Integrating R Machine Learning Algorithms in Stata using rcall

A Tutorial

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Overview

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  - covering tips about using `rcall` interactively
- Part 4: using `rcall` for writing Stata packages
  - Examples of embedding R in Stata packages

References

Data

- Statlog (German Credit Data) Data Set
- `https://archive.ics.uci.edu/ml/datasets/statlog+(german+credit+data)`
- The dataset is included in the presentation repository
  - `./examples/credit.csv`
- data is about identifying risky bank loans, includes 1000 Obs.
- The variable of interest is `default` i.e. loan goes to default:
  - 1 = NO (70%) and 2 = YES (30%)

Machine learning (ML) examples

- Solely focus on decision trees, using `C5` algorithm
- Machine learning with R, Brett Lantz
- `https://www.packtpub.com/product/machine-learning-with-r-third-edition/9781788295864`

Notes

Download the presentation, code, and data

- `https://github.com/haghish/machinelearning`

`R` is `rcall`'s abbreviation

- `rcall` command can be abbreviated as `R`
- In this presentation `rcall` and `R` commands are used interchangeably

Why teaching `rcall` with machine learning?

- ML models often require follow ups and refining
- The workflow is often *interactive*
  - the dataset is split into **training** and **test** datasets
  - the model(s) is developed on a training dataset
  - the model(s) are tested on the test dataset
  - often many models are compared, fine-tuned, and optimized
- They are idea for demonstrating the interactive workflow with `rcall`

Part 1: Introduction to `rcall` package

Why language interfacing matters?

- Definition
  - facilitate communication between programs written in different languages
  - facilitate sharing objects between programs
  - Interfacing is **different from automation**
  - We can write a script to execute multiple instructions:
  - e.g. Calling MPlus, R, Stata from shell script
  - Stata supports executing shell script and automation
  - Interfacing typically allows **object communication**
- Popularity
  - Saving resources
  - Avoiding *reinventing the wheel*
- Reproducibility
  - There is no statistical software that does everything
  - We might need a different program for a part of the analysis
  - Interfacing helps to keep the analysis in one place

Language interfacing for statistical analysis

- Interfacing is common in computer sciences
  - e.g. running a Java library within Python
  - e.g. running C++ within an R program to execute a loop
  - e.g. running MATA within Stata
- Embedding a different language inside a program requires a strict structure
- Statistical analysis is interactive
  - Interfacing for regular data analysis should be seamless
  - We need to be able to integrating different statistical programs for daily use

How does `rcall` work?

- `rcall` is a general interfacing program to embed R within Stata
- It provides a seamless procedure for using R in Stata
  - Can be used for interactive data analysis within Stata
  - Can also be used for embedding R in Stata programs and packages
- It facilitate object communications between Stata and R
  - dataset
  - matrices
  - scalars
  - variables
  - macros
- When calling R, the results will be available to Stata as objects

