

NetREXX Programming Guide

RexxLA

Version 3.09-GA of September 30, 2020

THE REXX LANGUAGE ASSOCIATION
NetRexx Programming Series
ISBN 978-90-819090-0-6

Publication Data

©Copyright The Rexx Language Association, 2011- 2020

All original material in this publication is published under the Creative Commons - Share Alike 3.0 License as stated at <http://creativecommons.org/licenses/by-nc-sa/3.0/us/legalcode>.

The responsible publisher of this edition is identified as *IBizz IT Services and Consultancy*, Amsteldijk 14, 1074 HR Amsterdam, a registered company governed by the laws of the Kingdom of The Netherlands.

This edition is registered under ISBN 978-90-819090-0-6

ISBN 978-90-819090-0-6



Contents

The NetREXX Programming Series	i
Typographical conventions	iii
Introduction	iv
1 Meet the REXX Family	1
1.1 Once upon a Virtual Machine	1
1.2 Once upon another Virtual Machine	1
1.3 Features of NetREXX	2
2 Learning to program	3
2.1 Console Based Programs	3
2.2 Comments in programs	5
2.3 Strings	5
2.4 Clauses	6
2.5 When does a Clause End?	6
2.6 Long Lines	7
2.7 Loops	7
2.8 Special Variables	9
3 NetREXX Options	11
4 NetREXX as a Scripting Language	16
5 NetREXX as an Interpreted Language	17
6 NetREXX as a Compiled Language	18
6.1 Programmatic use of the NetREXXC translator	18
6.2 Compiling from memory strings	18
6.3 Compile, load and go	18
6.4 Using the generated classfiles array	19
6.5 JSR199	19

7	Calling non-JVM programs	21
8	Using NetREXX classes from Java	25
9	Classes	26
9.1	Classes	26
9.2	Dependent Classes	27
9.3	Properties	27
10	Using Packages	28
10.1	The package statement	28
10.2	Translator performance consequences	28
10.3	Some NetREXX package history	28
10.4	CLASSPATH	29
11	Programming Patterns	30
11.1	Singleton	30
11.2	Observable and Events	31
11.3	Recursive Parse	31
11.4	More Observer/Observable	31
12	Incorporating Class Libraries	34
12.1	A Word About Java Generics	34
12.2	The Collection Classes	35
13	Input and Output	37
13.1	Improvements in 3.07 to Say and File reading	37
13.2	The File Class	37
14	Algorithms in NetREXX	41
14.1	Factorial	41
14.2	Fibonacci	42
15	Using Parse	44
15.1	Literal Parsing	44
15.2	Positional Parsing	45
15.3	Variable Templates	47
16	Using Trace	48
16.1	Tracing Program Statements	48
16.2	Tracing Variables	49
16.3	Examples	49
16.4	Tracing Notes	52

17	Concurrency	54
17.1	Threads	54
18	User Interfaces	56
18.1	AWT	56
18.2	Web Applets using AWT	56
18.3	Swing	60
18.4	Web Frameworks	60
19	Network Programming	61
19.1	Using Uniform Resource Locators (URL)	61
19.2	TCP/IP Socket I/O	61
19.3	RMI: Remote Method Interface	61
20	Database Connectivity with JDBC	62
21	WebSphere MQ	66
22	MQTT	72
22.1	Pub/Sub with MQ Telemetry	72
23	Component Based Programming: Beans	76
24	Using the NetRexxA API	77
24.1	The NetRexxA constructor	78
24.2	The parse method	78
24.3	The getClassObject method	79
24.4	The exiting method	79
24.5	Interpreting programs contained in memory strings	79
25	Interfacing to Scripting Languages	82
25.1	Which JSR223 engines are on my system?	82
25.2	Selecting an engine	83
25.3	Evaluating a script	83
25.4	Bindings	84
25.5	Interpreted execution of NetREXX scripts from jrunscript	85
25.6	Using JavaScript from NetREXX programs	85
25.7	Using AppleScript on macOS	86
25.8	Execution of NetREXX scripts from ANT tasks	86
25.9	Integration of NetRexx scripting in applications	87
25.10	Interfacing between ooRexx and NetREXX using BSF4ooRexx	87
25.11	General jsr-223 Implementation Notes	88

26 NetREXX Tools	89
26.1 Editor support	89
26.2 Java to Nrx (java2nrx)	90
27 Using Eclipse for NetREXX Development	91
27.1 Downloading Eclipse	91
27.2 Setting up the workspace	91
27.3 Shellshock	92
27.4 Installing Git	92
27.5 Downloading the NetREXX project from the SVN repository	92
27.6 Setting up the builds	92
27.7 Using the NetREXX version of the NetREXX Ant task	93
27.8 Setting up the Eclipse NetREXX Editor Plugin (Optional)	93
28 Platform dependent issues	94
28.1 Mobile Platforms	94
28.2 IBM Mainframe: Using NetREXX programs in z/OS batch	95
29 Building the NetREXX translator	96
29.1 Repository	96
29.2 The buildfile	96
29.3 Testing	97
30 Translator inner workings	98
30.1 Translator source files	98
30.2 Method resolution	101

The NetREXX Programming Series

This book is part of a library, the *NetREXX Programming Series*, documenting the NetREXX programming language and its use and applications. This section lists the other publications in this series, and their roles. These books can be ordered in convenient hardcopy and electronic formats from the Rexx Language Association.

Quick Start Guide	This guide is meant for an audience that has done some programming and wants to start quickly. It starts with a quick tour of the language, and a section on installing the NetREXX translator and how to run it. It also contains help for troubleshooting if anything in the installation does not work as designed, and states current limits and restrictions of the open source reference implementation.
Programming Guide	The Programming Guide is the one manual that at the same time teaches programming, shows lots of examples as they occur in the real world, and explains about the internals of the translator and how to interface with it.
Language Reference	Referred to as the NRL, this is the formal definition for the language, documenting its syntax and semantics, and prescribing minimal functionality for language implementors. It is the definitive answer to any question on the language, and as such, is subject to approval of the NetREXX Architecture Review Board on any release of the language (including its NRL).
Pipelines for NetREXX QuickStart Guide	The Data Flow oriented companion to NetREXX, with its z/VM CMS Pipelines compatible syntax, is documented in this manual. It discusses installing and running Pipes for NetREXX, and has ample examples of defining your own stages in NetREXX.

Typographical conventions

In general, the following conventions have been observed in the NetRexx publications:

- Body text is in this font
- Examples of language statements are in a **bold** type
- Variables or strings as mentioned in source code, or things that appear on the console, are in a typewriter type
- Items that are introduced, or emphasized, are in an *italic* type
- Included program fragments are listed in this fashion:

Listing 1: Example Listing

```
1 -- salute the reader
2 say 'hello reader'
```

- Syntax diagrams take the form of so-called *Railroad Diagrams* to convey structure, mandatory and optional items

???

Introduction

The Programming Guide is the book that has the broadest scope of the publications in the *NetREXX Programming Series*. Where the *Language Reference* and the *Quickstart Guide* need to be limited to a formal description and definition of the NetREXX language for the former, and a Quick Tour and Installation instructions for the latter, this book has no such limitations. It teaches programming, discusses computer language history and comparative linguistics, and shows many examples on how to make NetREXX work with diverse technologies as TCP/IP, Relational Database Management Systems, Messaging and Queuing (MQ™) systems, J2EE Containers as JBOSS™ and IBM WebSphere Application Server™, discusses various rich- and thin client Graphical User Interface Options, and discusses ways to use NetREXX on various operating platforms. For many people, the best way to learn is from examples instead of from specifications. For this reason this book is rich in example code, all of which is part of the NetREXX distribution, and tested and maintained.

Terminology

The *NetREXX Language Reference (NRL)* is the source of the definitive truth about the language. In this *Programming Guide*, terminology is sometimes used more loosely than required for the more formal approach of the NRL. For example, there is a fine line distinguishing *statement*, *instruction* and *clause*, where the latter is a more REXX-like concept that is not often mentioned in relation to other languages (if they are not COBOL or SQL). While we try not to be confusing, *clause* and *statement* will be interchangeably used, as are *instruction* and *keyword instruction*.

Acknowledgements

As this book is a compendium of decades of REXX and NetREXX knowledge, it stands upon the shoulders of many of its predecessors, many of which are not available in print anymore in their original form, or will never be upgraded or actualized; we are indebted to many anonymous¹ authors of IBM product documentation, and many others that we do know, and will thank in the following. If anyone knows of a name not mentioned here that should be, please be in touch. Dave Woodman, thank you for your contributions to this guide. A big IOU goes out to Alan Sampson, who singlehandedly contributed more than one hundred NetREXX programming examples. The Redbook authors (Peter

¹because they are unacknowledged in the original publications

Heuchert, Frederik Haesbrouck, Norio Furukawa, Ueli Wahli, Kris Buelens, Bengt Heijnesson, Dave Jones and Salvador Torres) have provided some important documents that have shown, in an early stage, how almost everything on the JVM is better and easier done in NetRexx. Kermit Kiser also provided examples and did maintenance on the translator. Bill Finlason provided the Eclipse instructions. If anyone feels their copyright is violated, please do let us know, so we can properly attribute offending passages, or take them out.²

²As the usage of all material in this publication is quoted for educational use, and consists of short fragments, a fair use clause will apply in most jurisdictions.

Meet the REXX Family

1.1 Once upon a Virtual Machine

On the 22nd of March 1979, to be precise, Mike Cowlshaw of IBM had a vision of an easier to use command processor for VM, and wrote down a specification over the following days. VM[™] (now called z/VM) is the original Virtual Machine operating system, stemming from an era in which time sharing was acknowledged to be the wave of the future and when systems as CTSS (on the IBM 704) and TSS (on the IBM 360 Family of computers) were early timesharing systems, that offered the user an illusion of having a large machine for their exclusive use, but fell short of virtualising the entire hardware. The CP/CMS system changed this; CP virtualised the hardware completely and CMS was the OS running on CP. CMS knew a succession of command interpreters, called EXEC, EXEC2 and REXX[™] (originally REX - until it was found out, by the IBM legal department, that a product of another vendor had a similar name) - the EXEC roots are the explanation why some people refer to a NetREXX program as an “exec”. As a prime example of a *backronym*, REXX stands for “Restructured Extended Executor”. It can be defended that REXX came to be as a reaction on EXEC2, but it must be noted that both command interpreters shipped around the same time. From 1988 on REXX was available on MVS/TSO and other systems, like DOS, Amiga and various Unix systems. REXX was branded the official SAA procedures language and was implemented on all IBM's Operating Systems; most people got to know REXX on OS/2. In the late eighties the Object-Oriented successor of REXX, Object REXX, was designed by Simon Nash and his colleagues in the IBM Winchester laboratory. REXX was thereafter known as Classic REXX. Several open source versions of Classic REXX were made over the years, of which Regina is a good example.

1.2 Once upon another Virtual Machine

In 1995 Mike Cowlshaw ported Java[™] to OS/2[™] and soon after started with an experiment to run REXX on the JVM[™]. With REXX generally considered the first of the general purpose scripting languages, NetREXX[™] is the first alternative language for the JVM. The 0.50 release, from April 1996, contained the NetREXX runtime classes and a translator written in REXX but tokenized and turned into an OS/2 executable. The 1.00 release came available in January 1997 and contained a translator bootstrapped to NetREXX. The REXX string type that can also handle unlimited precision numerics is called REXX in Java and NetREXX. Where Classic REXX was positioned as a system *glue* language and application macro language, NetREXX is seen as the one language that does it all, delivering system level programs or large applications.

Release 2.00 became available in August 2000 and was a major upgrade, in which interpreted execution was added. Until that release, NetREXX only knew *ahead of time* compilation (AOT).

