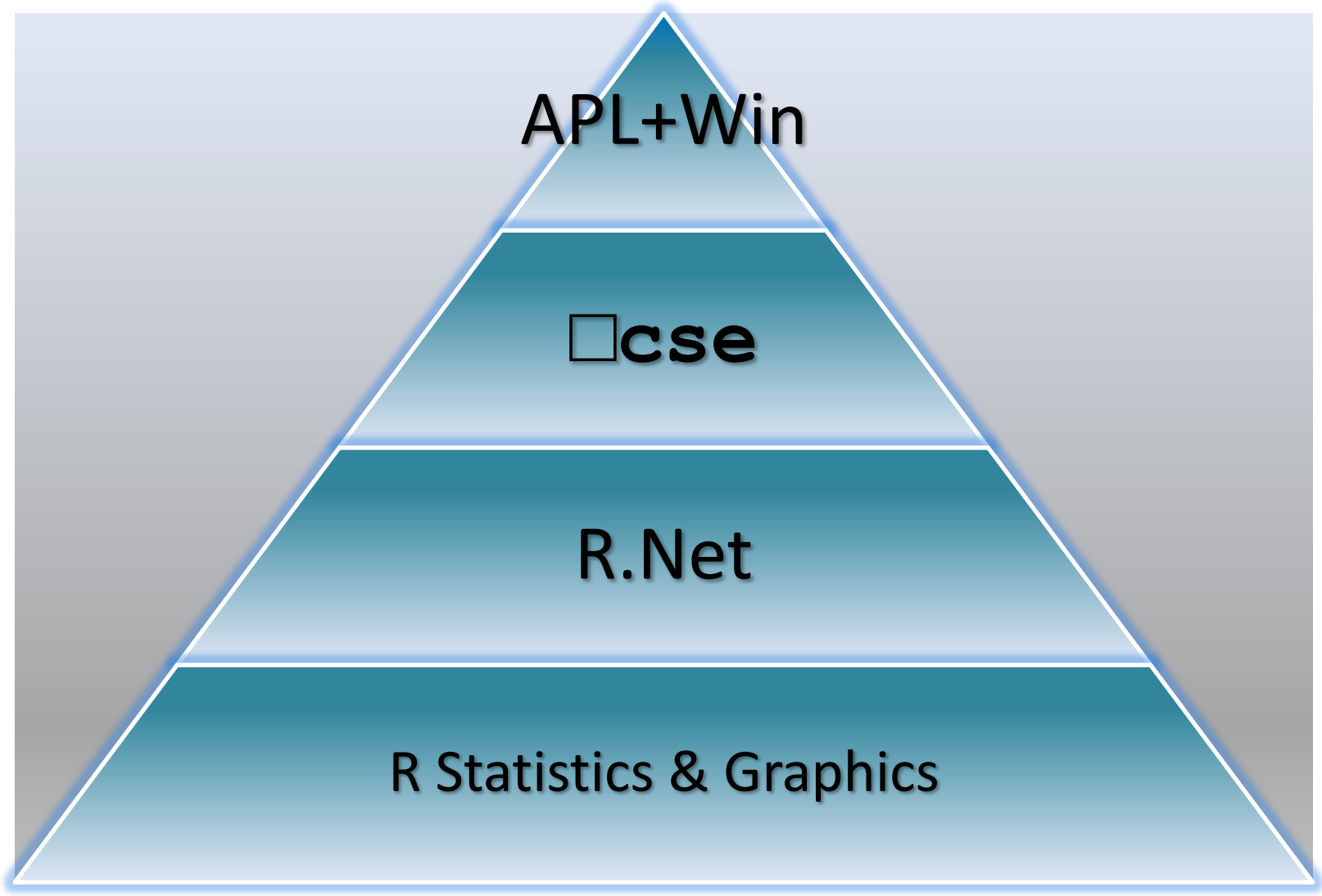


Contents

Summary

- This documentation has been updated for:
  - APL+Win v16.1.0
  - APLNext C# Script Engine v2.0.34.0
  - R Toolkit v3.2.5 x64 version
  - R.Net interface v1.5.10

The primary enhancements to the APL+Win interface to the R toolkit implemented via this updated ensemble of tools are:

- Simplification of the instantiation of an R engine instance, generally not requiring modification of the Path environment variable.
- Multiple instances of the R toolkit may be created in an APL+Win session.
- The R toolkit runs as an x64 process able to access 64-bit addressable memory (up to approximately 200Gb on a Windows 7 workstation) and create multiple objects, each greater than 2GB.

- The statistics and graphics features of R are easily accessible from APL+Win using the □cse system function and the R.Net interface to R.

- What is R?

R is a statistics and graphics toolkit. Its origin is the S language developed at Bell Laboratories. R provides a wide variety of statistics and graphics tools. R is available as no-cost, open source software under the terms of the Free Software Foundation's GNU General Public License. R is in wide use by many enterprises both public and private.

- What is R.Net?

R.NET is a .Net interface to the R toolkit. R.Net is composed of .Net assemblies which enable programs written using a .NET Framework programming language, e.g. C#, to collaborate with the R toolkit. R.Net is available as no-cost, open source software under the terms of its BSD license.

- What is the APL+Win CSE?

The APL+Win □cse system function is an interface to the APLNext C# Script Engine (CSE). Using the □cse system function, APL+Win can execute CSE scripts, employing the R.Net assemblies, to use the R toolkit.

- Why interface APL+Win and R?

Certainly any feature of R could be duplicated in APL+Win, assuming that the appropriate time and technical expertise are available to implement the required feature. R is used by many scientific, research and commercial entities worldwide so it incorporates tested tools for statistics and graphics. From the economic and practical points-of-view, using R for what it can do is a rational decision.

Prerequisites

To run the examples in this document the following components must be installed on the target workstation:

- APL+Win version 16.0.01+, available from APL2000, has its own installer.
- Microsoft .Net Framework 4.6.1, available from Microsoft at no cost, has its own installer.
- The APLNext C# Script Engine v2.0.34.0+ (CSE), included in the APL+Win subscription, has its own installer which should be 'run as administrator'.

- R toolkit 3.2.5+, available from many sources (e.g. US NIH), has its own installer which should be 'run as administrator'. Review the installation instructions and the R FAQ for this component. Since the APLNext CSE v2.0.34.0 runs as an x64 process, the x64 version of the R toolkit should be installed to the target workstation.
- The .Net assemblies (RDotnet.dll and RDotNet.NativeLibrary.dll) for the R.Net interface v1.5.10+ which are included in the .zip file containing this document or can be obtained from the R.Net project website. It may be necessary to 'Unblock' these assemblies in their Windows Explorer Properties dialog so that they can be loaded by the CSE.
- The APL+Win 'R Stat&Graph.w3' workspace, which accompanies this document, contains the APL+Win functions used in the examples.