rcall workflows

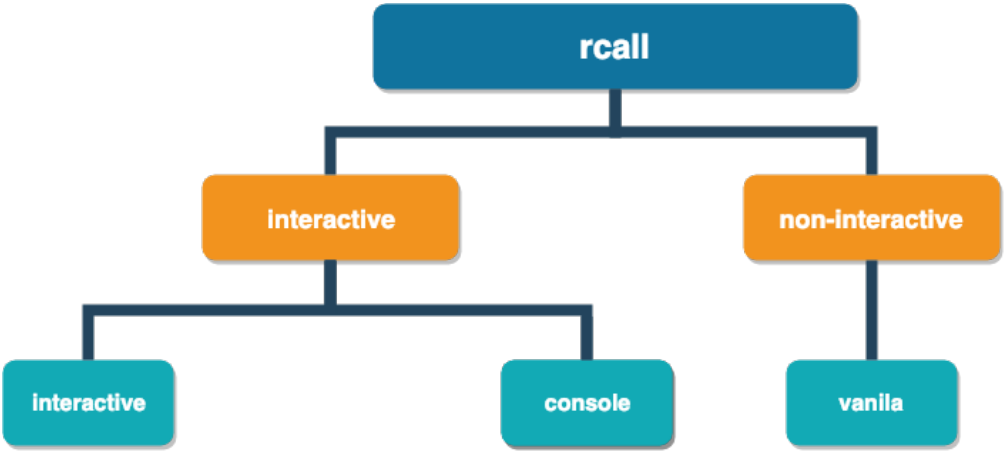


Figure 1: rcall modes

Interactive vs non-interactive workflows

- In interactive sessions R will preserve all objects existing in the memory
  - consequent commands that are executed in the same environment
  - This is similar to working interactively in Rstudio
  - Desired when R is used interactively for data analysis
- Non-interactive sessions do not have any memory
  - Every command is executed in a new environment
  - After the execution, the environment is removed
  - Restrict the session to a specific computation
  - Desired when R is embedded in Stata programs

Installing `rcall`

- `rcall` is hosted on GitHub.
- The only recommended installation method is using the **`github`** package
- First, install the **`github`** package:

```
net install github, from("https://haghish.github.io/github/")
```

- Then install the latest `rcall` stable release

```
github install haghish/rcall, stable
```

- You can alternatively install the latest development version

```
github install haghish/rcall
```

- `rcall` required R package will be installed automatically
- The dependencies can also be installed manually within R
- See the `dependency.do` file in the GitHub repo
- To update `rcall`, type: `github update rcall`

Syntax

1. `rcall [subcommand]`
2. `rcall script "filename.R" [, args() vanilla ]`
3. `rcall [mode] [:] [R-command]`
   - console
   - interactive
   - non-interactive (vanilla)

Data communication

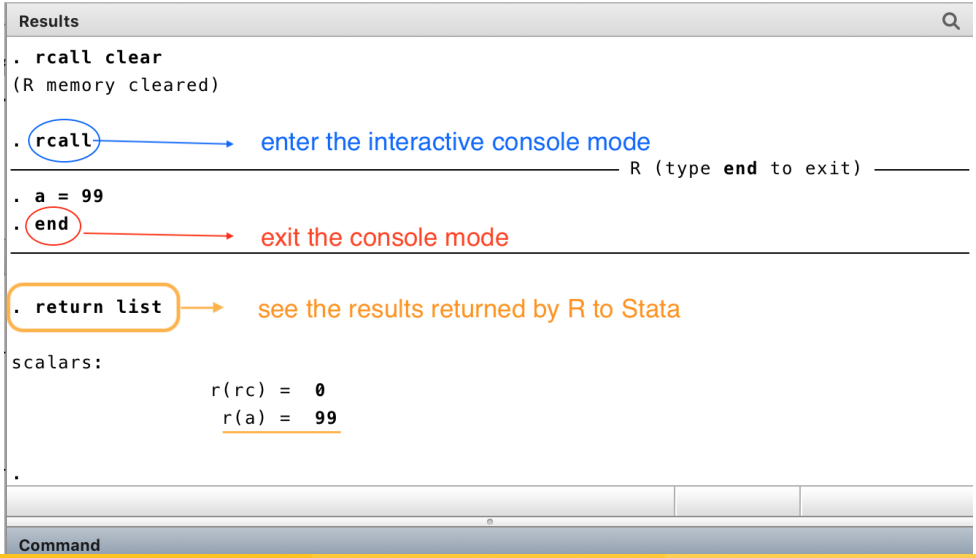
- `rcall` offers several functions for passing dataset, variables, matrices, and scalars to R
- datasets can also be loaded from R environment to Stata
- `rcall` returns matrices and scalars automatically from R to Stata

Function	Description
st.scalar(name)	passes a scalar to R
st.matrix(name)	passes a matrix to R
st.var(varname)	passes a numeric or string variable to R
st.data(filename)	passes Stata data to R. without filename, the currently loaded data is used.
st.load(dataframe)	loads data from R dataframe to Stata

Figure 2: `rcall` subcommands

Console mode

- Is useful for casual or exploratory work
- type `rcall` to enter the simulated R environment
- type `end` to exit the simulated environment