Mike Cowlshaw took early retirement from IBM in March 2010. IBM announced the transfer of NetREXX source code to the REXX Language Association (RexxLA) on June 8, 2011, 14 years after the v1.0 release, and on the same day, it released the NetREXX source code to RexxLA under the ICU open source license. RexxLA shortly after released this as NetREXX 3.00 and has followed with updates.

1.3 Features of NetREXX

Ease of use The NetREXX language is easy to read and write because many instructions are meaningful English words. Unlike some lower level programming languages that use abbreviations, NetREXX instructions are common words, such as **say**, **ask**, **if...then...else**, **do...end**, and **exit**.

Free format There are few rules about NetREXX format. You need not start an instruction in a particular column, you can also skip spaces in a line or skip entire lines, you can have an instruction span many lines or have multiple instructions on one line, variables do not need to be pre-defined, and you can type instructions in upper, lower, or mixed case.

Convenient built-in functions NetREXX supplies built-in functions that perform various processing, searching, and comparison operations for both text and numbers. Other built-in functions provide formatting capabilities and arithmetic calculations.

Easy to debug When a NetREXX exec contains an error, messages with meaningful explanations are displayed on the screen. In addition, the **trace** instruction provides a powerful debugging tool.

Interpreted The NetREXX language is an interpreted language. When a NetREXX exec runs, the language processor directly interprets each language statement, or translates the program in JVM bytecode.

Extensive parsing capabilities NetREXX includes extensive parsing capabilities for character manipulation. This parsing capability allows you to set up a pattern to separate characters, numbers, and mixed input.

Seamless use of JVM Class Libraries NetREXX can use any class, and class library for the JVM (written in Java or other JVM languages) in a seamless manner, that is, without the need for extra declarations or definitions in the source code.

Learning to program

2.1 Console Based Programs

One way that a computer can communicate with a user is to ask questions and then compute results based on the answers typed in. In other words, the user has a conversation with the computer. You can easily write a list of NetREXX instructions that will conduct a conversation. We call such a list of instructions a program. The following listing shows a sample NetREXX program. The sample program asks the user to give his name, and then responds to him by name. For instance, if the user types in the name Joe, the reply Hello Joe is displayed. Or else, if the user does not type anything in, the reply Hello stranger is displayed. First, we shall discuss how it works; then you can try it out for yourself.

Listing 2.1: Hello Stranger

```
1 /* A conversation */
2 say "Hello! What's your name?"
3 who=ask
4 if who = '' then say "Hello stranger"
5 else say "Hello" who
```

Briefly, the various pieces of the sample program are:

/* ... */ A comment explaining what the program is about. Where REXX programs on several platforms must start with a comment, this is not a hard requirement for NetREXX anymore. Still, it is a good idea to start every program with a comment that explains what it does.

say An instruction to display Hello! What's your name? on the screen.

ask An instruction to read the response entered from the keyboard and put it into the computer's memory.

who The name given to the place in memory where the user's response is put.

if An instruction that asks a question.

who = '' A test to determine if who is empty.

then A direction to execute the instruction that follows, if the tested condition is true.

say An instruction to display Hello stranger on the screen.

else An alternative direction to execute the instruction that follows, if the tested condition is not true. Note that in NetREXX, else needs to be on a separate line.

say An instruction to display Hello, followed by whatever is in who on the screen.

The text of your program should be stored on a disk that you have access to with the help of an *editor* program. On Windows, notepad or (notepad++), jEdit, X2 or SlickEdit are suitable candidates. On Unix based systems, including macOS, vim or emacs are

plausible editors. If you are on z/VM or z/OS, XEDIT or ISPF/PDF are a given. More about editing NetRexx code in chapter 26.1, *Editor Support*, on page 89.

When the text of the program is stored in a file, let's say we called it `hello.nrx`, and you installed NetRexx as indicated in the *NetRexx QuickStart Guide*, we can run it with

```
nrc -exec hello
```

and this will yield the result:

```
NetRexx portable processor, version NetRexx after3.01, build 1-20120406-1326
Copyright (c) RexxLA, 2011. All rights reserved.
Parts Copyright (c) IBM Corporation, 1995,2008.
Program hello.nrx
===== Exec: hello =====
Hello! What's your name?
```

If you do not want to see the version and copyright message every time, which would be understandable, then start the program with:

```
nrc -exec -nologo hello
```

This is what happened when Fred tried it.

```
Program hello.nrx
===== Exec: hello =====
Hello! What's your name?
Fred
Hello Fred
```

The **ask** instruction paused, waiting for a reply. Fred typed Fred on the command line and, when he pressed the ENTER key, the **ask** instruction put the word Fred into the place in the computer's memory called "who". The **if** instruction asked, is "who" equal to nothing:

```
who = ''
```

meaning, is the value of "who" (in this case, Fred) equal to nothing:

```
"Fred = ''
```

This was not true; so, the instruction after then was not executed; but the instruction after else, was.

But when Mike tried it, this happened:

```
Program hello.nrx
===== Exec: hello =====
Hello! What's your name?

Hello stranger
Processing of 'hello.nrx' complete
```

Mike did not understand that he had to type in his name. Perhaps the program should have made it clearer to him. Anyhow, he just pressed ENTER. The **ask** instruction put

” (nothing) into the place in the computer’s memory called “who”. The **if** instruction asked, is:

```
who = ''
```

meaning, is the value of “who” equal to nothing:

```
'' = ''
```

In this case, it was true. So, the instruction after **then** was executed; but the instruction after **else** was not.

2.2 Comments in programs

When you write a program, remember that you will almost certainly want to read it over later (before improving it, for example). Other readers of your program also need to know what the program is for, what kind of input it can handle, what kind of output it produces, and so on. You may also want to write remarks about individual instructions themselves. All these things, words that are to be read by humans but are not to be interpreted, are called comments. To indicate which things are comments, use:

```
/* to mark the start of a comment
*/ to mark the end of a comment.
```

The `/*` causes the translator to stop compiling and interpreting; this starts again only after a `*/` is found, which may be a few words or several lines later. For example,

```
/* This is a comment. */
say text /* This is on the same line as the instruction */
/* Comments may occupy more
than one line. */
```

NetREXX also has line mode comments - those turn a line at a time into a comment. They are composed of two dashes (hyphens, in listings sometimes fused to a typographical *em dash* - remember that in reality they are two *n dashes*).

```
-- this is a line comment
```

2.3 Strings

When the translator sees a quote (either `”` or `'`) it stops interpreting or compiling and just goes along looking for the matching quote. The string of characters inside the quotes is used just as it is. Examples of strings are:

```
'Hello'
"Final result: "
```

If you want to use a quotation mark within a string you should use quotation marks of the other kind to delimit the whole string.

```
"Don't panic"  
'He said, "Bother"'
```

There is another way. Within a string, a pair of quotes (of the same kind as was used to delimit the string) is interpreted as one of that kind.

```
'Don''t panic' (same as "Don't panic" )  
"He said, ""Bother"" (same as 'He said, "Bother"')
```

2.4 Clauses

Your NetREXX program consists of a number of *clauses*. A clause can be:

1. A *keyword instruction* that tells the interpreter to do something; for example,

```
say "the word"
```

In this case, the interpreter will display the word on the user's screen.

2. An *assignment*; for example,

```
Message = 'Take care!'
```

3. A *null clause*, such as a completely blank line, or

```
;
```

4. A *method call instruction* which invokes a *method* from a *class*

```
'hiawatha'.left(2)
```

2.5 When does a Clause End?

It is sometimes useful to be able to write more than one clause on a line, or to extend a clause over many lines. The rules are:

- Usually, each clause occupies one line.
- If you want to put more than one clause on a line you must use a semicolon (;) to separate the clauses.
- If you want a clause to span more than one line you must put a dash (hyphen) at the end of the line to indicate that the clause continues on the next line. If a line does not end in a dash, a semicolon is implied.

What will you see on the screen when this exec is run?

Listing 2.2: RAH Exec

```
1 /* Example: there are six clauses in this program */ say "Everybody cheer!"  
2 say "2"; say "4" ; say "6" ; say "8" ; say "Who do we" -  
3 "appreciate?"
```

2.6 Long Lines

Ever since the days of the punch card images are over, the lines in program sources have become longer and longer, and with NetRexx being a free format language, there is no real technical reason to limit line length. Still, for readability and for ease access to words within a line, it is often indicated to keep lines relatively short and tidy. For this reason, the *continuation character* '-' can be used. This also makes it possible to split long literal strings over lines.

Listing 2.3: Long lines

```
1 say 'good' -  
2 'night'
```

This example will concatenate 'good' and 'night' with a space inbetween. When you want to avoid that, use the '||' concatenation operator.

Listing 2.4: Long lines with string concatenation without space

```
1 say 'good' -  
2 || 'night'
```

2.7 Loops

We can go on and write clause after clause in a program source files, but some repetitive actions in which only a small change occurs, are better handled by the **loop** statement.

Imagine an assignment to neatly print out a table of exchange rates for dollars and euros for reference in a shop. We could of course make the following program:

Listing 2.5: Without a loop

```
1 say 1 'euro equals' 1 * 2.34 'dollars'  
2 say 2 'euro equals' 2 * 2.34 'dollars'  
3 say 3 'euro equals' 3 * 2.34 'dollars'  
4 say 4 'euro equals' 4 * 2.34 'dollars'  
5 say 5 'euro equals' 5 * 2.34 'dollars'  
6 say 6 'euro equals' 6 * 2.34 'dollars'  
7 say 7 'euro equals' 7 * 2.34 'dollars'  
8 say 8 'euro equals' 8 * 2.34 'dollars'  
9 say 9 'euro equals' 9 * 2.34 'dollars'  
10 say 10 'euro equals' 10 * 2.34 'dollars'
```

This is valid, but imagine the alarming thought that the list is deemed a success and you are tasked with making a new one, but now with values up to 100. That will be a lot of typing.

The way to do this is using the **loop**³ statement.

Listing 2.6: With a loop

```
1 loop i=1 to 100  
2 say i 'euro equals' i * 2.34 'dollars'  
3 end
```

³Note that Classic Rexx uses **do** for this purpose. In recent Open Object Rexx versions **loop** can also be used.

Now the *loop index variable* `i` varies from 1 to 100, and the statements between `loop` and `end` are repeated, giving the same list, but now from 1 to 100 dollars.

We can do more with the **loop** statement, it is extremely flexible. The following diagram is a (simplified, because here we left out the *catch* and *finally* options) rundown of the ways we can loop in a program.

FIGURE 1: Loop

???

A few examples of what we can do with this:

- Looping forever - better put, without deciding beforehand how many times

Listing 2.7: Loop Forever

```
1 loop forever
2   say 'another bonbon?'
3   x = ask
4   if x = 'enough already' then leave
5 end
```

The `leave` statement breaks the program out of the loop. This seems futile, but in the chapter about I/O we will see how useful this is when reading files, of which we generally do not know in advance how many lines we will read in the loop.

- Looping for a fixed number of times without needing a loop index variable

Listing 2.8: Loop for a fixed number of times without loop index variable

```
1 loop for 10
2   in.read() /* skip 10 lines from the input file */
3 end
```

- Looping back into the value of the loop index variable

Listing 2.9: Loop Forever

```
1 loop i = 100 to 90 by -2
2   say i
3 end
```

This yields the following output:

```
===== Exec: test =====
100
98
96
94
92
90
Processing of 'test.nrx' complete
```

2.8 Special Variables

We have seen that a *variable* is a place where some data, be it character data or numerical data, can be held. There are some special variables, as shown in the following program.