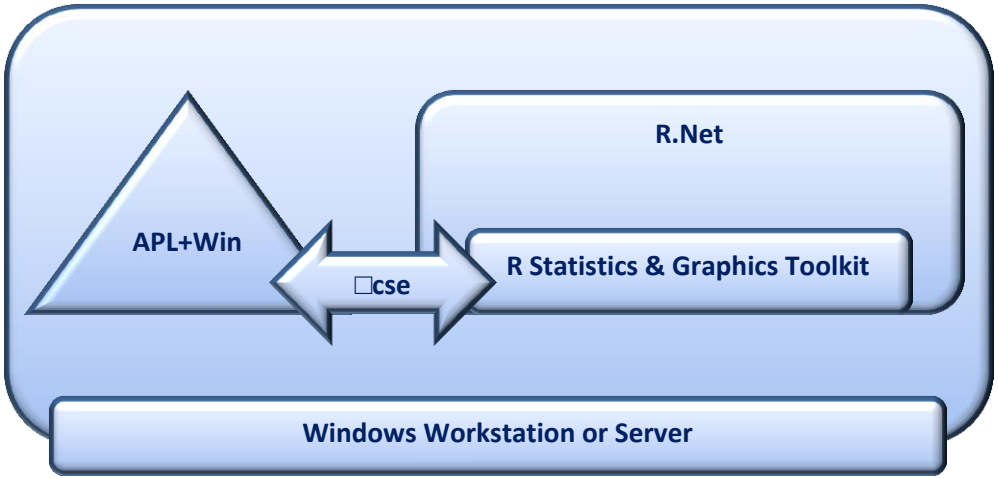
After the above components are installed:

- The examples in this document can be run starting from an APL+Win programmer session.
- The examples in this document are for demonstration purposes only.
- The examples use specific versions of R and R.Net, so modifications to the APL+Win functions may be necessary if subsequent versions of these components are used or if the installation locations on the target workstation differ from those in the examples.

- The location of the APL+Win interpreter executable and the R.Net assemblies using for the examples may need to be modified for your environment. The examples assume that the current folder, i.e. □chdir'', contains the R.Net assemblies.
- To run the examples in this document it is necessary create an instance of the R engine at the start of the APL+Win session (by running the APL+Win 'InitREngine' function) and close it at the end of the APL+Win session (by running the APL+Win 'CloseREngine' function).

Object Model of APL+Win and the R Statistics & Graphics Toolkit

R.Net is a .Net (C#) interface to the R Statistics and Graphics toolkit. From APL+Win the □cse system function creates an instance of the R.Net object so that APL+Win can use the R toolkit with an object-oriented object model.



Shared APL+Win Functions Used in the Examples

To initialize an instance of the CSE (with □cself set to 'RNet') and create an instance of the R.Net engine (called 'rEng'), the APL+Win 'InitREngine' function is used. Compared to prior versions of R.Net, this process is greatly simplified due to the REngine.SetEnvironmentVariables() method.

```
InitREngine;v
⍝20160419 APLNext LLC
:TRY *
 :IF 2003400>100⊥⎕ENLIST ⎕fi¨((v='.')⎕penclose v←'.','#'⎕cse 'version')~¨'.'
  'APLNext CSE v2.0.34.0+ required!'
 :ELSE
  ⎕cself←'RNet' ⎕cse 'Init' 'System' 10997
  ⍝↑10997: CSE SignalR port#
  ←⎕cse 'ExecStmt' 'using System;'
  ←⎕cse 'returnonerror' 1
  ⍝ ↑Express C# exceptions as APL+Win exceptions

  ←⎕cse 'LoadAssemblyByName' 'System.Core'
  ←⎕cse 'LoadAssemblyByName' 'System.Data'
  ←⎕cse 'LoadAssemblyByName' 'System.Data.DataSetExtensions'
  ←⎕cse 'LoadAssemblyByName' 'System.Numerics'
  ←⎕cse 'LoadAssemblyByName' 'System.Xml'
  ←⎕cse 'LoadAssemblyByName' 'System.Xml.Linq'
```

```
⍝↑Microsoft .Net assemblies in the GAC
←□cse 'LoadAssembly' 'RDotNet.dll'
←□cse 'LoadAssembly' 'RDotNet.NativeLibrary.dll'
⍝ ↑R.Net assemblies (1.5.10+) required for this project
⍝ ↑ They are assumed to be in the current folder
⍝    Alternatively they could be put into the .Net GAC and loaded with the
□cse 'LoadAssemblyByName' method

←□cse 'ExecStmt' 'using System.Collections.Generic;'
←□cse 'ExecStmt' 'using System.Linq;'
←□cse 'ExecStmt' 'using System.Text;'
←□cse 'ExecStmt' 'using System.IO;'
←□cse 'ExecStmt' 'using System.Data;'
←□cse 'ExecStmt' 'using RDotNet;'
⍝ ↑Establish namespace shortcuts
←□cse 'ExecStmt' 'REngine.SetEnvironmentVariables();'
⍝ ↑Examine Windows registry for the R toolkit
←□cse 'ExecStmt' 'REngine rEng = REngine.GetInstance(); '
```

```
  ⍝ ↑Create an instance of RDOTNET.REngine class called rEng
  ←⎕cse 'ExecStmt' 'rEng.Initialize();'
  ⍝ ↑Initialize the REngine instance
 :ENDIF
:CATCHALL
 ⎕error ('InitREngine failed: ',,⎕dm)
:ENDTRY
```

To close the R.Net engine instance and the CSE instance, the APL+Win ‘CloseREngine’ function is used.

```
CloseREngine
⍝20160419 APLNext LLC
:TRY
 :IF 0<1↑⍴'RNet' ⎕cse 'self'
  ←⎕cse 'ExecStmt' 'rEng.Dispose();'
  ←'RNet' ⎕cse 'Close'
 :ENDIF
:CATCHALL
:ENDTRY
```

Creating, Saving and Displaying an R-plot in APL+Win

This example illustrates saving an R-plot to an image file in the bitmap format and displaying that image on an APL+Win □wi form. Run the APL+Win 'ShowRPlotInAPLWinForm' function to see the results. This function uses the REngine instance to create an R-plot of the Gauss probability density as a bitmap file and uses that bitmap file to display the R-plot image in an APL+Win form.

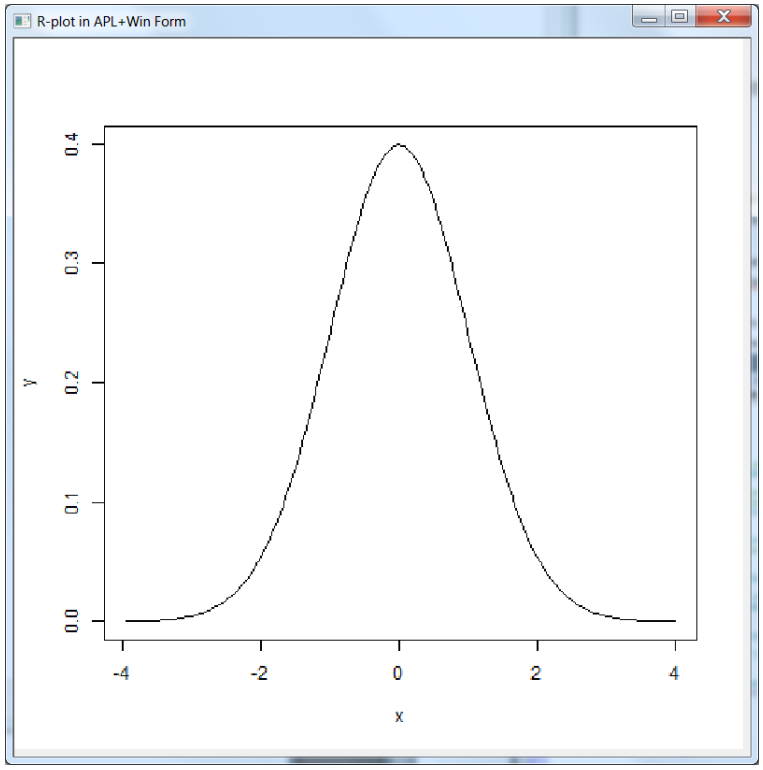
Instead of directly computing the Gauss probability density function for a selection of values and using the R 'plot(,)' function, it would also be possible to use the R-function 'rnorm(#vals, mean, stddev)' to generate samples of a Gauss-distributed random variable and then use the R 'hist()' function to generate a similar chart.

```
ShowRPlotInAPLWinForm;F;P;sink
⍝APLNext 20131229
:TRY *
 sink←⎕cse 'ExecStmt' 'double[] x = new double[200];'
 sink←⎕cse 'SetValue' 'x' (0.04×(⍳200)-100)
 ⍝ ↑Create x-axis elements for the plot using APL+Win
 ⍝ ↑Set the value of the C# variable 'x' from APL+Win
 sink←⎕cse 'ExecStmt' 'rEng.SetSymbol("x", rEng.CreateNumericVector(x));'
 ⍝ ↑Set R symbol "x"

 sink←⎕cse 'ExecStmt' 'rEng.Evaluate(@"y <- 1/sqrt(2*pi)*exp(-x^2/2)");'
 ⍝ ↑Using R, compute the Gauss probability density function for each x-axis
element
 ⍝  and assign the results to y

 sink←⎕cse 'ExecStmt' 'string chartFnm = @"chartFnm.bmp";'
 sink←⎕cse 'ExecStmt' 'File.Delete(chartFnm);'
```

```
 sink←⎕cse                                                    'ExecStmt'
'rEng.SetSymbol("chartFnm",rEng.CreateCharacterVector(new
string[]{chartFnm}));'
 sink←⎕cse 'ExecStmt' 'rEng.Evaluate("bmp(chartFnm)");'
 ⍝ ↑Set the saved chart bitmap destination

 sink←⎕cse 'ExecStmt' 'rEng.Evaluate(@"plot(x,y,type=""l"")");'
 ⍝ ↑Create the line plot using R
 sink←⎕cse 'ExecStmt' 'rEng.Evaluate(@"dev.off()");'
 ⍝ ↑Write the chart to the target bitmap file

 F←'F'⎕wi 'Create' 'Form' ('size' 40 80) ('caption' 'R-plot in APL+Win Form')
 P←'F.P'⎕wi 'Create' 'Picture' ('where' 0 0 40 80) ('imagesize' 38 78) ('style' 4)
 P⎕wi 'bitmap' 'chartFnm.bmp'
 sink←F⎕wi 'Wait'
⍝ ↑Display the chart in a modal APL+Win form

:CATCH
```

```
 'ShowRPlotInAPLWinForm failed: ',,⎕dm

:ENDTRY
```