Console mode

```
. sysuse auto, clear
(1978 Automobile Data)

. rcall
------------------------------------------------------------------ R (type end to exit) ------------------------------------------------------------------
. df <- st.data()
. head(df)
           make price mpg rep78 headroom trunk weight length turn displacement
1   AMC Concord  4099  22     3      2.5    11   2930    186   40           121
2     AMC Pacer  4749  17     3      3.0    11   3350    173   40           258
3    AMC Spirit  3799  22    NA      3.0    12   2640    168   35           121
4 Buick Century  4816  20     3      4.5    16   3250    196   40           196
5 Buick Electra  7827  15     4      4.0    20   4080    222   43           350
6 Buick LeSabre  5788  18     3      4.0    21   3670    218   43           231
  gear_ratio  foreign
1       3.58 Domestic
2       2.53 Domestic
3       3.08 Domestic
4       2.93 Domestic
5       2.41 Domestic
6       2.73 Domestic
. make <- as.matrix(df\$price)
. end
---------------------------------------------------------------------------------------------------------------------------------------------------------

. return list

scalars:
                 r(rc) =  0

matrices:
              r(make) :  74 x 1

.
```

Figure 4: example of working in console mode

Logging R code

```
. rcall history
```

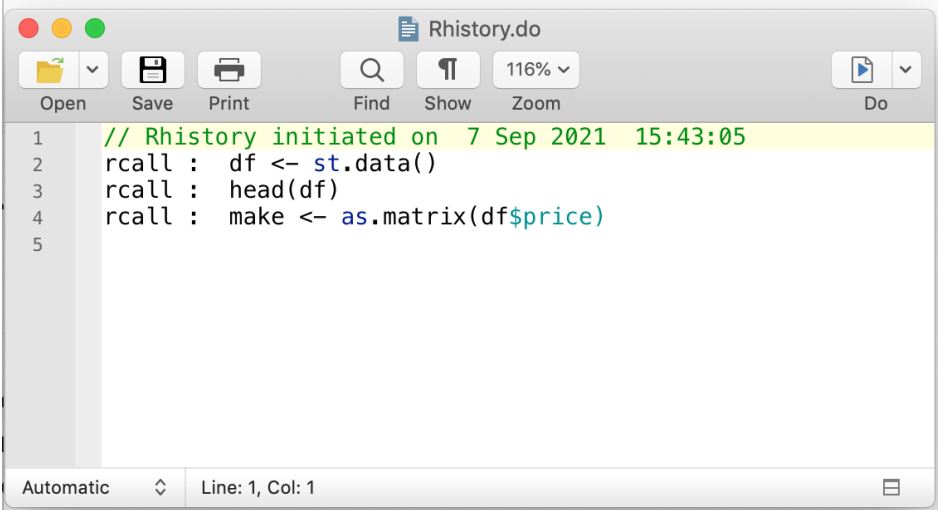


Figure 5: `rcall` history

Subcommands

- Commands for setting up and monitoring R within Stata

Subcommand	Description
setpath	permanently defines the path to executable R on the machine
clear	erases the R memory and history in the interactive mode
script	executes an R script file and returns the results to Stata
warnings	shows the warnings returned from R
describe	returns the R version and paths to R, RProfile, and Rhistory
history	opens **Rhistory.do** in do-file editor which stores the history of the interactive R session
site	opens **rprofile.site** in do-file editor which is used for customizing R when is called from Stata

Added in rcall 3.0

Script subcommand

- rcall can also source an R script file:
  - `rcall script "filename.R" [, args() vanilla ]`
- the `args()` can be used to give instructions or define objects in R, prior to sourcing
- e.g. pass dataset, matrices, variables, scalars, and macros to R
- the `script` subcommand is the simplest way for running R within Stata programs
  - In this case, the `vanila` option is recommended

Example 1

rscriptexample.R

Source on Save

```r
# This is a regular R script file
print(dim(df))
correlation = cor(df$price, df$mpg)
mat <- as.matrix(cbind(df$price, df$mpg))  # define a new matrix within R
```

Figure 6: rscriptexample.R file

```
clear
sysuse auto
rcall script: ./examples/rscriptexample.R  , args(df<-st.data()) vanilla
```

Example 1

```
. rcall script: ./examples/rscriptexample.R  , args(df<-st.data()) vanilla
[1] 74 12

. return list

scalars:
                 r(rc) =  0
        r(correlation) =  -.4685967

matrices:
               r(mat) :  74 x 2

.
```