Listing 2.10: NetREXX Special Variables

```
1  /* NetRExx */
2  options replace format comments java symbols binary
3
4  class RCSpecialVariables
5
6  method RCSpecialVariables()
7    x = super.toString
8    y = this.toString
9    say '<super>'x'</super>'
10   say '<this>'y'</this>'
11   say '<class>'RCSpecialVariables.class'</class>'
12   say '<digits>'digits'</digits>'
13   say '<form>'form'</form>'
14   say '<[1, 2, 3].length>'
15   say [1, 2, 3].length
16   say '</[1, 2, 3].length>'
17   say '<null>'
18   say null
19   say '</null>'
20   say '<source>'source'</source>'
21   say '<sourceline>'sourceline'</sourceline>'
22   say '<trace>'trace'</trace>'
23   say '<version>'version'</version>'
24
25   say 'Type an answer:'
26   say '<ask>'ask'</ask>'
27
28   return
29
30 method main(args = String[]) public static
31
32   RCSpecialVariables()
33
34   return
```

this The special variables **this** and **super** refer to the current instance of the class and its superclass - what this means will be explained in detail in the chapter **Classes** on page 26, as is the case with the **class** variable.

digits The special variable **digits** shows the current setting for the number of decimal digits - the current setting of **numeric digits**. The related variable **form** returns the current setting of **numeric form** which is either scientific or engineering.

null The special variable **null** denotes the *empty reference*. It is there when a variable has no value.

source The **source** and **sourceline** variables are a good way to show the sourcefile and sourceline of a program, for example in an error message.

trace The **trace** variable returns the current trace setting, which can be one of the words `off` `var` `methods` `all` `results`.

version The **version** variable returns the version of the NetREXX translator that was in use at the time the clause we processed; in case of interpreted execution (see chapter 5 on 17, it returns the level of the current translator in use.

The result of executing this exec is as follows:

```
===== Exec: RCSpecialVariables =====
```

```

<super>RCSpecialVariables@4e99353f</super>
<this>RCSpecialVariables@4e99353f</this>
<class>class RCSpecialVariables</class>
<digits>9</digits>
<form>scientific</form>
<[1, 2, 3].length>
3
</[1, 2, 3].length>
<null>

</null>
<source>Java method RCSpecialVariables.nrx</source>
<sourceline>21</sourceline>
<trace>off</trace>
<version>NetRexx 3.02 27 Oct 2011</version>
Type an answer:
hello fifi
<ask>hello fifi</ask>

```

It might be useful to note here that these special variables are not fixed in the sense of that they are not *Reserved Variables*. NetREXX does not have reserved variables and any of these special variables can be used as an ordinary variable. However, when it is used as an ordinary variable, there is no way to retrieve the special behavior.

NetRexx Options

There are a number of options for the translator, some of which can be specified on the translator command line, and others also in the program source on the **option** statement. In the following table, c stands for *commandline only*, and b stands for *both source and commandline*. On the commandline, options are prefixed with a *dash* (“-”), while in programsource they are not - there they are preceded by the `option` statement.

TABLE 1: Options

Option	Meaning	Place
arg words	interpret; remaining words are arguments	c
binary	classes are binary classes	b
classpath	specify a classpath	c
compile	compile (default; -nocompile implies -keep)	c
comments	copy comments across to generated .java	b
compact	display error messages in compact form	b
console	display messages on console (default)	c
crossref	generate cross-reference listing	b
decimal	allow implicit decimal arithmetic	b
diag	show diagnostic messages	b
ecj	prefer the ecj compiler	c
exec	interpret with no argument words	c
explicit	local variables must be explicitly declared	b
format	format output file (pretty-print)	b
java	generate Java source code for this program	b
javac	prefer the javac compiler	c
keep	keep any completed .java file (as xxx.java.keep)	c
keepasjava	keep any completed .java file (as xxx.java)	c
logo	display logo (banner) after starting	b
prompt	prompt for new request after processing	c
savelog	save messages in NetRexxC.log	c
replace	replace .java file even if it exists	b
sourcedir	force output files to source directory	b
strictargs	empty argument lists must be specified as ()	b
strictassign	assignment must be cost-free	b
strictcase	names must match in case	b
strictimport	all imports must be explicit	b

Continued on next page

Table 1 – *continued from previous page*

strictmethods	superclass methods are not compared to local methods for best match	b
strictprops	even local properties must be qualified	b
strictsignal	signals list must be explicit	b
symbols	include symbols table in generated .class files	b
time	display timings	c
trace[n]	trace stream [1 or 2], or 0 for NOTRACE	b
utf8	source file is in UTF8 encoding	b
verbose[n]	verbosity of progress reports [0-5]	b
warnexit0	exit with a zero returncode on warnings	c

Options valid for the options statement and on the commandline

These are the options that can be used on the **options** statement:

binary All classes in this program will be binary classes. In binary classes, literals are assigned binary (primitive) or native string types, rather than NetREXX types, and native binary operations are used to implement operators where appropriate, as described in “Binary values and operations”. In classes that are not binary, terms in expressions are converted to the NetREXX string type, REXX, before use by operators.

comments Comments from the NetREXX source program will be passed through to the Java output file (which may be saved with a .java.keep or .java extension by using the -keep and -keepasjava command options, respectively).

compact Requests that warnings and error messages be displayed in compact form. This format is more easily parsed than the default format, and is intended for use by editing environments. Each error message is presented as a single line, prefixed with the error token identification enclosed in square brackets. The error token identification comprises three words, with one blank separating the words. The words are: the source file specification, the line number of the error token, the column in which it starts, and its length. For example (all on one line):

```
[D:\test\test.nrx 3 8 5] Error: The external name
'class' is a Java reserved word, so would not be
usable from Java programs
```

Any blanks in the file specification are replaced by a null ('\0') character. Additional words could be added to the error token identification later.

crossref Requests that cross-reference listings of variables be prepared, by class.

decimal Decimal arithmetic may be used in the program. If nodecimal is specified, the language processor will report operations that use (or, like normal string comparison, might use) decimal arithmetic as an error. This option is intended for performance-critical programs where the overhead of inadvertent use of decimal arithmetic is unacceptable.

diag Requests that diagnostic information (for experimental use only) be displayed. The diag option word may also have side-effects.

- explicit** Requires that all local variables must be explicitly declared (by assigning them a type but no value) before assigning any value to them. This option is intended to permit the enforcement of “house styles” (but note that the NetREXX compiler always checks for variables which are referenced before their first assignment, and warns of variables which are set but not used).
- format** Requests that the translator output file (Java source code) be formatted for improved readability. Note that if this option is in effect, line numbers from the input file will not be preserved (so run-time errors and exception trace-backs may show incorrect line numbers).
- java** Requests that Java source code be produced by the translator. If `nojava` is specified, no Java source code will be produced; this can be used to save a little time when checking of a program is required without any compilation or Java code resulting.
- logo** Requests that the language processor display an introductory logotype sequence (name and version of the compiler or interpreter, etc.).
- sourcedir** Requests that all .class files be placed in the same directory as the source file from which they are compiled. Other output files are already placed in that directory. Note that using this option will prevent the `-run` command option from working unless the source directory is the current directory.
- strictargs** Requires that method invocations always specify parentheses, even when no arguments are supplied. Also, if `strictargs` is in effect, method arguments are checked for usage – a warning is given if no reference to the argument is made in the method.
- strictassign** Requires that only exact type matches be allowed in assignments (this is stronger than Java requirements). This also applies to the matching of arguments in method calls.
- strictcase** Requires that local and external name comparisons for variables, properties, methods, classes, and special words match in case (that is, names must be identical to match).
- strictimport** Requires that all imported packages and classes be imported explicitly using `import` instructions. That is, if in effect, there will be no automatic imports, except those related to the `package` instruction.
- strictmethods** Superclass methods are not compared to local methods for best match.
- strictprops** Requires that all properties, including those local to the current class, be qualified in references. That is, if in effect, local properties cannot appear as simple names but must be qualified by `this`. (or equivalent) or the class name (for static properties).
- strictsignal** Requires that all checked exceptions signalled within a method but not caught by a `catch` clause be listed in the `signals` phrase of the method instruction.
- symbols** Symbol table information (names of local variables, etc.) will be included in any generated .class file. This option is provided to aid the production of classes that are easy to analyse with tools that can understand the symbol table information. The use of this option increases the size of .class files.
- trace, traceX** If given as `-trace`, `-trace1`, or `-trace2`, then trace instructions are accepted. The trace output is directed according to the option word: `-trace1` requests that trace output is written to the standard output stream, `-trace` or `-trace2` imply that the output should be written to the standard error stream (the default).

utf8 If given, clauses following the options instruction are expected to be encoded using UTF-8, so all Unicode characters may be used in the source of the program. In UTF-8 encoding, Unicode characters less than `'\u0080'` are represented using one byte (whose most-significant bit is 0), characters in the range `'\u0080'` through `'\u07FF'` are encoded as two bytes, in the sequence of bits:

110xxxxx 10xxxxxx

where the eleven digits shown as x are the least significant eleven bits of the character, and characters in the range `'\u0800'` through `'\uFFFF'` are encoded as three bytes, in the sequence of bits:

1110xxxx 10xxxxxx 10xxxxxx

where the sixteen digits shown as x are the sixteen bits of the character. If `noutf8` is given, following clauses are assumed to comprise only Unicode characters in the range `'\x00'` through `'\xFF'`, with the more significant byte of the encoding of each character being 0. Note: this option only has an effect as a compiler option, and applies to all programs being compiled. If present on an options instruction, it is checked and must match the compiler option (this allows processing with or without utf8 to be enforced).

verbose, **verboseX** Sets the “noisiness” of the language processor. The digit X may be any of the digits 0 through 5; if omitted, a value of 3 is used. The options **-noverbose** and **verbose0** both suppress all messages except errors and warnings

Options valid on the commandline

The translator also implements some additional option words, which control compilation features. These cannot be used on the **options** instruction⁴, and are:

arg The **-arg words** option is used when interpreting programs, it indicates that after the **-arg** statement, commandline arguments for their interpreted program follow

classpath The **-classpath** option allows dynamic specification of the classpath used by the NetREXXC compiler without having to depend on the CLASSPATH environment variable. (since: NetREXX 3.02) .

exec The **-exec words** option is used when interpreting programs. With this option, no commandline arguments are possible.

ecj prefer the ecj compiler when available

keep keep the intermediate *.java* file for each program. It is kept in the same directory as the NetREXX source file as *xxx.java.keep*, where *xxx* is the source file name. The file will also be kept automatically if the *javac* compilation fails for any reason.

javac prefer the javac compiler when available

keepasjava keep the intermediate *.java* file for each program. It is kept in the same directory as the NetREXX source file as *xxx.java*, where *xxx* is the source file name. Implies **-replace**. Note: use this option carefully in mixed-source projects where you might have *.java* source files around.

nocompile do not compile (just translate). Use this option when you want to use a different Java compiler. The *.java* file for each program is kept in the same directory

⁴Although at the moment, there will be no indication of this

as the NetREXX source file, as the file *xxx.java.keep* (where *xxx* is the source file name).

noconsole do not display compiler messages on the console (command display screen). This is usually used with the *savelog* option.

savelog write compiler messages to the file *NetREXXC.log*, in the current directory. This is often used with the *noconsole* option.

time display translation, *javac* or *ecj* compile, and total times (for the sum of all programs processed).

run run the resulting Java class as a stand-alone application, provided that the compilation had no errors.

warnexit0 Exit the translator with returncode 0 even if warnings are issued. Useful with build tools that would otherwise exit a build.

NetREXX as a Scripting Language

The term *scripting* is used here in the sense of using the programming language for quickly composed programs that interact with some application or environment to perform a number of simple tasks.