To keep this example simple, the format of the illustrated plot is elementary. With some study of the R documentation for plotting and graphics much more sophisticated charts can be prepared.



R-Plot illustrating the Central Limit Theorem

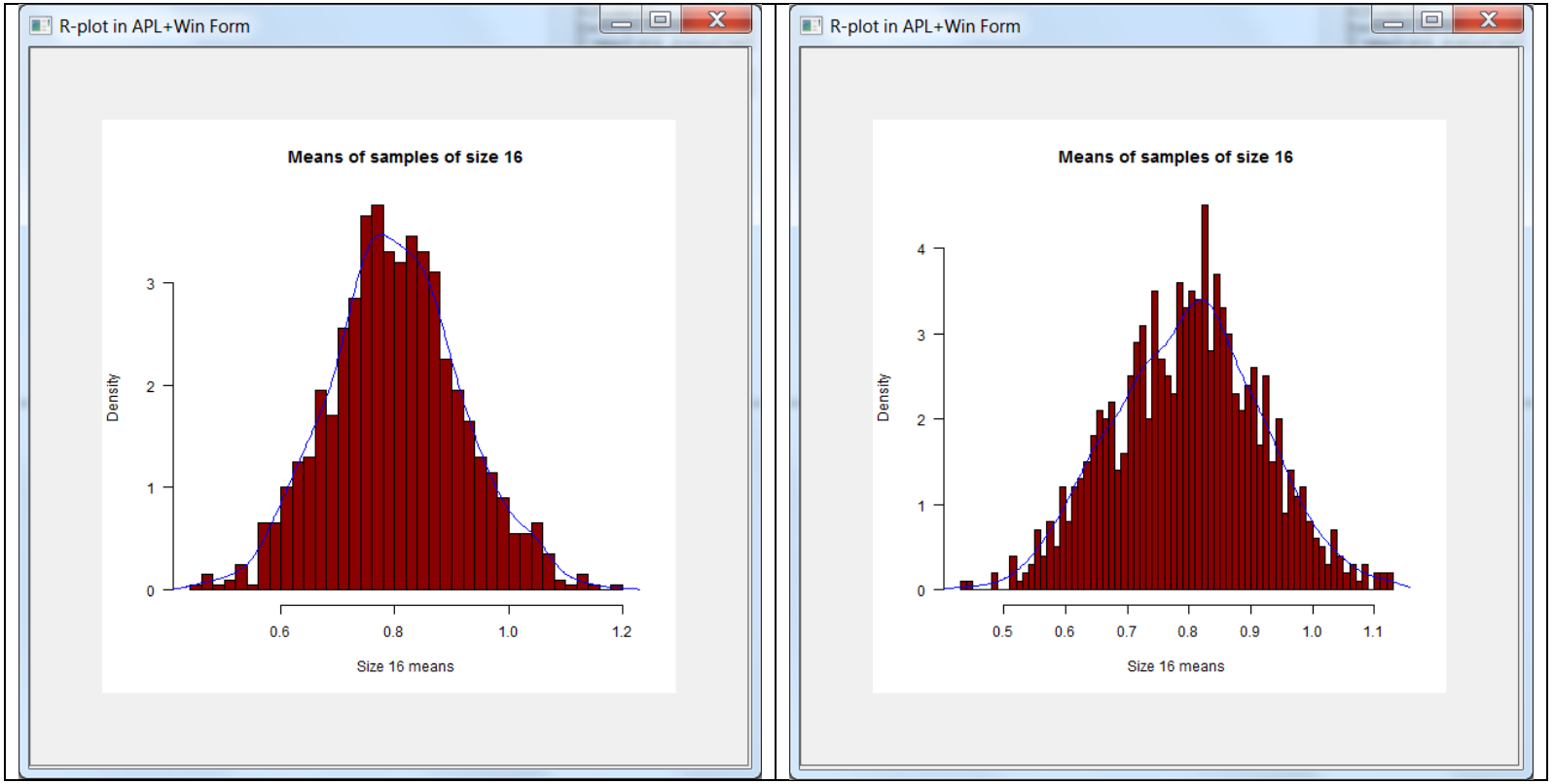
In this example two R-plots are placed in the same chart. The first is a histogram of sample averages and the second is a line chart of the same averages to illustrate the anticipated effect of the Central Limit Theorem.

```
CentralLimitChart;F;P;sink;trialVals
⍝APLNext 20140222
:TRY *
 sink←⎕cse 'ExecStmt' 'string chartFnm = @"chartFnm.bmp";'
 sink←⎕cse 'ExecStmt' 'File.Delete(chartFnm);'
 sink←⎕cse                                                    'ExecStmt'
'rEng.SetSymbol("chartFnm",rEng.CreateCharacterVector(new
string[]{chartFnm}));'
 sink←⎕cse 'ExecStmt' 'rEng.Evaluate("bmp(chartFnm)");'
 ⍝ ↑Set the saved chart bitmap destination

 trialVals←1E¯4×16 1000⍴?¨(×/16 1000)⍴×/16 1000
 ⍝ ↑In a production environment, trialVals would come from a simulation or
other experiment involving trials of a model
 sink←⎕cse 'ExecStmt' 'double[,] trialVals = new double[16,1000];'
 ⍝ ↑Create C# matrix to receive APL+Win values
 sink←⎕cse 'SetValue' 'trialVals' trialVals
```

```
 ⍝ ↑Set C# matrix with the APL+Win values
 sink←⎕cse 'ExecStmt' 'var rmt = rEng.CreateNumericMatrix(trialVals);'
 ⍝ ↑Create an R.Net variable containing the APL+Win values
 sink←⎕cse 'ExecStmt' 'rEng.SetSymbol("rmt",rmt);'
 ⍝ ↑Create a R symbol containing the APL+Win values

 sink←⎕cse 'ExecStmt' 'rEng.Evaluate(@"mns <- cbind(rmt[ 1, ],apply(rmt[ 1:4,
], 2, mean),apply(rmt[ 1:16, ], 2, mean))");'
 ⍝ ↑Compute the means of samples of 1, 4, 16
 sink←⎕cse 'ExecStmt' 'rEng.Evaluate(@"meds <- cbind(rmt[ 1, ],apply(rmt[
1:4, ], 2, median),apply(rmt[ 1:16, ], 2, median))");'
 ⍝ ↑Compute the medians of samples of 1, 4, 16
 sink←⎕cse 'ExecStmt' 'rEng.Evaluate(@"hist(mns[,3], main = ""Means of
samples of size 16"",xlab = ""Size 16 means"", las = 1, col = ""darkred"", breaks
= 50, prob = TRUE)");'
 sink←⎕cse 'ExecStmt' 'rEng.Evaluate(@"lines(density(mns[,3]), col =
""blue"")");'
 ⍝ ↑Define the R-plot type, axis labels, colors, etc.
```

```
 sink←⎕cse 'ExecStmt' 'rEng.Evaluate(@"dev.off()");'
 ⍝ ↑Write the chart to the target bitmap file

 F←'F'⎕wi 'Create' 'Form' ('size' 40 80) ('caption' 'R-plot in APL+Win Form')
 P←'F.P'⎕wi 'Create' 'Picture' ('where' 0 0 40 80) ('size' 30 60) ('style' 0)
 P⎕wi 'bitmap' 'chartFnm.bmp'
 sink←F⎕wi 'Wait'
⍝ ↑Display the chart in a modal APL+Win form

:CATCH
 'CentralLimitChart failed: ',,⎕dm
:ENDTRY
```