Figure 7: Example of running an R script within Stata

Part 2: Decision trees

Decision trees

- very popular ML classifiers, due to their simplicity
- Can be applied on most data types
- a tree-like structure to model the relationships among potential outcomes
- intuitive and human-readable, offering high transparency in decision making
- the model structure:
  - begins at a wide trunk (**root node**)
  - splits into narrower branches (**decision nodes**)
  - every split is a decision, creating **branches**
  - with the final decision, the model reaches **leaf nodes** or **terminal nodes**
- Here I focus on the **C5.0** decision tree algorithm

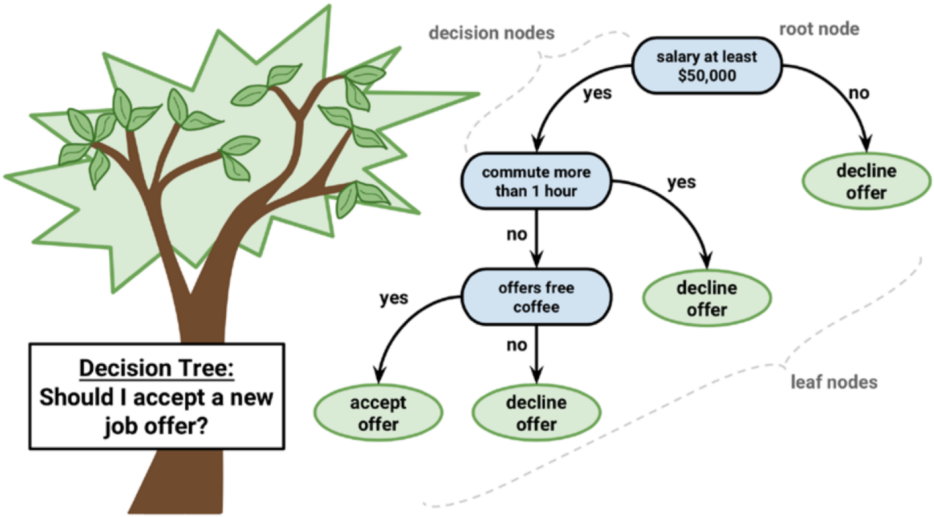


Figure 8: Decision tree example

Pros and cons

Pros

- general purpose classifier
- well on most problems
- offer automatic learning process
- can work with different types
- can handle missing data
- can work on different sample sizes
- highly interpretable

Cons

- become over-complex with complicated data structures
- biased toward splits on variables with higher levels
- prone to overfitting and underfitting

Part 3: Using `rcall` interactively

Using `rcall` from Stata do-file editor

- R code can be executed within Stata do-file editor
  - `rcall [mode] [:] [R-command]`
- in `rcall 3.0`, the `mode` argument can be
  - **vanilla** for non-interactive session
  - for interactive session, no *mode* is required
  - the *sync* mode is removed in `rcall` version 3
- When using `rcall` interactively, **ALWAYS** start a new R session
  - type: `rcall clear` to start a fresh session

Example 1

Loading `credit.csv` dataset from R to Stata

- I can load the dataset with `rcall` as follows

```
// load the data in a new R session and pass it to Stata
rcall clear
rcall: df<-read.csv("./examples/credit.csv", stringsAsFactor = TRUE)
rcall: st.load(df)

. table default

----------------------
  default |      Freq.
----------+-----------
        1 |         700
        2 |         300
----------------------
```

- I could load the CSV data with Stata, without converting strings to factors:
  - `import delimited "./examples/credit.csv"`

Working with the C5 R package

```
// load the dataset for the analysis
use credit, clear


R clear                    // cleaning the R environment
R: credit <- st.data()     // pass the data to R
R: class(credit\$default) //check that it is a factor

// prepare the train and test datasetså
R: set.seed(123);                              ///
  train_sample <- sample(1000, 900);           ///
  train <- credit[train_sample, ];             ///
  test  <- credit[-train_sample, ]


// load the library and create the model
R: library(C50);                               ///
   model <- C5.0(train[-17], train\$default)

R: model
```

Figure 9: Preparing the data for C5

Working with the C5 R package

```
. R: model

Call:
C5.0.default(x = train[-17], y = train$default)

Classification Tree
Number of samples: 900
Number of predictors: 20

Tree size: 42

Non-standard options: attempt to group attributes

.
```