You can use NetREXX as a simple scripting language without having knowledge of, or using any of the features that is needed in a Java program that runs on the JVM - like defining a class name, and having a `main` method that is static and expects an array of `String` as its input.

Scripts can be written very fast. There is no overhead, such as defining a class, constructors and methods, and the programs contain only the necessary instructions. In this sense, a NetREXX script looks like an oo-version of a classic script, as the ceremonial aspects of defining class and method can be skipped. These will be automatically generated in the Java language source that is being generated for a script.

The scripting feature can be used for test purposes. It is an easy and convenient way of entering some statements and testing them. The scripting feature can also be used for the start sequence of a NetREXX application.

Scripts can be interpreted or compiled - there is no rule that a script needs to be interpreted. In interpreted mode, the edit-compile-run cycle is shortened, in the sense that there is no separate compilation step necessary and incremental editing and testing can be done very efficiently. In both cases, interpreted or compiled, the NetREXX translator adds the necessary syntactic overhead into the Java source to enable the JVM to execute the resulting program.

The scripting facility and its automatic generation of a class statement can lead to one surprising message when there is an error in the first part of the program: *class x already implied* when the automatically generated class statement (using the program file name) somehow clashes with the specified name that contains the error. When not in scripting mode, this error message nearly always indicates an error that occurred before the first class statement.

NetREXX as an Interpreted Language

In the JVM environment, compilation and interpretation are concepts that are not as straightforward as in other environments; JVM code is interpreted on several levels. When we are referring to *interpreted* NetREXX code, we indicate that there is no intermediate Java compilation step involved. A JVM .class file is always interpreted by the JVM runtime; the NetREXX translator is able to execute programs without generating either .java or .class files.

This enables a very quick edit-debug-run cycle, especially when combined with the command line feature that keeps the translator classes resident (the -prompt option), or one of the IDE plugins for NetREXX.

For NetREXX to deliver this functionality, the translator has been designed to have an analogous interpret facility for every code generation part.⁵

⁵This is the right order in which to explain this feature, because historically, the compiler was first (1996) and the interpretation facility was added later (in 2000) -(but not without an extensive redesign of the compiler).

NetREXX as a Compiled Language

6.1 Programmatic use of the NetREXXC translator

NetREXXC can be used in a program, to compile NetREXX programs from files, or to compile from strings in memory.

6.2 Compiling from memory strings

Programs may also be compiled from memory strings by passing an array of strings containing programs to the translator using these methods:

Listing 6.1: From Memory

```
1 method main(arg=Rexx, programarray=String[], log=PrintWriter null) static returns int
2 method main2(arg=String[], programarray=String[], log=PrintWriter null) static returns
   int
```

Any programs passed as strings must be named in the arg parameter before any programs contained in files are named. For convenience when compiling a single program, the program can be passed directly to the compiler as a String with this method:

Listing 6.2: With String argument

```
1 method main(arg=Rexx, programstring=String, logfile=PrintWriter null) constant returns
   int
```

Here is an example of compiling a NetREXX program from a string in memory:

Listing 6.3: Example of compiling from String

```
1 import org.netrexx.process.NetRexxC
2 program = "say 'hello there via NetRexxC'"
3 NetRexxC.main("myprogram",program)
```

This will generate a myprogram.class file on disk.

6.3 Compile, load and go

There is also a possibility to generate a program dynamically, compile it from a string, and execute the resulting class(es) without writing intermediate class files to disk. In this case, even the classfile is executed from memory with a special classloader, the RxMapClassLoader. The compile, load and go method calls the main method of the generated

class, without arguments. This method is used to dynamically generate and execute NetRexx Pipelines. An example:

Listing 6.4: Example of compile-load-go

```
1 nrxsrc = "say 'hello dynamic world'"
2 clsName = 'helloDyn'
3 org.netrexx.process.NetRexxC.clgMain(clsName,nrxsrc)
```

6.4 Using the generated classfiles array

There is an overloaded main method in NetRexxC that does the compile in-memory and fills a specified collection with the compiled classfile images. This is in fact what clgMain() does. The generated classfile, including their classloader, are then usable in your own code.

Listing 6.5: Example of using the classes collection

```
1 classList = ArrayList()
2 rc = main(arg' -nologo -verbose0',[String programstring],null,classList)
3 mapLoader = RxMapClassLoader classList.get(0)
4 do
5     c = mapLoader.findClass(arg)
6     paramTypes = Class[1]
7     paramTypes[0] = String[].class
8     methodName = String "main"
9     m = c.getMethod(methodName, paramTypes)
10    params = Object[1]
11    params[0] = String[0]
12    m.invoke(null, params)
13 catch e=Exception
14     say 'Reflection exception encountered:'
15     say e.getMessage()
16 end
```

6.5 JSR199

NetRexx uses the jsr-199 way of invoking the compiler, and a .java file is not written to disk by default. The following program illustrates how a complete program can be compiled and executed without anything being written to disk.

Listing 6.6: JSR199 example

```
1 import org.netrexx.
2
3 pname="jsr199hello" -- program name
4 nrp=' say "hello"\n say arg \n say "program complete" ' -- NetRexx program code
5
6 classlist=ArrayList() -- this requests a class loader and class files returned in
   memory
7 NetRexxC.main(pname "-verbose0", nrp, null, classlist) -- ask NetRexxC to compile from
   string nrp
8 loader=ClassLoader classlist.get(0) -- find class loader build by NetRexx translator
9 pclass=loader.loadClass(pname) -- load our class file into the jvm
10 pclass.getMethod("main", [Class -
11 String[0].getClass()]).invoke(null,[Object [String 'argument
12 string']]) -- locate main, call it with reflection = all done!
```

Programs may also be interpreted directly from memory strings, as shown in 24.5 on ^{3.01} page 79.

Calling non-JVM programs

Although NetREXX currently misses the Address facility that Classic REXX and Object REXX do have, it is easy to call non-JVM programs from a NetREXX program - not as easy as calling a JVM class of course, but if the following recipe is observed, it will show not to be a major problem. The following example is reusable for many cases.

Listing 7.1: Calling Non-JVM Programs

```

1  /* script\NonJava.nrx
2
3  This program starts an UNZIP program, redirect its output,
4  parses the output and shows the files stored in the zipfile */
5
6  parse arg unzip zipfile .
7
8  -- check the arguments - show usage comments
9  if zipfile = '' then do
10     say 'Usage: Process unzipcommand zipfile'
11     exit 2
12 end
13
14 do
15     say "Files stored in" zipfile
16     say "-".left(39,"-") "-".left(39,"-")
17     child = Runtime.getRuntime().exec(unzip ' -v' zipfile) -- program start
18
19     -- read input from child process
20     in = BufferedReader(InputStreamReader(child.getInputStream()))
21     line = in.readLine()
22
23     start = 0 -- listing of files are not available yet
24     count = 0
25     loop while line \= null
26         parse line sep program
27         if sep = '-----' then start = \start
28         else
29             if start then do
30                 count = count + 1
31                 if count // 2 > 0 then say program.word(program.words).left(39) '\-'
32                 else say program.word(program.words)
33             end
34             line = in.readLine()
35         end
36     end
37
38     -- wait for exit of child process and check return code
39     child.waitFor()
40     if child.exitValue() \= 0 then
41         say 'UNZIP return code' child.exitValue()
42
43     catch IOException
44         say 'Sorry cannot find' unzip
45     catch e2=InterruptedException
46         e2.printStackTrace()
47 end

```

Just firing off a program is no big deal, but this example (in script style) shows how easy it is to access the in- and output handles for the environment that executes the

program, which enables you to capture the output the non-jvm program produces and do useful things with it.⁶ Line 17 starts the external command using the JVM Runtime class in a process called child. In line 20 we create a `BufferedReader` from the child processes' output. This is called an `InputStream` but it might as well have been called an `OutputStream`- everything regarding I/O is relative - but fortunately the designers of the JVM took care of deciding this for you. In lines 25-35 we loop through the results and show the files stored in the zipfile. Note that we **do** (line 14) have to **catch** (line 42) the *IOException* that ensues if the runtime cannot find the `unzip` program, maybe because it is not on the path or was not delivered with your operating system.

Starting from JVM 1.5 releases, there is a new way to accomplish the same goal, in a cleaner manner and with the added bonus of being able to redirect streams, and use environment variables. In this regard, the environment variable has made an important comeback from having its calls deprecated, to easy to use support in the *ProcessBuilder* class.

Listing 7.2: Use of ProcessBuilder

```

1  /**
2  * Class OSProcess implements ways to execute and get output from an OS Process
3  */
4  class OSProcess
5
6      properties indirect
7      pid = Process
8      returncode
9      commandList = ArrayList()
10     outList = ArrayList()
11
12     properties private
13     listeners = HashSet()
14     /**
15     * Default constructor
16     */
17     method OSProcess()
18         return
19
20     /*
21     * helper method that makes an ArrayList of out a Rexx string for use
22     * in the similarly named method that has an ArrayList as input
23     */
24     method outtrap(command_=Rexx) returns ArrayList
25         if command_ = '', command_ = null then return null
26         a = ArrayList()
27         loop until command_ = ''
28             parse command_ first command_
29             a.add(first.toString())
30         end
31         return this.outtrap(a)
32
33     /*
34     * helper method that makes an ArrayList of out a Rexx string for use
35     * in the similarly named method that has an ArrayList as input
36     */
37     method exec(command_=Rexx, wait=1)
38         if command_ = '', command_ = null then return
39         a = ArrayList()
40         loop until command_ = ''
41             parse command_ first command_
42             a.add(first.toString())
43         end
44         this.exec(a,wait)
45
46     /**

```

⁶This is akin to what one would do with *queue* on z/VM CMS and *outtrap* on z/OS TSO in Classic Rexx.

```

47 * Method outtrap starts an OS process from a command line in an ArrayList
48 * @param command is a List that has the command to be executed as elements
49 * @return List containing the output of the command
50 */
51 method outtrap(command_=ArrayList) returns ArrayList
52   this.commandList = command_
53   do
54     pb = ProcessBuilder(command_)
55     pb.redirectErrorStream(1)
56     this.pid = pb.start()
57     in = BufferedReader(InputStreamReader(this.pid.getInputStream()))
58     line = REXX in.readLine()
59     loop while line <> null
60   this.outList.add(line)
61   line = REXX in.readLine()
62   end
63   pid.waitFor()
64   returncode = pid.exitValue()
65   return this.outList
66 catch iox=IOException
67   say iox.getMessage()
68   return ArrayList()
69 catch InterruptedException
70   say "interrupted"
71   return ArrayList()
72 end -- do
73
74 /**
75 * Method exec starts an OS process from a command line in an ArrayList
76 * @param then fires off outputEvent events to every registered listener
77 * @return void
78 */
79 method exec(command_=ArrayList,wait=1)
80   this.commandList = command_
81   do
82     pb = ProcessBuilder(command_)
83     pb.redirectErrorStream(1)
84     this.pid = pb.start()
85     if wait then do
86       in = BufferedReader(InputStreamReader(this.pid.getInputStream()))
87       line = in.readLine()
88       loop while line <> null
89         line = in.readLine()
90         i = this.listeners.iterator()
91         loop while i.hasNext()
92           op = OutputEventListener i.next()
93           op.outputReceived(OutputLineEvent(this,line,this.pid))
94         end
95       end
96       pid.waitFor()
97       returncode = pid.exitValue()
98     end
99   catch iox=IOException
100     say iox.getMessage()
101   catch InterruptedException
102     say "interrupted"
103   end -- do
104
105
106 /**
107 * Method addOutputEventListener supports registering an event listener
108 * @param listener_ is a OutputEventListener
109 */
110 method addOutputEventListener(listener_=OutputEventListener)
111   this.listeners.add(listener_)
112
113 /**
114 * Method removeOutputEventListener supports de-registering an event listener
115 * @param listener_ is a OutputEventListener
116 */
117 method removeOutputEventListener(listener_=OutputEventListener)
118   this.listeners.remove(listener_)

```

In the above sample, we are using two different ways to obtain the output from a process started by the JVM from our own program. The method *outtrap* waits until the invoked process is finished and returns all output lines in an `ArrayList`. Its name is not entirely coincidental with the similar TSO *outtrap* function.