When the APL+Win 'CentralLimitChart' function is run, an APL+Win form is displayed containing the JPEG-format image containing the R-plot. Since the 'trial' data used in this example is based on the APL+Win 'deal' function, running this function a few times gives a graphic representation of the APL+Win random number generator results.



R-Plot of Beta Distribution

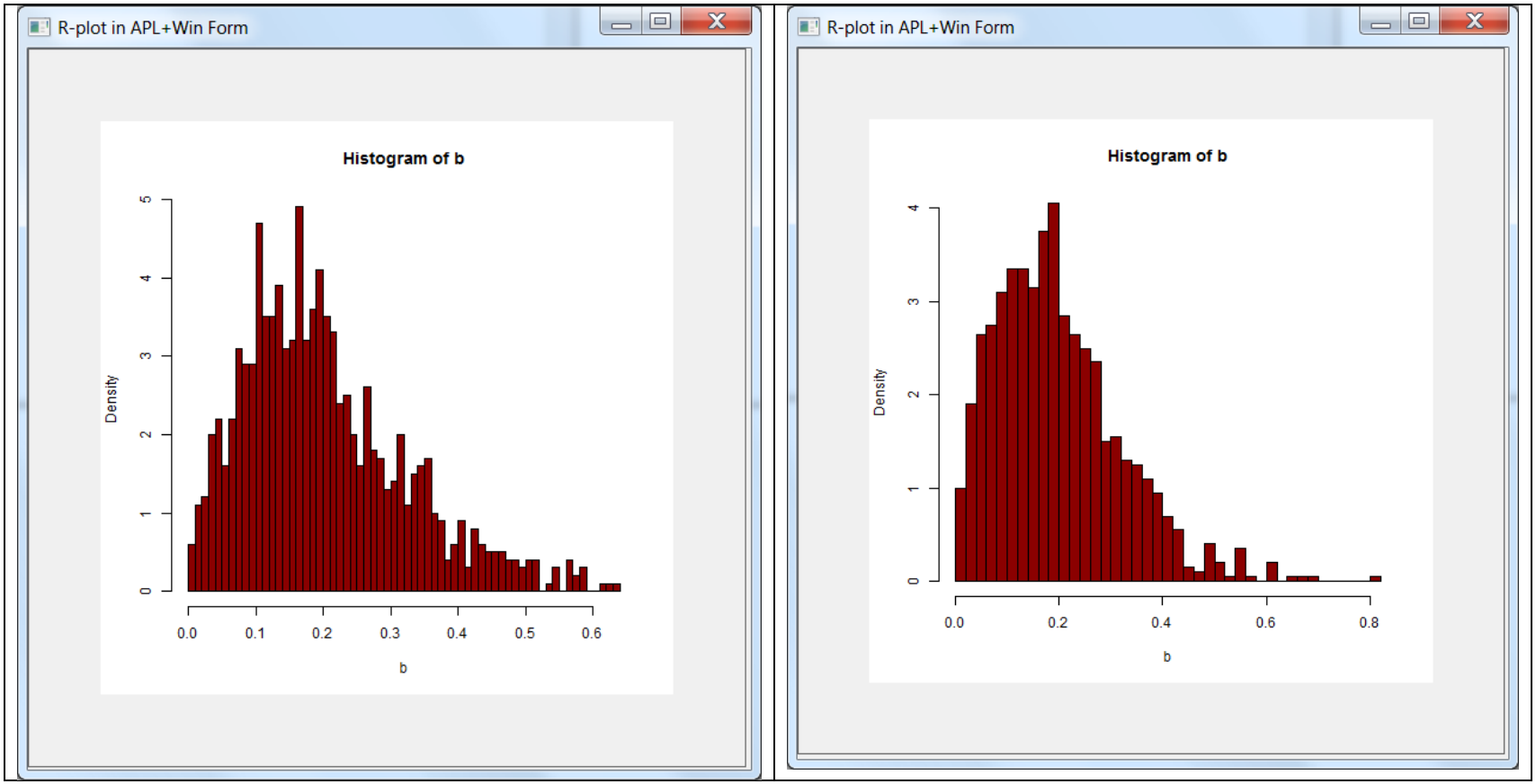
The beta distribution has two parameters α and β which provide flexibility to specify an asymmetrical probability distribution with mean 1+(1/(β/α)). The APL+Win 'BetaDistChart' function has a three element right argument (#values α β). This function uses the R-function 'rbeta(#vals, α, β)' to generate n sample values of a beta-distributed random variable and then plots these values using the R-function 'hist()'.

```
BetaDistChart X;F;P;sink;trialVals;n;a;b
⍝APLNext 20140226
⍝ X[1]: #vals
⍝ X[2]: alpha
⍝ X[3]: beta

(n a b)←X
:TRY *
 sink←⎕cse 'ExecStmt' 'string chartFnm = @"chartFnm.bmp";'
 sink←⎕cse 'ExecStmt' 'File.Delete(chartFnm);'
 sink←⎕cse 'ExecStmt'
'rEng.SetSymbol("chartFnm",rEng.CreateCharacterVector(new
string[]{chartFnm}));'
 sink←⎕cse 'ExecStmt' 'rEng.Evaluate("bmp(chartFnm)");'
 ⍝ ↑Set the saved chart bitmap destination

 sink←⎕cse 'ExecStmt' 'double[] n = new double[1];'
```

```
sink←⎕cse 'SetValue' 'n[0]' n
sink←⎕cse 'ExecStmt' 'rEng.SetSymbol("n",rEng.CreateNumericVector(n));'

sink←⎕cse 'ExecStmt' 'double[] a = new double[1];'
sink←⎕cse 'SetValue' 'a[0]' a
sink←⎕cse 'ExecStmt' 'rEng.SetSymbol("a",rEng.CreateNumericVector(a));'

sink←⎕cse 'ExecStmt' 'double[] b = new double[1];'
sink←⎕cse 'SetValue' 'b[0]' b
sink←⎕cse 'ExecStmt' 'rEng.SetSymbol("b",rEng.CreateNumericVector(b));'



sink←⎕cse 'ExecStmt' 'rEng.Evaluate(@"b <- rbeta(n,a,b)");'
sink←⎕cse 'ExecStmt' 'rEng.Evaluate(@"hist(b, prob = TRUE, breaks=50, col =
""darkred"")");'
⍝ ↑Define the R-plot type, axis labels, colors, etc.

sink←⎕cse 'ExecStmt' 'rEng.Evaluate(@"dev.off()");'
```

```
⍝ ↑Write the chart to the target bitmap file

F←'F'⎕wi 'Create' 'Form' ('size' 40 80) ('caption' 'R-plot in APL+Win Form')
P←'F.P'⎕wi 'Create' 'Picture' ('where' 0 0 40 80) ('size' 30 60) ('style' 0)
P⎕wi 'bitmap' 'chartFnm.bmp'
sink←F⎕wi 'Wait'
⍝ ↑Display the chart in a modal APL+Win form

:CATCH
 'CentralLimitChart failed: ',,⎕dm
:ENDTRY
```