Figure 10: Preparing the data for C5

Summarizing the training model

. R: `summary(model)`

- shows the structure of the decision trees
- shows how much different variables are contributed to the model
- confusion matrix of the training dataset

```
Evaluation on training data (900 cases):

           Decision Tree
         ----------------
         Size      Errors

           42  136(15.1%)   <<


          (a)   (b)    <-classified as
         ----  ----
          612    23    (a): class no
          113   152    (b): class yes
```

Predicting the test dataset

```
47
48    R: prediction <- predict(model, test)
49    R: prediction
50
```

Figure 12: Predicting the test dataset

```
. R: prediction
  [1] no  no  no  yes no  yes no  yes no  no  no  no  no  yes no  no  no  no
 [19] no  no  no  no  no  no  no  no  no  no  no  no  yes no  no  no  yes no
 [37] yes no  no  yes no  yes no  no  no  no  yes no  no  no  no  no  no  no
 [55] no  no  no  no  yes no  yes no  no  no  no  no  no  yes yes no  no  yes
 [73] no  no  no  no  no  yes no  yes no  no  no  no  yes yes yes no  no  no
 [91] no  no  no  yes no  no  yes no  no  yes
Levels: no yes
```

Figure 13: Predicted variable

Producing the confusion matrix

```
26
27    R: prediction <- predict(model, test)
28    R: prediction
29    R: table(test\$default, prediction,      ///
30       dnn = c("actual default", "predicted default"))
31
```

Figure 14: Predicting the test dataset

```
              predicted default
actual default no yes
           no  55  10
           yes 22  13
```

Using `rcall` from do-file editor is similar to console mode

```
Results

. R
------------------------------------------------------------------------------- R (type end to exit) -------------------------------------------------------------------------------
. prediction
  [1] no  no  no  yes no  yes no  yes no  no  no  no  no  yes no  no  no  no
 [19] no  no  no  no  no  no  no  no  no  no  no  no  yes no  no  no  yes no
 [37] yes no  no  yes no  yes no  no  no  no  yes no  no  no  no  no  no  no
 [55] no  no  no  no  yes no  yes no  no  no  no  no  no  yes yes no  no  yes
 [73] no  no  no  no  no  yes no  yes no  no  no  no  yes yes yes no  no  no
 [91] no  no  no  yes no  no  yes no  no  yes
Levels: no yes
. ls()
[1] "adj.names"    "credit"       "model"        "prediction"   "rc"
[6] "stata.output" "test"         "train"        "train_sample"
. end
------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

. return list

scalars:
                 r(rc) =  0

macros:
       r(train_sample) : "415 463 179 526 195 938 818 118 299 229 244 14 374 665 602 603 768 709 91 953 348 649 355 840.."
```

Figure 15: Accessing R session from `rcall` console

Return a particular matrix or table to Stata

```
. R: confusion <- table(test\$default, prediction,    ///
>    dnn = c("actual default", "predicted default"))

. R: class(confusion)
[1] "table"

. R: confusion <- as.matrix(unclass(confusion), dnn = NULL)

. // the matrix will be returned to Stata
. R: confusion
              predicted default
actual default no yes
           no  55  10
           yes 22  13

. return list

scalars:
                 r(rc) =  0

macros:
       r(train_sample) : "415 463 179 526 195 938 818 118 299 229 244 14 374 665 602 603 768 709 91 953 348 649 355 840.."

matrices:
          r(confusion) :  2 x 2

.
end of do-file
```

Figure 16: Convert the class of object to Matrix to return it to Stata

```
. matrix list r(confusion)

r(confusion)[2,2]
      no  yes
 no   55   10
yes   22   13
```

Figure 17: Access the returned matrix in Stata

Break a complex R object to a number of simple objects

- Complex objects can be thought of lists
  - might include datasets
  - matrices
  - scalars
  - arrays . . .
- You can unclass or slice a complex object into simple objects
- Simple objects must be recognized by Stata
  - numeric matrices
  - scalars
  - datasets
- Such objects will be returned by `rcall` automatically
- If you want to avoid returning an object, just remove it in the R code!