Sometimes we cannot wait until the child process is finished, for example when it is a long running process and we need to capture the output on a line-by-line basis to see what is happening - in case of the example, this was done to capture the output as part of a testsuite for a multithreaded file transfer application, which has a server resident process that is not supposed to end, because one of its tasks is to poll a directory for incoming files with a specific pattern in the file names. This is implemented using an Event based pattern (as explained in 11.2 on page 31).

Listing 7.3: Output Line Event

```
1 import java.util.EventObject
2 /**
3  * Class OutputLineEvent embodies the OutputLineEvent
4  */
5 class OutputLineEvent extends EventObject
6
7     properties indirect
8     pid = Process
9     line
10 /**
11  * Default constructor
12  */
13 method OutputLineEvent(ob=Object, line_, pid_=Process)
14     super(ob)
15     this.line = line_
16     this.pid = pid_
17     return
```

Listing 7.4: Output Event Listener

```
1 import java.util.EventListener
2 /**
3  * Interface OutputEventListener specifies the one mandatory method for this interface
4  */
5 class OutputEventListener interface implements EventListener
6
7     method outputReceived(ob=OutputLineEvent)
```

The call would look something like this:

Listing 7.5: Example of calling the `OSProcess` class - registering an eventhandler

```
1 os = OSProcess()
2 os.addOutputEventListener(this)
3 os.exec(command)
```

The class must extend `OutputEventListener`, and implement this method:

Listing 7.6: Example of implementing the listener method

```
1 method outputReceived(ob=OutputLineEvent)
2     this.counter = this.counter+1
3     say this.counter ob.getPid() ob.getLine()
```

Using NetREXX classes from Java

If you are a Java programmer, using a NetREXX class from Java is just as easy as using a Java class from NetREXX. NetREXX compiles to Java classes that can be used by Java programs. You should import the `netrexx.lang` package to be able to use the short class name for the REXX (NetREXX string and numerics) class.

A NetREXX method without a `returns` keyword can return nothing, which is the void type in Java, or a REXX string. NetREXX is case independent⁷; Java is case dependent. NetREXX generates the Java code with the case used in the class and method instructions. For example, if you named your class `Spider` in the NetREXX source file, the resulting Java class file is `Spider.class`. The public class name in your source program must match the NetREXX source file name. For example, if your source file is `SPIDER.NRX`, and your class is `Spider`, NetREXX generates a warning and changes the class name to `SPIDER` to match the file name. A Java program using the class name `Spider` would not find the generated class, because its name is `SPIDER.class` - if the compile succeeded, which is not guaranteed in case of casing mismatches. If you have problems, compile your NetREXX program with the **options -keepasjava -format**. You then can look at the generated java file for the correct spelling style and method parameters.

⁷With the default of options `nostrictcase` in effect.

Classes

Somewhere in the nineties Object Orientation became one of the mainstream ways to organize computer programs, and support for this was added to programming languages. C became C++ with a preprocessor that generates C⁸ that is not entirely unlike the NetREXX translator produces Java. Java in itself is syntax-wise a cleaned up version of C++, but in essence an entirely different language. Its inventor and architect, James Gosling, has stated on various occasions that he was planning a fully different syntax for what finally became Java - but that Sun management more or less forced him to use a C++ derived syntax, because C++ compilers was what SUN did well at the time. With Brendan Eich having to base JavaScript qua naming and syntax on Java, the circle that brought the world terse, curly braces based notations, is complete.

For an audience of REXX programmers, the usual OO presentation goes into the advantages of the paradigm. Today, that is not really necessary, and OO is a given; it slightly deviates from earlier notation as result of trying to put data and procedure into *Objects*, but it is no great deal, and this NetREXX Programmer's Guide does not need a special section on the benefits of the OO paradigm. It is assumed that with a few examples everyone should be able to *get* it; some old programmers might resist but there is really no use in fighting the mainstream. Consequently, this section discusses the way to do this in NetREXX; the way NetREXX does it is for a very large part formed by the way the JVM dictates it, adapted to REXX notational style and conventions.

Where traditional REXX would say:

```
l=left(ourstring,1)
```

the OO-versions of REXX would say:

```
l=ourstring.left(1)
```

As often the case, the hard part is in the notational omission that OO has as its characteristic: the instance pointer is no part of the function call and has moved to the left (in what now is called a *method*. The weight has shifted from the operation to the object it is called on.

9.1 Classes

Classes represent a blueprint, 'cookie cutter' approach in creating objects that do useful things. A class is defined in a file by the same name (exceptions here for dependent classes). So a class called Cookie is defined in a file called Cookie.nrx. Its *real*, which

⁸Cfront

means its most specific name, including its package specification, is not given by the file name but by the combination of the `class=file` + the name given on the package statement. This enables one to put classes in different packages without having to change the file names.

9.2 Dependent Classes

Dependent Classes are the NetREXX way to implement Java minor classes. There is no in-line definition possible, and dependent classes need their own class definition, but can be defined in the same source file as the classes they depend on. The notational advantage of 'nested' class definition, like customary in (for example) Java Swing programs is absent. What is present, is the way dependent classes can seamlessly access properties of their parent classes.

9.3 Properties

The properties statement enables us to define variables that are global to the class definition, and as such can be used by all methods of the class.

A properties statement needs at least one *visibility* or *modifier* keyword. When this is left out, a variable called "properties" is defined, which is not an error, but (most of the times) not what was intended.

Because the properties of a class can be externally visible (depending on *visibility* they need to have a type. When the type is omitted in the definition, they are of type `REXX`. So-called *indirect properties*, defined with the `properties indirect` modifier, give rise to automated generation of *getter* and *setter* methods for use in Java Beans.

Using Packages

Any non-toy, non-trivial program needs to be in a package. Only examples in programming books (present company included) have programs without package statements. The reason for this is that there is a fairly large chance that you will give something a name that is already used by someone else for something else. Things are not their names⁹, and the same names are given to wildly dissimilar things. The *package* construct is the JVM's approach to introducing *namespaces* into the total set of programs that programmers make. Different people will probably write some method that is called `listDifferences` sometime. With all my software in a package called `com.frob.nitz` and yours in a package called `com.frob.otzim`, there is no danger of our programs calling the wrong class and listing the wrong differences.

It is imperative to understand this chapter before continuing - it is a mechanical nuts-and-bolts issue but an essential one at that.

10.1 The package statement

The final words about the NetREXX **package** statement is in the NetREXX Language Reference, but the final statement about the package *mechanism* is in the JVM documentation.

10.2 Translator performance consequences

Because the NetREXX translator has to scan all packages that it can see (meaning a recursive scan of the directories below its own level in the directory tree, and on its classpath, it is often advisable (and certainly if `.` (a dot, representing the current directory) is part of the classpath) to do development in a subdirectory, instead of, for example, the top level home directory. If a large number of packages and classes are visible to the translator, compile times will be negatively impacted.

10.3 Some NetREXX package history

All IBM versions of NetREXX had the translator in a package called

`COM.ibm.netrexx.process`

⁹Willard Van Orman Quine, *Word and Object*, MIT Press, 1960, ISBN 0-262-67001-1

The official, SUN ordained convention for package names was, to prepend the reversed domain name of the vendor to the package name, while uppercasing the top level domain. NetREXX, being one of the first programs to make use of packages, followed this convention, that was quickly dropped by SUN afterwards, probably because someone experienced what trouble it could cause with version management software that adapted to case-*sensitive* and case-*insensitive* file systems. For NetREXX, which had started out keenly observing the rules, this insight came late, and it is a sober fact that as a result some needlessly profane language was uttered on occasion by some in some projects that suffered the consequences of this. With the first REXXLA release of NetREXX in 2011, the package name was changed to `org.netrexx`, while the runtime package name was kept as `netrexx.lang`, also because some major other languages follow this convention.

10.4 CLASSPATH

Most implementations of Java use an environment variable called CLASSPATH to indicate a search path for Java classes. The Java Virtual Machine and the NetREXX translator rely on the CLASSPATH value to find directories, zip files, and jar files which may contain Java classes. The procedure for setting the CLASSPATH environment variable depends on your operating system (and there may be more than one way).

- For Linux and Unix (BASH, Korn, or Bourne shell), use:

```
CLASSPATH=<newdir>:\$CLASSPATH
export CLASSPATH
```

- Changes for re-boot or opening of a new window should be placed in your `/etc/profile`, `.login`, or `.profile` file, as appropriate.
- For Linux and Unix (C shell), use:

```
setenv CLASSPATH <newdir>:\$CLASSPATH
```

Changes for re-boot or opening of a new window should be placed in your `.cshrc` file. If you are unsure of how to do this, check the documentation you have for installing the Java toolkit.

- For Windows operating systems, it is best to set the system wide environment, which is accessible using the Control Panel (a search for “environment” offsets the many attempts to relocate the exact dialog in successive Windows Control Panel versions somewhat).

Programming Patterns

Much has been made of patterns as aggregations of higher level embodiments of programming solutions. It has been observed¹⁰ that of a number of the C++ oriented patterns in Design Patterns¹¹, some owe their existence to complications in the C++ language and are not readily reproducible in a Java Patterns or Ruby Patterns book. The same goes for NetRexx- in this chapter we would like to present a number of Java patterns usable in NetRexx, and a number of patterns that are unique to NetRexx.

11.1 Singleton

Sometimes we only want one instance of a class, and we want every user of the class to refer to that same instance. In this case, we need to adapt the class construction mechanism to make sure this happens. There are different ways to implement this, one way is shown below.

Listing 11.1: Singleton

```

1 class TheGatherer
2
3   properties static
4   instance = TheGatherer
5
6   method getInstance() returns TheGatherer static protect
7     if TheGatherer.instance <> null then
8       do
9         return TheGatherer.instance
10      end
11    else
12      do
13        TheGatherer.instance = TheGatherer()
14        return TheGatherer.instance
15      end
16
17    /**
18     * private constructor enforces singleton
19     */
20    method TheGatherer() private signals ClassNotFoundException

```

The way that has been chosen here is to make the constructor private, so no other class can use it. We need an alternative method to make the first and only instance of this class, and this is the `getInstance()` method. This checks if a static property `instance` is null, in which case the private constructor is run and its return value put in `instance`. Every subsequent call to `getInstance()` sees the value of the static variable `instance` being not null, and returns that value, which now refers to the single instance. There are

¹⁰This observation from a Java patterns book.

¹¹Gamma, Helm, Johnson, Vlissides, Design Patterns: Elements of Reusable Object-Oriented Software, Addison-Wesley Professional; 1994

several ways to enhance this method, but this is a simple way and it fits the bill. For added security, override the methods for class serialization.

There is a common naming pattern for Singletons, which is the prepend the name of the class with *The*, as in the above example.

11.2 Observable and Events

The observer pattern can also be referred to as *Callback*, and the Java Event class delivers support for it. It is very usable if some result needs to be available for a set of callers, where the set is 0 to many. It works as follows: (see a simple implementation in section 7.4 on page 24) An object, maintains a list of its dependents, called observers, and notifies them automatically of any state changes, usually by calling one of their methods. It is mainly used to implement distributed event handling systems. The Observer pattern is also a key part in the familiar Model View Controller (MVC) architectural pattern. In the JVM, this object needs to implement the methods of the Listener interface; this interface specifies the `addListener` and `removeListener` methods; it keeps a collection in which references to the added listener objects are maintained. The listening is done to subclassed Java Event classes. The event specifies the method to be called when 'firing off' and event. This means that this method is called on every listener.