Sample R-plots (mean 0.2) using a right argument of 1000 2 8 for the APL+Win 'BetaDIstChart' function.



Using R for *ad hoc* Calculations in APL+Win

This example illustrates creating an APL+Win GUI form application which requests user input, responds to the user's button click event and uses the R Engine to perform an *ad hoc* calculation. The APL+Win 'UseRToCalculateAdHoc' function defines the APL+Win GUI form with Edit controls for input and output Edit and a Button control, subscribed to the Button click event with the 'UseRToCalculateAdHocEH' function and waits for user input.

```
UseRToCalculateAdHoc;F;LI;EE;EI;BN;LO;EO;sink
⍝APLNext 20131215
:TRY

 F←'F'⎕wi 'Create' 'Form' ('size' 20 80) ('caption' 'Use R for ad hoc calculation')
 LI←'F.LI'⎕wi 'Create' 'Label' ('where' 1 0) ('caption' 'Enter Radius: ')
 EI←'F.EI'⎕wi 'Create' 'Edit' ('where' 1 20 2 20) ('text' '1')
 BN←'F.BN'⎕wi 'Create' 'Button' ('where' 4 2 2 25) ('caption' 'Calculate using
APL+Win and R')
 BN⎕wi 'onClick' 'UseRToCalculateAdHocEH'
 LO←'F.LO'⎕wi 'Create' 'Label' ('where' 8 0) ('caption' 'Area of Circle: ')
 EO←'F.EO'⎕wi 'Create' 'Edit' ('where' 8 20 2 20)
 EE←'F.EE'⎕wi 'Create' 'Edit' ('where' 12 10 5 50) ('style' 4 16)
 sink←F ⎕wi 'Wait'
 ⍝ ↑Define an APL+Win GUI form, set the button click event handler, wait for
user
 sink←F ⎕wi 'Close'
```

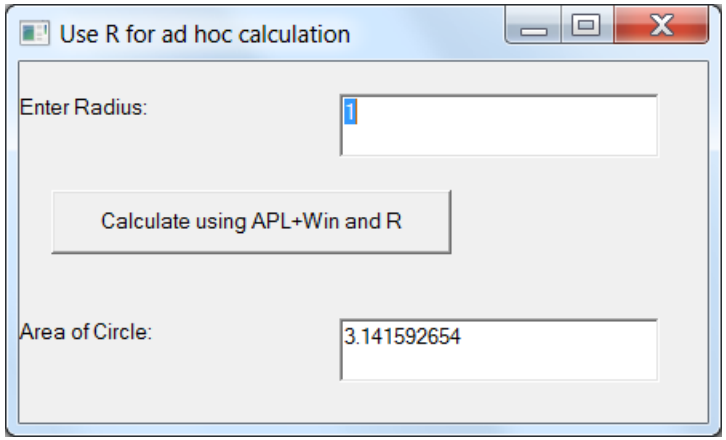
```
:CATCHALL
 'UseRToCalculateAdHoc failed: ',,⎕dm
:ENDTRY
```

The ‘UseRToCalculateAdHocEH’ event handler function obtains the user input, passes it to the R.Net engine instance, requests the calculation from the R Engine, gets the result into APL+Win and displays the result on the APL+Win GUI form.

```
UseRToCalculateAdHocEH;radius;area
⍝APLNext 20131215

:TRY
 'F.BN'⎕wi 'enabled' 0
 ⍝ ↑Disable user input during event handler function execution
 radius←1↑⎕FI 'F.EI'⎕wi 'text'
 ⍝ ↑Get the user input from the APL+WIN form

 sink←⎕cse 'ExecStmt' 'double radius = 0;'
 sink←⎕cse 'SetValue' 'radius' (1⊃radius,0.5)
 ⍝ ↑Set C# input variable from the APL+Win variable coerced to double in
APL+Win
 sink←⎕cse 'ExecStmt' 'rEng.SetSymbol("radius",
rEng.CreateNumericVector(new double[]{radius}));'
 ⍝ ↑Set R symbol "radius"
```

```
 sink←⎕cse 'ExecStmt' 'rEng.Evaluate(@"area <- pi*(radius^2)");'
 ⍝ ↑Using R, compute the area of the circle and assign the value to the R-symbol "area"

 area←⎕cse 'GetValue' 'rEng.GetSymbol("area").AsNumeric().First()'
 ⍝ ↑Get the result from R

 'F.EO'⎕wi 'text' (⍕area)
 ⍝ ↑Display result in APL+Win form

:CATCH
 'F.EE'⎕wi 'text' ('Error: ',,⎕dm)

:FINALLY
 'F.BN'⎕wi 'enabled' 1
:ENDTRY
```

After the ‘UseRToCalclulateAdHoc’ function is run, the user enters a radius value and clicks the ‘Calculate…’ button:



Creating and Executing a user-defined function in R with a scalar argument and result

Sometimes it is convenient to create a user-defined function in R so that it can be executed several times during the APL+Win session.

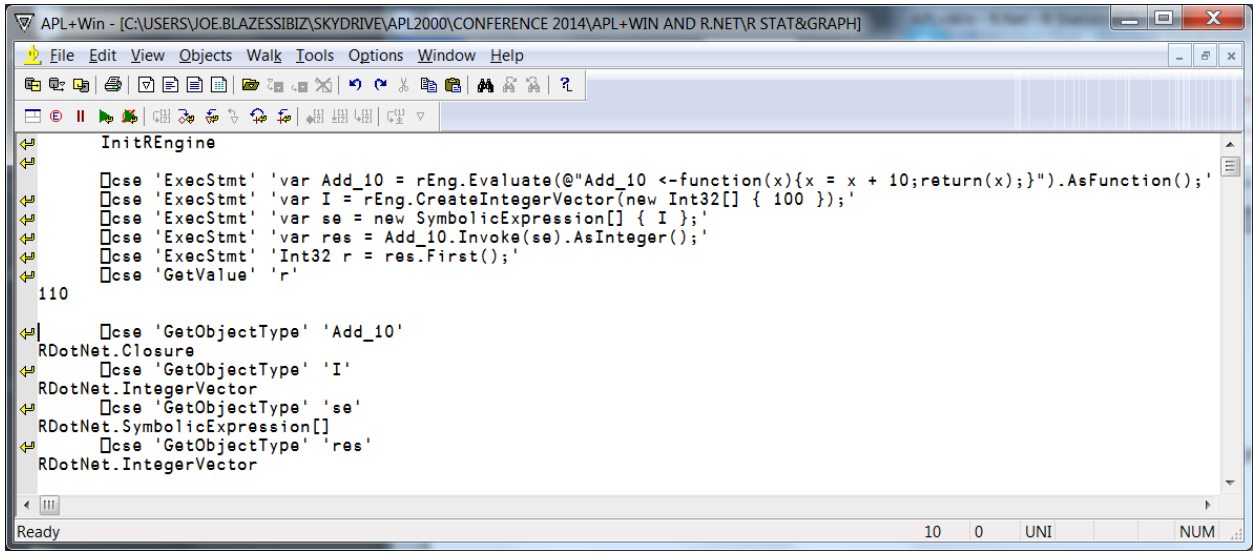
- Use the R.Net engine to evaluate a valid R function definition and cast it as an R.Net ‘Function’
- Create the arguments for the function as an R.Net ‘SymbolicExpression[]’
- Use the R.Net ’Invoke’ method to execute the R.Net function