Break a complex R object to a number of simple objects

```
. R
──────────────────────────────────────────────────────────── R (type end to exit) ────────────────────────────────────────────────────────────
. class(model)
[1] "C5.0"
. str(model)
List of 16
 $ names       : chr "| Generated using R version 4.1.0 (2021-05-18)\n| on Thu Sep 09 10:02:16 2021\noutcome.\n\noutcome: n
> o,yes.\nch"| __truncated__
 $ cost        : chr ""
 $ costMatrix  : NULL
 $ caseWeights : logi FALSE
 $ control     :List of 11
  ..$ subset         : logi TRUE
  ..$ bands          : num 0
  ..$ winnow         : logi FALSE
  ..$ noGlobalPruning: logi FALSE
  ..$ CF             : num 0.25
  ..$ minCases       : num 2
  ..$ fuzzyThreshold : logi FALSE
  ..$ sample         : num 0
  ..$ earlyStopping  : logi TRUE
  ..$ label          : chr "outcome"
  ..$ seed           : int 1098
 $ trials      : Named num [1:2] 1 1
  ..- attr(*, "names")= chr [1:2] "Requested" "Actual"
 $ rbm         : logi FALSE
 $ boostResults: NULL
 $ size        : int 42
 $ dims        : int [1:2] 900 20
 $ call        : language C5.0.default(x = train[-17], y = train$default)
 $ levels      : chr [1:2] "no" "yes"
 $ output      : chr "\nC5.0 [Release 2.07 GPL Edition]  \tThu Sep  9 10:02:16 2021\n-------------------------------\n\nCla
> ss specifi"| __truncated__
 $ tree        : chr "id=\"See5/C5.0 2.07 GPL Edition 2021-09-09\"\nentries=\"1\"\ntype=\"3\" class=\"no\" freq=\"635,265\"
>  att=\"che"| __truncated__
 $ predictors  : chr [1:20] "checking_balance" "months_loan_duration" "credit_history" "purpose" ...
 $ rules       : chr ""
 - attr(*, "class")= chr "C5.0"
.
```

Figure 18: Viewing the model object

Better, faster, and cleaner workflow?

```r
# credit object must be defined before execution
# ------------------------------------------------
credit$default <- as.factor(credit$default)

# set seed and define the train and test datasets
set.seed(123)
train_sample <- sample(1000, 900)
train <- credit[train_sample, ]
test  <- credit[-train_sample, ]

library(C50)
model <- C5.0(train[-17], train$default)

prediction <- predict(model, test)
table(test$default, prediction,
      dnn = c("actual default", "predicted default"))

```

```
// load the dataset for the analysis
use credit, clear
R clear                    // cleaning the R environment
R script "./examples/decisiontree.R", args(credit<-st.data())
return list
```

Part 4: using `rcall` for writing Stata packages

Stata programming with `rcall`

- `rcall` allows embedding R code inside Stata programs
- It also provides a strict procedures for executing the computation
  - checking for required dependencies (R version, versions of R packages)
  - making sure the analysis is reproducible, by starting a new R environment
  - providing tools for checking required Stata dependencies and `rcall` version
- Programming with `rcall` is best practiced if Stata syntax is adopted

Example Stata programs utilizing `rcall`

- examples in the manuscript: Seamless interactive language interfacing between R and Stata
- example packages written by the community
  - type `github search rcall, all in(all)`

github search rcall, all in(all)

Results

rcall	haghish	Install *1968k*	Seamless interactive R in Stata. rcall allows communicating data sets, matrices, variables, and scalars between Stata and R conveniently homepage http://www.haghish.com/packa~p updated on 2021-09-07 **Fork:**22 **Star:**64 **Lang:**Stata (dependency)
did	NickCH-K	Install *452k*	A Stata package that acts as a wrapper for Callaway and Santannas R did package updated on 2021-08-19 **Fork:**11 **Star:**26 **Lang:**Stata
stata-rcallst~t	luispfons~a	Install *27k*	Call Rs stringdist package from Stata using rcall updated on 2020-01-15 **Fork:**2 **Star:**1 **Lang:**Stata (dependency)
importsav	jh-min	Install *51k*	Program to convert SPSS file to Stata (requires R) updated on 2020-07-27 **Fork:**0 **Star:**1 **Lang:**Stata
stata-rcallco~e	luispfons~a	Install *49k*	Call Rs countrycode package from Stata using rcall updated on 2021-03-10 **Fork:**0 **Star:**0 **Lang:**Stata (dependency)
cquadr	fravale	Install *253k*	Run the cquad R package in Stata by rcall updated on 2020-12-02 **Fork:**0 **Star:**0 **Lang:**Stata
rcall	kapustinmax	Install *43k*	No description, website, or topics provided. updated on 2020-04-04 **Fork:**0 **Star:**0 **Lang:**Stata (dependency)
ehcvm-tri-aut~e	arthur-shaw		Trie automatiquement les entretiens de lEHCVM en trois tas : à rejeter, à regarder de plus près, à approuver updated on 2019-06-13 **Fork:**1 **Star:**1 **Lang:**Stata
Should-We-Tal~r	edwardgol~g		No description, website, or topics provided. updated on 2019-02-06