One of the larger benefits: it decouples the observer from the subject. The subject doesn't need to know anything special about its observers. Instead, the subject simply allows observers to subscribe. When the subject generates an event, it simply passes it to each of its observers. Another benefit is that event consuming classes don't have to wait until a process is finished, and can consume events as they come in. The `OSProcess` class on page 24) uses an event approach to consume output lines from a subprocess - in the version that puts the output in an `ArrayList` needs to wait for the subprocess to end, but the event driven version can monitor a long running process and analyze output lines whenever they are received.

11.3 Recursive Parse

This is a pattern unique to REXX, by virtue of REXX having the `Parse` statement. It also works in NetREXX.

11.4 More Observer/Observable

Java has special support for the Observer/Observable pattern in the form of the *Observer* class and the *Observable* interface. In the following snippet one can see the Observer class in working.

The class is the same *singleton* as shown above, and starts several threads which need to be observed.

Listing 11.2: Observer

```
1 class TheGatherer implements Observer
```

The Observable threads need to implement the *Observable* interface, and to be able to be started as a thread, *Runnable*. This is how we start it; its definition follows.

Listing 11.3: Observable: starting Observable Threads

```
1 method TheGatherer() private signals ClassNotFoundException
2   logger_.info( "TheGatherer: start")
3   t1 = TransactionStatusMonitor(Rexx 10000)
4   t1.addObserver(this)
5   Thread(t1).start()
6   logger_.info( "TheGatherer: started thread TransactionStatusMonitor")
```

We instantiate the Observable class as `t1`, and add the instance of our Observer class, `TheGatherer`, to it as Observer. After we have done this, we start it by instantiating a `Thread` object with it and calling the `start` method, which, by virtue of it implementing the *Runnable* interface, starts its **run** method.

Note that the `TransactionStatusMonitor` extends a class called `Monitor`, which in turn, implements the *Observable* interface. The reason for this is, we run several monitoring threads, and they all behave in the same way.

Listing 11.4: The Monitor Superclass

```
1 import java.util.Observable
2 class Monitor extends Observable
3
4   properties public
5   logger_ = Logger.getLogger(Monitor.class.getName())
6   sleeptime
7
8   properties static
9   da = TheDataAccess null
10
11   method Monitor()
12     this.da = TheDataAccess.getInstance()
```

Listing 11.5: an Observable Thread

```
1 class TransactionStatusMonitor implements Runnable extends Monitor
2
3   method TransactionStatusMonitor(s) signals ClassNotFoundException
4     this.sleeptime = s
5
6   method run()
7     do
8       loop forever
9         pi = this.da.idealq1()
10        if pi.getID().length() < 5 then
11          do
12            nop
13          end
14        else do
15          pi.setIdType('ideal')
16          ibidp = this.da.getIBPostIDStatuses(pi)
17          setChanged()
18          notifyObservers(ibidp.getStatusDelta())
19        end
20      end
21      Thread.currentThread().sleep(this.sleeptime) -- sleep for sleeptime seconds
22    end
23    catch InterruptedException
24      parse source s
25      say "thread interrupted:" s
26    end
```

In lines 17 and 18 the magic happens: the `setChanged()` method sets the status of this

instance as updated, and the `notifyObservers()` method calls for all the registered *Observers* their `update()` methods; this has the following signature:

Listing 11.6: the `update()` method

```
1  method update(o=Observable, obj=Object) protect
2      cl = o.getClass().getName()
```

The `update()` method receives an `Object`. The `.getClass().getName` call is for illustrative purposes and can be used to decide how to treat the received update object.

Incorporating Class Libraries

12.1 A Word About Java Generics

Many classes in Java are expressed as generics. It is important to note that the generic is a *compile time only* java type enforcement mechanism, and therefore does not affect NetREXX.

A generic class has, underlying it, a class that accepts one or more objects as parameters - taking as an example the `ArrayList` class, the Java documentation shows that this has a class signature of `public class ArrayList<E>` with one of the constructors being `ArrayList()` and, for example, a method `add(E e)`. If the `ArrayList` is instantiated in Java as follows:-

```
ArrayList<String> stringList = new ArrayList<String>();
```

then the Java compiler will note that the `ArrayList` is instantiated with a `<String>` object - and will enforce `String` usage everywhere else that the `<E>` is used in the class documentation - in this case the type `add(E e)`.

Thus

```
stringList.add("Item");
```

will be permitted by the compiler, since a string is being added. In contrast,

```
stringList.add(new Integer(7));
```

will fail since a string is not being added.

Remembering that the `ArrayList` deals directly with objects the following short NetREXX program will correctly use `ArrayList` without worrying about the "complication" of generics.

Listing 12.1: ArrayList Example

```

1  a1 = ArrayList() -- An ArrayList just deals with Objects
2
3  a1.add("Eric") -- so we give it some REXX objects
4  a1.add("Erica")
5  num = 0
6  a1.add(num)
7
8  say "There are" a1.size "elements in the list" -- and show they are present
9
10 /* Now, to retrieve them */
11
12 loop item over a1
13     say item
14 end
```

If one does not need generics, then it could be asked why they have been implemented at all - the answer is that they prevent many Java run-time errors resulting from a failure to cast the object used to the correct type. When programming in NetREXX the use of the "universal" REXX class means that this is rarely an issue. When retrieving objects from a generic class used from within Java one must remember to use the correct type, cast or the binary option just as would be expected when using a Java object in any other way.

12.2 The Collection Classes

The Java collections framework (JCF) is a set of classes and interfaces that implement commonly reusable collection data structures. The JCF provides both interfaces that define various collections and classes that implement them. Collection implementations in pre-JDK 1.2 versions of the Java platform included few data structure classes, but did not contain a collections framework. The standard methods for grouping Java objects were via the array, the Vector, and the Hashtable classes, which were not easy to extend, and did not implement a standard member interface. The collections framework was designed and developed primarily by Joshua Bloch, and was introduced in JDK 1.2.

Almost all collections in Java are derived from the `java.util.Collection` interface. Collection defines the basic parts of all collections. The interface states the `add()` and `remove()` methods for adding to and removing from a collection respectively. Also required is the `toArray()` method, which converts the collection into a simple array of all the elements in the collection. Finally, the `contains()` method checks if a specified element is in the collection. The Collection interface is a subinterface of `java.util.Iterable`, so any Collection is iterable (using an iterator for a loop over the contents). All collections have an iterator that goes through all of the elements in the collection.

The Collection framework is one of the aspects of where NetREXX relegates to Java for its implementation. Where ooREXX has had its collection classes in the language definition from day one, in NetREXX they are not part of the language; most of the data related support is in the indexed strings feature. This, in turn, makes use of the Dictionary mechanism already implemented in the earliest versions of Java; NetREXX language design was long complete when JDK 1.2 came out.

The Pre-Java Generic classes JFC had, in order to be generic, an interface in which objects could be added in as a `java.lang.Object`, but on return, that object needed to be typecast to the right type. Using collection classes did entail a good deal of casting return values, as type REXX was not part of the set of types that collections had native support for. Modern NetREXX versions have builtin support for using type REXX in collection classes¹², so these can be added to and retrieved from collection classes without further ado.

The NetREXX native REXX datatype contains a Java Hashtable which is part of the Collections Framework. New classes, constructors and methods have been added to implement the Java Map interface and allow better interoperability with Java. Some of the new collections support methods include `isIndexed()` to check if a Map currently exists, `size()` to determine the count of map entries and `buildmap(sequence1, sequence2)` to construct REXX maps from arrays or Java Lists. Other classes and methods are documented in the

¹²In actuality, the needed interfaces, like *Comparable* and *Comparator* are now provided in the REXX type

Java Collections Map interface Javadocs. "isindexed()" returns 0 if no indexed values exist and 1 if there is at least one indexed value in a Rexx object. To build a new indexed Rexx map with the buildmap method you can do this: `Rexx(default).buildMap(keys, values)` where keys and values are any arrays or Java collections framework Lists and default is the default value for the Rexx variable (using the standard Rexx constructors).

All elements are converted to strings before being added to the indexed Rexx variable which is returned. Null can be passed for one of the keys or values parameters to default to a 1-n integer sequence matching the other parameter but if both parameters are provided they must have the same length. Note that arrays do not need to be string arrays and that primitive arrays such as `int[]` are also accepted.

Collection is a Java generic. Any collection can be written to store any class. For example, `Collection<String>` can hold strings, and the elements from the collection can be used as strings without any casting required. NetREXX 3.02 added loop over support in NetREXX programs for collection classes; this has been implemented without the need for Java generics. This makes it impossible to use the generics mechanism to constrain collection class membership to a specified type. This, however, can be easier accomplished by subclassing the collection class and overriding its constructors.

Input and Output

A conscious design decision was to leave I/O operations out of the language, and to wholly depend on the JVM functionality for this. This turned out to be a good decision, as JVM I/O has been enhanced and changed over the years; also, the various environments in which NetREXX can be used as a programming language, are not limited to file I/O, but have various implementations to interact with the outside world. A NetREXX program that employs Flash technology has different method calls to make than a program that uses ISPF for user interaction.

This does not preclude us to implement file I/O in a way that is reminiscent of Classic REXX, and in fact this has been done, and the future might see some standardization in this respect. The *contrib* part of the NetREXX source code repository has various examples of how this is done. In the remaining part, however, we are discussing how to use standard JVM libraries to accomplish I/O.

13.1 Improvements in 3.07 to Say and File reading

Starting with version 3.07 it became a bit easier, c.q. less verbose, to print directly to a file using the Say statement, or, for example, to a file and to Stderr. Also, a pattern in which there is an action for every line in a file, is now supported with the oneliner file handler, `RexxIO.forEachLine`.

This is shown in the figures 2, 3 and 4.

13.2 The File Class

13.2.1 Line mode I/O using `BufferedReader` and `FileOutputStream`

Listing 13.1: Buffered I/O

```

1  /* linecomment.nrx -- convert appropriate block comments to line comments */
2
3  /* This is a sample file input and output program, showing how to open,
4     check, and process text files, and handle exceptions.
5     Note the use of the Reader and Writer classes, which convert your
6     local computer's 'code page' (character encoding) to Unicode during
7     reading and back again during writing. */
8
9  parse arg fin fout . -- get the arguments: input and output files
10 if fout='' then do
11   say '# Please specify both input and output files'
12   exit 1
13 end
14
```



FIGURE 2: Onliner file handler

```

15 /* Open and check the files */
16 do
17   infile=File(fin)
18   instream=FileInputStream(infile)
19   inhandle=BufferedReader(InputStreamReader(instream))
20   outfile=File(fout)
21   if outfile.getAbsolutePath=infile.getAbsolutePath then do
22     say '# Input file cannot be used as the output file'
23     exit 1
24   end
25   outstream=FileOutputStream(outfile)
26   outhandle=OutputStreamWriter(outstream)
27   say 'Processing' infile'...'
28   catch e=IOException
29     say '# error opening file' e.getMessage
30   end
31
32   linesep=System.getProperty('line.separator') -- be platform-neutral
33
34   /* The main processing loop */
35   loop linenum=1 by 1
36     line=Rexx inhandle.readLine -- get next line [as Rexx string]
37     if line=null then leave linenum -- normal end of file
38
39     parse line pre '/'*' mid '*'/' post -- process the line
40     if pre\='' then
41       if mid\='' then
42         if post\='' then
43           line=pre'--'mid
44
45     if linenum>1 then outhandle.write(linesep, 0, linesep.length)
46     outhandle.write(line, 0, line.length)
47   catch e=IOException
48     say '# error reading or writing file' e.getMessage
49   catch RuntimeException
50     say '# processing ended'
51   finally do -- close files
52     if inhandle\=null then inhandle.close
53     if outhandle\=null then outhandle.close
54   catch IOException
55     -- ignore errors during close
56   end
57 end linenum
58