RUserDefinedFunction

```
cse 'ExecStmt' 'var Add_10 = rEng.Evaluate(@"Add_10 <-function(x){x = x + 10;return(x);}").AsFunction();'

cse 'ExecStmt' 'var I = rEng.CreateIntegerVector(new Int32[] { 100 });'

cse 'ExecStmt' 'var se = new SymbolicExpression[] { I };'

cse 'ExecStmt' 'var res = Add_10.Invoke(se).AsInteger();'

cse 'ExecStmt' 'Int32 r = res.First();'

cse 'GetValue' 'r'

cse 'GetObjectType' 'Add_10'
cse 'GetObjectType' 'I'
```

```
cse 'GetObjectType' 'se'
cse 'GetObjectType' 'res'
```

When the APL+Win ‘RUserDefinedFunction’ function is run the ‘Add_10 (100)’ R-function is executed and the result captured in APL+Win.



Creating an Executing a user-defined function in R with an array argument and result

In this example the user-defined R function will return a vector of values based upon arguments provided by APL+Win. Because the C# 'for{…}' control structure is used, a CSE script is created and run using the CSE 'Exec' method. The R-function 'runif' is used to generate n sample values of the uniform distribution over the interval [min, max].

```
Z←RUserDefinedFunctionArrayResult X;S;N;MI;MX
⍝ N : #Uniform distribution values to return
⍝ MI: Minimum value of the range of uniform distribution values
⍝ MX: Maximum value of the range of uniform distribution values

(N MI MX)←X
X←⍬
⎕cse 'ExecStmt' 'Int32 N;'
⎕cse 'SetValue' 'N' N
⎕cse 'ExecStmt' 'Int32 MI;'
⎕cse 'SetValue' 'MI' MI
⎕cse 'ExecStmt' 'Int32 MX;'
⎕cse 'SetValue' 'MX' MX

S←⊂'var runif = rEng.Evaluate(@"RUNIF<-function(n,mn,mx){res =
runif(n,min=mn,max=mx);return(res);}").AsFunction();'
S←S,⊂'var nArg = rEng.CreateIntegerVector(new Int32[]{N});'
```

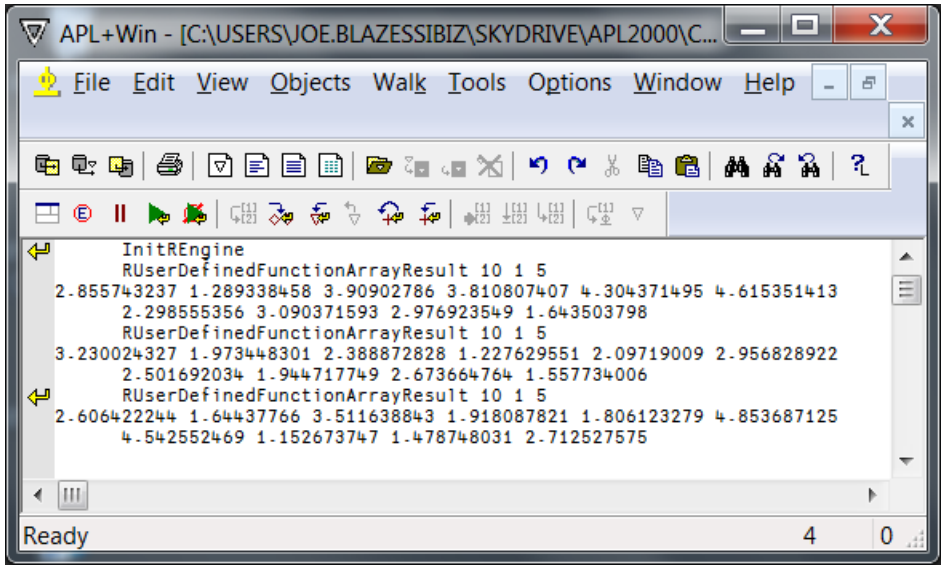
```
S←S,⊂'var mnArg = rEng.CreateIntegerVector(new Int32[]{MI});'
S←S,⊂'var mxArg = rEng.CreateIntegerVector(new Int32[]{MX});'
S←S,⊂'var se = new SymbolicExpression[] { nArg, mnArg, mxArg };'
S←S,⊂'var res = runif.Invoke(se).AsNumeric();'
S←S,⊂'double[] dRes = new double[res.Count()];'
S←S,⊂'for (Int32 I = 0;I<res.Count();I++)'
S←S,⊂'{'
S←S,⊂'  dRes[I] = res[I];'
S←S,⊂'}'

S←⊃S
⎕cse 'Exec' S
Z←⎕cse 'GetValue' 'dRes'
```

Here is the CSE script which this APL+Win function creates:

```
var runif = rEng.Evaluate(@"RUNIF<-function(n,mn,mx){res = runif(n,min=mn,max=mx);return(res);}").AsFunction();
var nArg = rEng.CreateIntegerVector(new Int32[]{N});
```

```
var mnArg = rEng.CreateIntegerVector(new Int32[]{MI});
var mxArg = rEng.CreateIntegerVector(new Int32[]{MX});
var se = new SymbolicExpression[] { nArg, mnArg, mxArg };
var res = runif.Invoke(se).AsNumeric();
double[] dRes = new double[res.Count()];
for (Int32 I = 0;I<res.Count();I++)
{
  dRes[I] = res[I];
}
```

When the APL+Win 'RUserDefinedFunctionArrayResult' function is run three times, 10 pseudo-random values of the uniform distribution over the interval [1, 5] are provided by the R engine for each execution of the function:



Programming Styles using R, R.Net Toolkit and APL+Win

The ensemble of R, the R.Net toolkit and APL+Win supports several programming styles. The R.Net toolkit documentation describes the first three of these programming styles. For simplicity the R cos() trigonometric function used, even though it is available in APL+Win and APL+Win merely displays the values obtained from R. In a production application R functions which are not available or convenient in C# or APL+Win would be used and the results obtained from R would be further manipulated by C# or APL+Win.

In the examples in this section it is important to note the methods by which APL+Win values are assigned to R.Net and R variables and analogously how the values of R.Net and R variables are assigned to APL+Win variables.

R variables are associated with symbols (e.g. text variable names). R variables have simple types analogous to vectors (rank 1) and matrices (rank 2).

The R.Net toolkit for R provides .Net object types such as Function, NumericVector, NumericMatrix (rank 2), CharacterVector, CharacterMatrix (rank 2), which correspond to the R variable types. The R.Net tool kit for R also provides methods to get and set the value of R variables such as CreateNumericVector(double[]), GetSymbol(string).AsNumeric(), SetSymbol(string, NumericVector).