Figure 19: Stata packages based on `rcall`

Example 1: Loading data from CSV file

```
1   // Don't use this program at home! This is an example for loading data
Open //      from R to Stata
    // ------------------------------------------------------------------------
4
5   program define rdata
6     version 14
7     syntax using/ , [stringsasfactor]
8     confirm file `"`using'"'
9
10    // should strings be converted as factors?
11    if "`stringsasfactor'" != "" local strfactor ", stringsAsFactors=TRUE"
12
13    // load the data in a new R session and pass it to Stata
14    rcall vanilla: df<-read.csv("`macval(using)'"`strfactor'); st.load(df)
15  end
16
```

Figure 20: example program for loading CSV files in Stata

```
//import delimited "credit.csv",  clear
rdata using "credit.csv", stringsasfactor
```

Is R installed? What R version is needed?

```
// Don't use this program at home! This is an example for loading data
//     from R to Stata
// ------------------------------------------------------------------

program define rdata
  version 14
  syntax using/ , [stringsasfactor]
  confirm file `"`using'"'

  //is R recognized by rcall?
  //what is the minimum required R version
  rcall_check , rversion(4.1)

  // should strings be converted as factors?
  if "`stringsasfactor'" != "" local strfactor ", stringsAsFactors=TRUE"

  // load the data in a new R session and pass it to Stata
  rcall vanilla: df<-read.csv("`macval(using)'"`strfactor'); st.load(df)
end

```

Figure 21: example program for loading CSV files in Stata

What if error occurs?

```
// Don't use this program at home! This is an example for loading data
//     from R to Stata
// ------------------------------------------------------------------------

program define rdata
  version 14
  syntax using/ , [stringsasfactor]
  confirm file `"`using'"'

  //is R recognized by rcall?
  //what is the minimum required R version
  rcall_check , rversion(4.1)

  // should strings be converted as factors?
  if "`stringsasfactor'" != "" local strfactor ", stringsAsFactors=TRUE"

  // load the data in a new R session and pass it to Stata
  rcall vanilla: df<-read.csv("`macval(using)'"`strfactor'); st.load(df)

  // in case of error, the program will stop and R's or Stata's error is returned
  // otherwise, r(rc) =  0 is returned
  if `r(rc)' == 0 {
    di as txt "(write something here...)"
  }

end
```

Figure 22: example program for loading CSV files in Stata

Package versions & returning objects to Stata?

- you can specify a particular package version or a minimum version for dependencies
- check the version of the dependencies using `packageVersion("pkgname")` function

```
. R: packageVersion("C50")
[1] ‘0.1.5’
```

- The `rcall_check` command can examine the required package dependencies as well
- `rcall` automatically returns objects from R to Stata function
  - include the `return add` command to pass the objects to the mother enviornment

```
1  program define c5, rclass
2    version 14
3    syntax [anything]
4
5    //make sure R is accessible to rcall
6    //make sure R is at least version 4.1.0
7    //make sure rcall is at least version 3.0.3
8    //make sure C50 is at least version 0.1.5
9    rcall_check C50>=0.1.5 , r(4.1.0) rcall(3.0.3)
10   rcall vanilla: hw = "Hello World"
11   return add // will pass the objects returned by rcall to the mother environment
12 end
13
```

```
. return list

scalars:
                  r(rc) =  0

macros:
                  r(hw) : "Hello World"
```