```

III >>

>> 11

setOutputStream

- You can set an OutputStream on the RexxIO class (which is static)
 - For the first time, you can switch between stdout and stderr
 - You may also specify a FileOutputStream
 - All **say** output from that moment on will go to that file
 - Reset it by setting it back to System.out
- Every **say** always flushes the output stream (and always did)
- Even when this is taken into account:
 - On systems with slow consoles (read: windows):
 - The speedup is stunning when writing to a file

```

class ZzFacilityReport
properties inheritable
bpSet = TreeSet()

/**
 * Default constructor
 */
method ZzFacilityReport()
return

method main(Cargs-String[]) static
z = ZzFacilityReport()
RexxIO.setOutputStream(FileOutputStream("fiscfac.csv"))
RexxIO().File("data/erp_wb_dpsob_bp_acc.txt").foreachLine(z.file())
RexxIO().File("data/pr1_zzfacility.txt").foreachLine(z.fileZ())

class ZzFacilityReport.file1 dependent implements LineHandler
method handle(in)
parse in '1'.'1'bp'1'
parent.bpSet.add(bp.strip)

class ZzFacilityReport.file2 dependent implements LineHandler
method handle(in)
z = ZzFacility()
z.parse(in)
if z.getPARTNER = '' then return
if parent.bpSet.contains(z.getPARTNER.strip) then return
if z.getPARTNER = 'PARTNER' then return
if z.getZACTVSTART = '' then z.setZACTVSTART('01.01.1900')

```

FIGURE 3: Set the output stream for Say

59 say linenum-1 'lines written'

39

What if we want some **say** output going to more outputstreams?

- To make **say** output go to more streams (stdout, a file, stderr) we can:
 - pushOutputStream
 - Add one outputstream
 - popOutputStream
 - Remove the latest added outputstream
 - StdOut in RexxIO is now a ConcurrentLinkedDeque
 - Which should make it reasonable thread safe

```
method setOutputStream(out=OutputStream) static
  StdOut.clear()
  StdOut.push(PrintWriter(out))

method pushOutputStream(out=OutputStream) static
  StdOut.push(PrintWriter(out))

method popOutputStream() static
  do
    StdOut.pop()
  catch java.util.NoSuchElementException
    StdOut.push(PrintWriter(System.out))
end
```

FIGURE 4: Using more outputstreams

Algorithms in NetRexx

14.1 Factorial

A *factorial* is the product of an integer and all the integers below it; the mathematical symbol used is ! (the exclamation mark). For example 4! is equal to 24 (because $4*3*2*1=24$). The following program illustrates a recursive (a method calling itself) and an iterative approach to calculating factorials.

Listing 14.1: Factorial

```

1  /* NetRexx */
2
3  options replace format comments java symbols nobinary
4
5  numeric digits 64 -- switch to exponential format when numbers become larger than 64
   digits
6
7  say 'Input a number: \-'
8  say
9  do
10   n_ = long ask -- Gets the number, must be an integer
11
12   say n_ '! =' factorial(n_) '(using iteration)'
13   say n_ '! =' factorial(n_, 'r') '(using recursion)'
14
15   catch ex = Exception
16     ex.printStackTrace
17 end
18
19 return
20
21 method factorial(n_ = long, fmethod = 'I') public static returns Rexx signals
   IllegalArgumentException
22
23 if n_ < 0 then -
24   signal IllegalArgumentException('Sorry, but' n_ 'is not a positive integer')
25
26 select
27   when fmethod.upper = 'R' then -
28     fact = factorialRecursive(n_)
29   otherwise -
30     fact = factorialIterative(n_)
31   end
32
33 return fact
34
35 method factorialIterative(n_ = long) private static returns Rexx
36
37   fact = 1
38   loop i_ = 1 to n_
39     fact = fact * i_
40   end i_
41
42   return fact
43
44 method factorialRecursive(n_ = long) private static returns Rexx
45

```

```

46  if n_ > 1 then -
47      fact = n_ * factorialRecursive(n_ - 1)
48  else -
49      fact = 1
50
51  return fact

```

Executing this program yields the following result:

```
===== Exec: RCFactorial =====
```

Input a number:

42

42! = 1405006117752879898543142606244511569936384000000000 (using iteration)

42! = 1405006117752879898543142606244511569936384000000000 (using recursion)

As you can see, fortunately, both approaches come to the same conclusion about the results. In the above program, both approaches are a bit intermingled; for more clarity about how to use recursion, have a look at this:

Listing 14.2: Factorial Recursive

```

1  class Factorial
2  numeric digits 64
3
4  method main(args=String[]) static
5      say factorial_(42)
6
7  method factorial_(number) static
8      if number = 0 then return 1
9      else return number * factorial_(number-1)

```

In this program we can clearly see that the `factorial_` method, that takes an argument number (which is of type REXX if we do not specify it to be another type), calls itself in the method body. This means that at runtime, another copy of it is run, with as argument number that the first invocation returns (the result of 42×41), and so on.

In general, a recursive algorithm is considered more elegant, while an iterative approach has a better runtime performance. Some language environments are optimized for recursion, which means that their processors can spot a recursive algorithm and optimize it by not making many useless copies of the code. Some day in the near future the JVM will be such an environment. Also, for some problems, for example the processing of tree structures, using a recursive algorithm seems much more natural, while an iterative algorithm seems complicated or forced.

14.2 Fibonacci

Listing 14.3: Fibonacci

```

1  /* NetRexx */
2  options replace format comments java symbols
3
4  numeric digits 210000          /*prepare for some big ones. */
5  parse arg x y .                /*allow a single number or range.*/
6  if x == '' then do             /*no input? Then assume -30-->+30*/
7      x = -30
8      y = -x
9  end
10
11 if y == '' then y = x          /*if only one number, show fib(n)*/

```

```

12 loop k = x to y           /*process each Fibonacci request.*/
13 q = fib(k)
14 w = q.length             /*if wider than 25 bytes, tell it*/
15 say 'Fibonacci' k="q
16 if w > 25 then say 'Fibonacci' k "has a length of" w
17 end k
18 exit
19
20 /*-----FIB subroutine (non-recursive)---*/
21 method fib(arg) private static
22 parse arg n
23 na = n.abs
24
25 if na < 2 then return na   /*handle special cases. */
26 a = 0
27 b = 1
28
29 loop j = 2 to na
30   s = a + b
31   a = b
32   b = s
33 end j
34
35 if n > 0 | na // 2 == 1 then return s /*if positive or odd negative... */
36 else return -s /*return a negative Fib number. */

```

Using Parse

The `Parse` statement is one of the stalwarts of the Rexx family of languages, and allows one to easily split a string into parts without needing to resort to more traditional techniques of string processing.

The syntax of a parse statement is

```
parse term template
```

where `term` is a string or a previously initialised variable. The template is a list of instructions describing how to split the string.

15.1 Literal Parsing

The most common use of `parse` is to split a string up into parts separated with a delimiter - whilst the most common delimiter is a simple space any string may be used:-

Listing 15.1: Simple Parse Example

```
1 log = "2014/05/15 21:35:47.012 - error in {{{findit}}}"
2 parse log year "/" month "/" day hour ":" minute ":" second "." msecond "-" text
3 say "On day" day "of month" month "at about" hour ":" minute "we got" text
4 parse text "{{[" name "]}}"
5 say name
```

Here `log` is composed of a timestamp separated from a message by a hyphen. The timestamp is composed of a date separated from a time by a space - within the date the year month and day are delimited by a slash and within the date the hour, minute and second fields by a colon. The millisecond field is separated from the seconds by a decimal point. The first parse divides these using the relevant delimiter - where there is no delimiter then a space is used.

The term is the variable `log` and the template is

```
year "/" month "/" day hour ":" minute ":" second "." msecond "-" text
```

This first template may be read as the following sequence of actions

1. Assign the contents of `log` to the variable `year` until a `/` is encountered (2014)
2. Following the `/` assign `month` with the sting found up until another `/` (05)
3. Place the contents following the `/` until a space into the variable `day` (15)
4. Following the space, assign the value found up until the `:` into the hour variable (21)
5. Repeat for the variable `minute` (35)

6. Assign the second value up until the .
7. Take the value for msecond until a delimiter of - is seen
8. Assign the remainder to variable text

The second parse statement shows how the delimiters can be more complex - the template is

```
"{{[" name "]}}"
```

and extracts the value between {[and]}} to the variable (name)

Running the above example will produce the following output:-

```
At about 21:35 we got error in {[findit]}
findit
```

As another example, consider

Listing 15.2: Parse Word-Split Example

```
1 quote = "Now is the winter of our discontent"
2 loop forever
3   parse quote word quote
4   say word
5   if quote = "" then leave
6 end
```

This will take the first word from quote, and assign the remainder back into quote, print the word taken and repeat until the variable quote is the empty string. The output from this will be

```
Now
is
the
winter
of
our
discontent
```

15.1.1 The Placeholder (dummy) Variable

The first example assigns values to several variables that are not used - this is unnecessary and can be avoided by the use of a placeholder variable which is the . character.

If this is done, the first parse statement becomes

```
parse log . "/" month "/" day hour ":" minute ":" . "." . "-" text
```

The output will remain the same.

15.2 Positional Parsing

Whilst the majority of parsing can be done using a fixed literal delimiter, the parse instruction also allows parsing based on positional patterns. This is achieved with the use

of numerical values in the template - the values may also take a prefix of +, - or =

no prefix or = indicates that the number is an **absolute** column value in the string being parsed

+ indicates a **relative** position that starts from the specified position *after* the position where the last match occurred

- indicates a **relative** position that starts from the specified position *before* the last match

These points are best illustrated by example

Listing 15.3: Positional Parsing

```
1 quote = "Now is the winter of our discontent"
2 tens = "      11111111112222222222333333"
3 units = "12345678901234567890123456789012345"
4
5 say quote
6 say tens
7 say units
8
9 parse quote 10 str1 20 -8 str2 +6 str3
10 -- str1 starts at column 10 and is 10 chars long
11 say str1 "("str1.length")"
12 -- str2 steps back 8 chars and is 6 chars long
13 say str2 "("str2.length")"
14 -- str3 is the remainder of the string (as should be expected)
15 say str3
```

Running this gives the following

```
Now is the winter of our discontent
      11111111112222222222333333
12345678901234567890123456789012345
e winter o (10)
winter (6)
  of our discontent
```

Both `literal` and `positional` parsing can be combined. Keen-eyed readers will have noted that the output from the first example contained an extra space before the word `error`

```
At about 21:35 we got error in {[findit]}
Extra space here      ^^
```

This is the result of assigning the *remainder* of the string to the variable `text` - leading blanks are normally removed *except* in this special case.

One can use a positional pattern to eliminate this extra space:-

Listing 15.4: Combined Parsing

```
1 log = "2014/05/15 21:35:47.012 - error in {[findit]}"
2 parse log . "/" month "/" day hour ":" minute ":" . "." . "-" +2 text
3 say "On day" day "of month" month "at about" hour ":" minute "we got" text
4 parse text "{[[" name "]}"
5 say name
```

Note that the relative positional pattern used here is `+2 - 0` is the position of the last match which is the hyphen, `+1` is the position of the following space and thus `+2` is the start of the target string.

