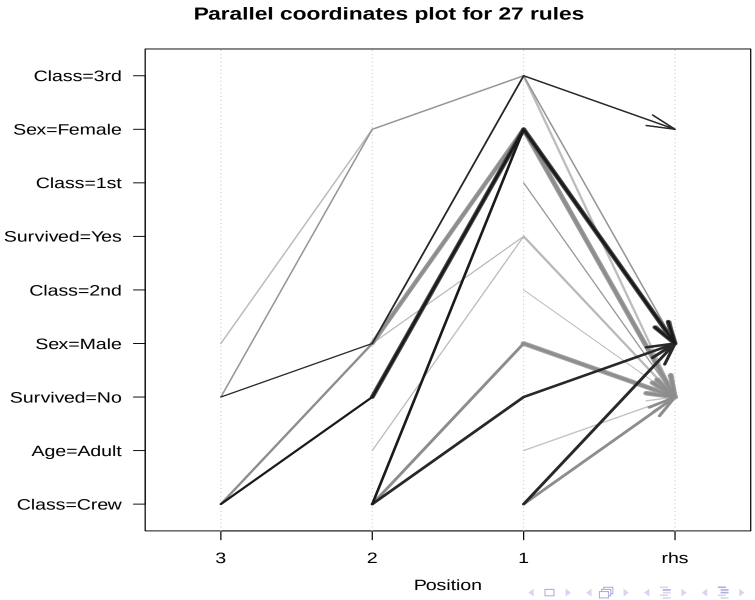
```r
plot(rules.all, method = "graph")
```



```r
plot(rules.all, method = "graph", control = list(type = "items"))
```



```r
plot(rules.all, method = "paracoord", control = list(reorder = TRUE))
```



Outline

Further Readings

- More than 20 interestingness measures, such as chi-square, conviction, gini and leverage

  Tan, P.-N., Kumar, V., and Srivastava, J. (2002). Selecting the right interestingness measure for association patterns. In Proc. of KDD '02, pages 32-41, New York, NY, USA. ACM Press.
- Post mining of association rules, such as selecting interesting association rules, visualization of association rules and using association rules for classification

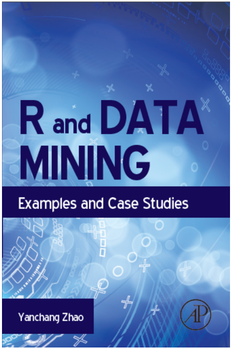
  Yanchang Zhao, Chengqi Zhang and Longbing Cao (Eds.). "Post-Mining of Association Rules: Techniques for Effective Knowledge Extraction", ISBN 978-1-60566-404-0, May 2009. Information Science Reference.
- Package *arulesSequences*: mining sequential patterns

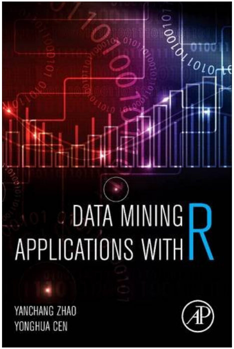
  `http://cran.r-project.org/web/packages/arulesSequences/`

Online Resources

- Chapter 9: Association Rules, in book
  R and Data Mining: Examples and Case Studies
  http://www.rdatamining.com/docs/RDataMining.pdf
- R Reference Card for Data Mining
  http://www.rdatamining.com/docs/R-refcard-data-mining.pdf
- Free online courses and documents
  http://www.rdatamining.com/resources/
- RDataMining Group on LinkedIn (8,000+ members)
  http://group.rdatamining.com
- RDataMining on Twitter (1,800+ followers)
  @RDataMining

The End





Thanks!

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