Programmers can get benefit of both Stata and R syntax

- Tips
  - Implement Stata syntax in your program carefully
  - Consider writing an R functions as well
  - simplifies passing arguments between Stata and R

```
1
2   // summary program
3   // ===============
4   //
5   // Using the "summary" function in R to summarize data in Stata
6
7   program summary, byable(recall)
8     version 12
9     syntax varlist [if] [in]
10    marksample touse
11
12    rcall_check , rversion(3.0) rcall(2.5.0) //required rcall version and R version
13
14    preserve
15    quietly keep if `touse'
16    quietly keep `varlist'
17    rcall vanilla: sapply(st.data(), summary)
18    restore
19  end
```

```
. by foreign: summary price mpg if price < 4500
```

```
-> foreign = Domestic
          price   mpg
Min.    3291.00 18.00
1st Qu. 3923.50 19.00
Median  4090.50 22.00
Mean    4049.15 23.15
3rd Qu. 4243.50 25.25
Max.    4482.00 34.00
```

```
-> foreign = Foreign
          price   mpg
Min.    3748.00 21.00
1st Qu. 3822.25 26.50
Median  3945.00 29.00
Mean    4038.50 28.50
3rd Qu. 4220.75 30.75
Max.    4499.00 35.00
```

Figure 23: Example program to summarize variables with Stata syntax

Example of programming with R graphical packages

```
1
2   // Using the qplot R function in Stata
3   // ===================================
4
5   program rplot
6       version 14
7       syntax varlist [, filename(name) colour(name) shape(name) format(name)]
8
9       // check for the required packages and versions
10      // ------------------------------------------------------------------------
11      rcall_check ggplot2>=2.1.0 , r(3.1.0) rcall(2.5.0)
12
13      // Checking the variables
14      // ------------------------------------------------------------------------
15      tokenize `varlist'
16      if !missing("`3'") {
17        di as err "maximum of 2 variables (y & x) are allowed"
18        err 198
19      }
20
21      if !missing("`2'") {
22        local x "`2'"
23        local y "`1'"
24      }
25      else {
26        local x "`1'"
27        local y NULL
28      }
29
30      // Processing the options' syntax
31      // ------------------------------------------------------------------------
32      if !missing("`colour'") {
33        confirm variable `colour'           // is it a variable?
34        local colour ", colour = `colour'"
35      }
36      if !missing("`shape'") local shape ", shape = `shape'"
37      if missing("`filename'") local filename Rplot
38      if missing("`format'") local format pdf
39
40      rcall vanilla : `format'("`filename'.`format'"); library(ggplot2);        ///
41            qplot(data=st.data(), x =`2', y =`1' `colour' `shape')
42
43      di as txt "({browse Rplot.`format'} was produced)"
44  end
45
```

Figure 24: A Stata program that utilizes ggplot2 package

~ . rplot price mpg , filename(graph) colour(foreign) shape(foreign) format(png) ~

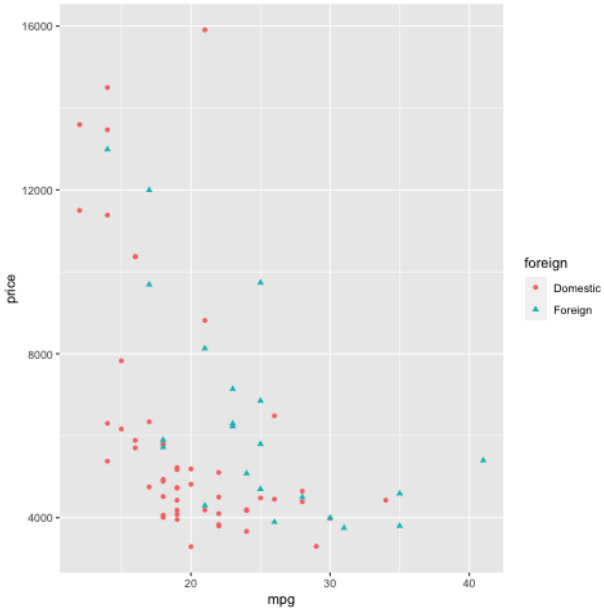


Figure 25: Example output generated by ggplot2