The R.Net object types can be coerced into arrays of .Net value types such as double[], double[,], bool[]. For example the R.Net NumericVector can be converted in C# to a double[] using C# generic extension methods, i.e. NumericVector.ToArray<double>().

The APL+Win □cse system function ‘GetValue’ and ‘SetValue’ methods can be used to get and set the value of .Net variables that have been derived from R.Net variables using APL+Win variable values.

R.Net style #1

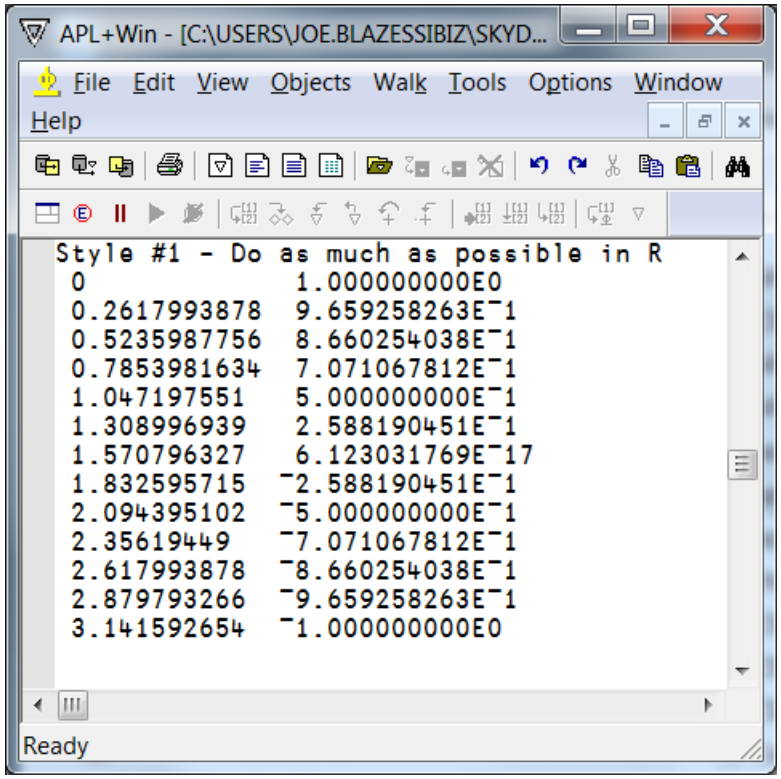
This style uses R expressions to perform calculations and prepare results exclusively in R. The advantage of this style is that R sample code can generally be used directly.

The APL+Win ‘RNetStyle1’ function illustrates this style:

```
RNetStyle1;x;y
⍝APLNext 20131229
:TRY
'Style #1 - Do as much as possible in R'
⎕cse 'ExecStmt' 'rEng.Evaluate(@"x <- (0:12) * pi / 12");'
⍝ ↑Create the R symbol 'x' containing the values at which
⍝  the function will be evaluated

⎕cse 'ExecStmt' 'rEng.Evaluate(@"y <- cos(x)");'
⍝ ↑Evaluate the cos() function at desired values and
⍝  assign the results to the R symbol 'y'

x←⎕cse 'GetValue' 'rEng.Evaluate("x").AsNumeric().ToArray<double>();'
y←⎕cse 'GetValue' 'rEng.Evaluate("y").AsNumeric().ToArray<double>();'
x,[1.5]y
⍝ ↑Get the R-calculated values into APL+Win
```

```
:CATCH
 'RNetStyle1: ',,⎕dm
:ENDTRY
```

When this function is executed, the results are available in APL+Win



R.Net Style #2

This style uses R expressions to perform calculations and prepare results which can only be done in R and otherwise uses C# expressions supported by the R.Net toolkit for R whenever that is more convenient or familiar.

The APL+Win ‘RNetStyle2’ function illustrates this style:

```
RNetStyle2;x;y
⍝APLNext 20131229
:TRY
'Style #2 - Mostly R Expressions, but use C# whenever convenient or familiar'
⎕cse 'ExecStmt' 'var x  = rEng.Evaluate(@"x <- (0:12) * pi / 12").AsNumeric();'
⍝ ↑Create the C# variable x containing the values at which the function will
⍝  be evaluated.  The variable x has R.Net.NumericVector type.

⎕cse 'ExecStmt' 'rEng.SetSymbol("x", x);'
⍝ ↑Set the value of the R symbol "x" from the value of the R.Net C# yariable x

⎕cse 'ExecStmt' 'var y = rEng.Evaluate("cos(x)").AsNumeric();'
⍝ ↑Create the R.Net C# variable 'y' containing the results of the cos() function
⍝  at the desired values.  The variable x has R.Net.NumericVector type.

x←⎕cse 'GetValue' 'x.ToArray<double>();'
y←⎕cse 'GetValue' 'y.ToArray<double>();'
```

```
x,[1.5]y
⍝ ↑Get the R-calculated values into APL+Win

:CATCH
 'RNetStyle2: ',,⎕dm
:ENDTRY
```

When the APL+Win ‘RNetStyle2’ function is executed the same results as the APL+Win ‘RNetStyle1’ function are produced.

R.Net Style #3

This style increases the abstraction of R syntax using more of the R.Net toolkit features. This style has the advantage that the resulting C# methods can be re-used and composed with other methods in the same .Net project. This style also continues to use C# whenever it is more convenient or familiar.

The APL+Win ‘RNetStyle3’ function illustrates this style:

```
RNetStyle3;x;y
⍝APLNext 20131229
:TRY
'Style #3 - C# Abstraction of R syntax using the R.Net toolkit'
⎕cse 'ExecStmt' 'var x = rEng.CreateNumericVector(Enumerable.Range(0, 13).Select(i => i * Math.PI / 12).ToArray());'
⍝ ↑Create the C# variable (R.Net.NumericVector type) x containing the values at which the function will be evaluated.

⎕cse 'ExecStmt' 'var cos = rEng.GetSymbol("cos").AsFunction();'
⍝ ↑Create the C# variable (R.Net.Function type) cos which encapsulates the R cos() function.

⎕cse 'ExecStmt' 'var y = cos.Invoke(new[] { x }).AsNumeric();'
⍝ ↑Create the C# variable (R.Net.NumericVector type) containing the results of the evaluation by using the
⍝  R.Net.Invoke() method on the R.Net.Function variable cos.
```

```
x←⎕cse 'GetValue' 'x.ToArray<double>();'
y←⎕cse 'GetValue' 'y.ToArray<double>();'
x,[1.5]y
⍝ ↑Get the R-calculated values into APL+Win

:CATCH
 'RNetStyle3: ',,⎕dm
:ENDTRY
```

When the APL+Win ‘RNetStyle3’ function is executed the same results as the APL+Win ‘RNetStyle1’ or ‘RNetStyle2’ functions are produced.

R.Net and APL+Win Style #4

This programming style is similar to style #3 except that APL+Win is used whenever it is more convenient or familiar.

The APL+Win ‘RNetAndAPLStyle4’ function illustrates this style:

```
RNetAndAPLStyle4;x;y
⍝APLNext 20131231
⎕io←1
:TRY
'Style #4 - Use APL+Win whenever more convenient or familiar'
⎕cse 'ExecStmt' 'double[] dV;'
x←○(¯1+⍳13)÷12 ⍝Use APL+Win to generate the required values
⎕cse 'SetValue' 'dV' x ⍝Set the C# variable dV using the APL+Win values
⎕cse 'ExecStmt' 'var x = rEng.CreateNumericVector(dV);'
⍝ ↑Create the C# variable (R.Net.NumericVector type) x containing the values at which the function will be evaluated.

⎕cse 'ExecStmt' 'var cos = rEng.GetSymbol("cos").AsFunction();'
⍝ ↑Create the C# variable (R.Net.Function type) cos which encapsulates the R cos() function.

y←⎕cse 'GetValue' 'cos.Invoke(new[] { x }).AsNumeric().ToArray<double>();'
```

```
⍝ ↑Get the R-calculated values into APL+Win using the R.Net.Invoke() method
on the R.Net.Function variable cos.

x,[1.5]y ⍝Display or use the values in APL+Win

:CATCH
 'RNetStyle4: ',,⎕dm
:ENDTRY
```

When this function is executed the same results are obtained as the functions illustrating the other styles.

Utility functions in the APL+Win 'R Stat& Graph.w3' workspace

The APL+Win 'R Stat&Graph.w3' workspace contains the APL+Win 'Plot' function which makes 2-D R-plots easy by separating the generation of values from the mechanics of creating an R-plot.

```
Plot X;xyVals;xLAB;yLAB;mainLAB
⍝ xyVals[;1]: x-axis values
⍝ xyVals[;2]: y-axis values
⍝ xLAB     : text x-axis label
⍝ yLAB     : text y-axis label
⍝ mainLAB  : chart title

(xyVals xLAB yLAB mainLAB)←X
X←⍬
sink←⎕cse 'ExecStmt' 'string chartFnm = @"chartFnm.bmp";'
sink←⎕cse 'ExecStmt' 'File.Delete(chartFnm);'
sink←⎕cse                                          'ExecStmt'
```

```
'rEng.SetSymbol("chartFnm",rEng.CreateCharacterVector(new
string[]{chartFnm}));'
sink←⎕cse 'ExecStmt' 'rEng.Evaluate("bmp(chartFnm)");'
⍝ ↑Set the saved chart bitmap destination

sink←⎕cse 'ExecStmt' 'double[,] xyVals = new double[,]{};'
sink←⎕cse 'SetValue' 'xyVals' xyVals
sink←⎕cse                                                    'ExecStmt'
'rEng.SetSymbol("xyVals",rEng.CreateNumericMatrix(xyVals));'

sink←⎕cse 'ExecStmt' 'string xLAB = "";'
sink←⎕cse 'SetValue' 'xLAB' xLAB
sink←⎕cse                                                    'ExecStmt'
'rEng.SetSymbol("xLAB",rEng.CreateCharacterVector(new string[]{xLAB}));'

sink←⎕cse 'ExecStmt' 'string yLAB = "";'
sink←⎕cse 'SetValue' 'yLAB' yLAB
sink←⎕cse                                                    'ExecStmt'
```

```
'rEng.SetSymbol("yLAB",rEng.CreateCharacterVector(new string[]{yLAB}));'

sink←□cse 'ExecStmt' 'string mainLAB = "";'
sink←□cse 'SetValue' 'mainLAB' mainLAB
sink←□cse                                                    'ExecStmt'
'rEng.SetSymbol("mainLAB",rEng.CreateCharacterVector(new
string[]{mainLAB}));'

sink←□cse  'ExecStmt'  'rEng.Evaluate(@"plot(xyVals[,c(1)],xyVals[,c(2)],  col  =
""darkred"", xlab=xLAB, ylab=yLAB, main=mainLAB)");'
sink←□cse 'ExecStmt' 'rEng.Evaluate(@"dev.off()");'

F←'F'□wi 'Create' 'Form' ('size' 40 80) ('caption' 'R-plot in APL+Win Form')
P←'F.P'□wi 'Create' 'Picture' ('where' 0 0 40 80) ('size' 30 60) ('style' 0)
P□wi 'bitmap' 'chartFnm.bmp'
sink←F□wi 'Wait'
```

The APL+Win ‘Gauss’ and ‘Unif’ functions can be used to generate pseudo-random samples from the normal and uniform probability distributions respectively.

```
Z←Gauss X;n;m;s;sink
⍝ X[1]: #estimates desired
⍝ X[2]: mean of Gauss distribution
⍝ X[3]: standard deviation of Gauss distribution
⍝ Z   : Vector of estimates

(n m s)←X
sink←⎕cse 'ExecStmt' 'double mGauss = 0;'
sink←⎕cse 'SetValue' 'mGauss' m
sink←⎕cse 'ExecStmt'
'rEng.SetSymbol("mGauss",rEng.CreateNumericVector(new
double[]{mGauss}));'

sink←⎕cse 'ExecStmt' 'double sGauss = 0;'
```

```
sink←⎕cse 'SetValue' 'sGauss' s
sink←⎕cse 'ExecStmt'
'rEng.SetSymbol("sGauss",rEng.CreateNumericVector(new double[]{sGauss}));'

sink←⎕cse 'ExecStmt' 'Int32 nGauss = 0;'
sink←⎕cse 'SetValue' 'nGauss' n
sink←⎕cse 'ExecStmt'
'rEng.SetSymbol("nGauss",rEng.CreateIntegerVector(new Int32[]{nGauss}));'

Z←⎕cse 'GetValue'
'rEng.Evaluate("rnorm(nGauss,mGauss,sGauss)").AsNumeric().Take(nGauss).To
Array();'
```

```
Z←Unif X;n;max;min;sink
⍝ X[1]: #estimates desired
⍝ X[2]: minimum value of the range of estimates
⍝ X[3]: maximum value of the range of estimates
⍝ Z   : Vector of estimates

(n min max)←X
sink←⎕cse 'ExecStmt' 'Int32[] nUnif = new Int32[1];'
sink←⎕cse 'SetValue' 'nUnif[0]' n
sink←⎕cse 'ExecStmt'
'rEng.SetSymbol("nUnif",rEng.CreateIntegerVector(nUnif));'

sink←⎕cse 'ExecStmt' 'double[] minUnif = new double[1];'
sink←⎕cse 'SetValue' 'minUnif[0]' min
sink←⎕cse 'ExecStmt'
'rEng.SetSymbol("minUnif",rEng.CreateNumericVector(minUnif));'

sink←⎕cse 'ExecStmt' 'double[] maxUnif = new double[1];'
```

```
sink←□cse 'SetValue' 'maxUnif[0]' max
sink←□cse 'ExecStmt'
'rEng.SetSymbol("maxUnif",rEng.CreateNumericVector(maxUnif));'

Z←□cse 'GetValue' 'rEng.Evaluate("runif(nUnif, min=minUnif, max =
maxUnif)").AsNumeric().Take((Int32)(nUnif[0])).ToArray();'
```

R For Actuaries

A few interesting links about the use of R in actuarial mathematics:

- http://toolkit.pbworks.com/f/R%20Examples%20for%20Actuaries%20v0.1-1.pdf
- http://toolkit.pbworks.com/w/page/22358245/R%20Examples%20For%20Actuaries
- http://www.r-bloggers.com/sampling-for-monte-carlo-simulations-with-r/
- http://www.springer.com/statistics/computational+statistics/book/978-1-4419-1575-7

Resources

- APL2000 Consulting Services
- R-Project.org
- Comprehensive R Archive Network
- R.Net
- R.Net documentation
- Beta distribution in R
- Rclr
- Some examples:
  - http://psychwire.wordpress.com/2011/06/25/importing-and-displaying-a-data-frame-with-c-and-r-net/
  - http://www.codeproject.com/Articles/25819/The-R-Statistical-Language-and-C-NET-Foundations
  - http://msenux.redwoods.edu/math/R/normal.php
  - http://www.ats.ucla.edu/stat/r/library/lecture_graphing_r.htm

- http://rtutorialseries.blogspot.com
- http://www.stat.berkeley.edu/classes/s133/saving.html
- https://github.com/jmp75/rdotnet-onboarding
- http://csg.sph.umich.edu/docs/R/graphics-1.pdf
- Bing or Google: “plotting in R stat”