15.3 Variable Templates

Variables may be used as the pattern in the templates in order to accommodate the occasions when the pattern may need to be specified at runtime. An illustration of this is the following evolution of the first example that will correctly parse dates specified in two distinct ways

Listing 15.5: Variables in Patterns

```
1 log = ""
2 log[1] = "2014/05/15 21:35:47.012 - error in {[findit]}]"
3 log[2] = "2014-05-15 21:35:47.012 - error in {[findit]}]"
4
5 loop i = 1 to 2
6   dtsep = log[i].substr(5,1)
7   parse log[i] . (dtsep) month (dtsep) day hour ":" minute ":" . "." . "-" +2 text
8   say "On day" day "of month" month "at about" hour ":" minute "we got" text
9 end
```

Note that the date separator `dtsep` is determined and then used in the parse pattern by enclosing it in parentheses, thus `(dtsep)`. The output of this program is

On day 15 of month 05 at about 21:35 we got error in {[findit]}

On day 15 of month 05 at about 21:35 we got error in {[findit]}

It can be seen that the date was successfully parsed in both cases.

It is important to note that any pattern specified by a variable *will be assumed to be literal unless it has a +, - or = prefix*. Should one wish to use positional patterns then the prefix **must** be used.

Listing 15.6: Variables in Positional Patterns

```
1 message = "this is a message that contains the number 10- just there, see?"
2 pat = "10"
3 parse message part1 5 (pat) part2
4 say "literal:" part1 part2
5 parse message part1 5 =(pat) part2
6 say "positional:" part1 part2
```

When run this illustrates the difference between the two parse statements

literal: this - just there, see?

positional: this message that contains the number 10- just there, see?

Using Trace

The `trace` command is the inbuilt debugging facility of the REXX family, and, as might be expected from its name, allows one to trace the execution of your program. It is possible to trace both program statements and the state of variables within your code.

(Trace) is a compile-time option, and should be disabled once debugging has been completed.

The syntax of the trace command is

```
trace traceitem
```

where `traceitem` defines the behaviour of the trace command. Only one `traceitem` may be given, and only one of the program statement tracing options will be in use at any time. Variable tracing options, however, are *additive* and such statements may appear multiple times.

All trace output is headed by three hyphens followed by the source file name, as follows

```
--- TerribleExample.nrx
```

16.1 Tracing Program Statements

The trace options that affect the tracing of program statements are

all will display all statements as they are executed. Each line in the trace output will be prefixed with `==` or a `*=` should output span subsequent lines.

The trace `all` statement can be placed anywhere in the program source.

methods will show the each method as it is invoked, along with any parameters to it.

The trace output for method traces is prefixed by a `==` for the method call itself and a `>a>` indicating the assignment of a value to a method parameter. *No other program statements will be traced.*

The trace `methods` statement should be placed *before* the first method is defined in a class.

results acts as though the trace `all` statement had been given, and, if placed *before* any method will also act as though trace `methods` was also specified.

In addition to the `all` and `methods` tracing implied by `results` the following will also take place

Properties will have their assignments shown. These will be identified by `>p>`

Local variables will also be traced, with assignments identified by `>v>`

Expressions will have their evaluations shown if not shown for as a part of `properties` or `local variable` trace output. Such evaluations are indicated by `>>`

`off` `trace off` disables tracing. No further tracing output will take place.

16.2 Tracing Variables

The all-or-nothing tracing offered by, for instance `trace results` can lead to a deluge of trace information in many cases.

In these instances one may more finely control which variables one wishes to monitor using the `trace var` statement. The syntax of the `trace var` statement is

```
trace var var1 [var2...]
```

or

```
trace var -var1 [-var2...]
```

where the first form adds variables to the list that should be watched, and the second removes them. The forms may be mixed to add some variables and remove others simultaneously, as here:-

```
trace var var1 -var2 var3 -var4 -var5
```

to monitor `var1` and `var3` and remove `var2`, `var5` and `var5` from the list of watched variables.

Multiple `trace var` statements may be used, as mentioned above.

It is not an error to specify a variable name that does not exist.

Each variable can appear only *once* in a `trace` statement.

A variable name may be that of any type - including arrays (without the `[]`).

Program tracing options never alter the list of watched variables. If tracing has previously been turned off then variable tracing may be resumed simply with a `trace var` statement.

16.3 Examples

16.3.1 Program Trace

Trace All

Running the program below

Listing 16.1: Trace Example 1

```
1 trace all
2
3 class traceExample
4
5     properties
6         aIs
7         bIs
8
9     method traceExample(a, b)
10         aIs = a
```

```

11     bIs = b
12
13     method times
14         return aIs * bIs
15
16     method main($cmdin1=String[]) static
17         arg=Rexx($cmdin1)
18         te = traceExample(2, 3)
19         fred = te.times
20         say fred

```

gives trace output of

```

--- traceExample.nrx
16 ** method main($cmdin1=String[]) static
   >a> $cmdin1 "[Ljava.lang.String;@72ebbf5c"
17 **   arg=Rexx($cmdin1)
18 **   te = traceExample(2, 3)
   9 ** method traceExample(a, b)
     >a> a "2"
     >a> b "3"
10 **   aIs = a
11 **   bIs = b
12 **
19 **   fred = te.times
13 ** method times
14 **   return aIs * bIs
20 **   say fred

```

This output may be read thus

- **traceExample.nrx** Identification of the program being traced. This is the tracing context.
- 16 ** method main(\$cmdin1=String[] static)** The first line that is actually executed is line 16.
- >a> \$cmdin1 "[Ljava.lang.String;@72ebbf5c"** Variable \$cmdin1 is assigned a string value from the java virtual machine.
- 17 ** arg=Rexx(\$cmdin1)** Line 17 is executed next...
- 18 ** te = traceExample(2, 3)** followed by line 18
- 9 ** method traceExample(a, b)** Line 18 is a method call to a method on line 9...
- >a> a "2"** which assigns a value of 2 to parameter a
- >a> b "3"** and a value of 3 to parameter b
- 10 ** aIs = a** the following lines document only code execution
- 11 ** bIs = b**
- 12 ****
- 19 ** fred = te.times**
- 13 ** method times**
- 14 ** return aIs * bIs**
- 20 ** say fred**

Trace Methods

Replacing the `trace all` from line 1 with `trace methods` gives trace output of

```
--- traceExample.nrx
16 ** method main($cmdin1=String[]) static
  >a> $cmdin1 "[Ljava.lang.String;@8094cc7"
  9 ** method traceExample(a, b)
    >a> a "2"
    >a> b "3"
13 ** method times
```

As should be expected, this is a subset of the output provided when using `trace all`.

Trace Results

Replacing the `trace all` from line 1 with `trace results` would give

```
--- traceExample.nrx
16 ** method main($cmdin1=String[]) static
  >a> $cmdin1 "[Ljava.lang.String;@72ebbf5c"
17 ** arg=Rexx($cmdin1)
  >>> "[Ljava.lang.String;@72ebbf5c"
  >v> arg ""
18 ** te = traceExample(2, 3)
  >>> "2"
  >>> "3"
  9 ** method traceExample(a, b)
    >a> a "2"
    >a> b "3"
10 ** aIs = a
  >p> aIs "2"
11 ** bIs = b
12 *-
11 >p> bIs "3"
18 >v> te "traceExample@53606bf5"
19 ** fred = te.times
13 ** method times
14 ** return aIs * bIs
  >>> "6"
19 >v> fred "6"
20 ** say fred
  >>> "6"
```

Here it can be seen that more information is available. Noticeably, the values of assignments are given. For instance

Line 17 now has an entry of `>v> arg ""` showing that the value of the variable `arg` was set to the empty string

Line 18 now has the values of the specified parameters evaluated (»> "2" and »» "3")
 Lines 10 and 11 show that values were assigned to parameters (>p> aIs "2" and >p> bIs "3")
 Line 18 then shows the assignment of the instantiated class to variable te
 Line 14 shows the evaluation of the multiplication (»> "6"), which is assigned to variable fred in line 19 (>v> fred "6") on line 19.
 Finally we see the evaluation of variable fred on line 20.

16.3.2 Variable Tracing

Consider the following example:-

Listing 16.2: Trace Example 2

```

1 a = "a"
2 b = "b"
3 c = 1
4 d = 2
5 e = 3
6
7 trace var a b c d e f y
8 z = a || b
9 y = c + d
10 f = y + 2
11 e = f
12
13 trace var -a -c -d -e
14 y = y * 2
15 a = y
16 e = a

```

Running this will produce the output below

```

--- variableTraceExample.nrx
9 ** y = c + d
  >v> y "3"
10 ** f = y + 2
  >v> f "5"
11 ** e = f
  >v> e "5"
14 ** y = y * 2
  >v> y "6"

```

It can be seen that only the lines that contain watched variables are traced. This the variable assignments on lines 9, 10 and 11 are displayed, since the variables being watched from line 7 to line 12 are a, b, c, d, e, f and y.

Following this, however only the assignment to variable y is shown, since the variables a, b, c, d and e are removed from the list with the command `trace var -a -c -d -e`.

16.4 Tracing Notes

One further prefix may be encountered in the trace output +++ which signifies an error. Whenever tracing transfers to a different source file, a new tracing context, identified by the – prefix is output.

Tracing is expensive, and may dramatically impact the run-time performance of the program being traced. Judicious use may therefore be warranted.

Concurrency

17.1 Threads

Threads are a built-in multitasking feature of the JVM. Where earlier JVM implementations sometime ran on so-called *Green Threads*, which is a library that implements thread support for OS'es that do not have this facility (an early version of Java was called *GreenTalk* for this reason), modern versions all use native OS thread support.

A new thread is created when we create an instance of the Thread class. We cannot tell a thread which method to run, because threads are not references to methods. Instead we use the Runnable interface to create an object that contains the run method:

Every thread begins its concurrent life by executing the run method. The run method does not have any parameters, does not return a value, and is not allowed to signal any exceptions. Any class that implements the Runnable interface can serve as a target of a new thread. An object of a class that implements the Runnable interface is used as a parameter for the thread constructor.

Threads can be given a name that is visible when listing the threads in your system. It is good practice to name every thread, because if something goes wrong you can see which threads are still running. Additionally, threads are grouped by thread groups. If you do not supply a thread group, the new thread is added to the thread group of the currently executing thread. The threads of a group and their subgroups can be destroyed, stopped, resumed, or suspended by using the ThreadGroup object.

The next two samples are used in the following programs that illustrate thread usage.

Listing 17.1: Thread sample 1

```

1  /* thread/ThrdTst1.nrx */
2
3  h1 = Hello1('This is thread 1')
4  h2 = Hello1('This is thread 2')
5
6  Thread(h1, 'Thread Test Thread 1').start()
7  Thread(h2, 'Thread Test Thread 2').start()
8
9  class Hello1 implements Runnable
10     Properties inheritable
11     message = String
12
13     method Hello1( s = String)
14         message = s
15
16     method run()
17         loop for 50
18             say message
19     end

```

Listing 17.2: Thread sample 2

```
1  /* thread/ThrdTst2.nrx */
2
3  h1 = Hello2('This is thread 1')
4  h2 = Hello2('This is thread 2')
5
6  h1.start()
7  h2.start()
8
9  class Hello2 extends Thread
10   Properties inheritable
11   message = String
12
13   method Hello2( s = String)
14     super('Thread Test - Message' s)
15     message = s
16
17   method run()
18     loop for 50
19       say message
20     do
21       sleep(10)
22     catch InterruptedException
23     end
24   end
```

The second class, `Hello2`, does not *implement* the `Runnable` interface, but subclasses it, so it inherits its methods. This is a valid approach, and it is up to the developer to choose an implementation and worry about the semantics of an inherited thread interface. A newly created thread remains idle until the `start` method is invoked. The thread then wakes up and executes the `run` method of its target object. The `start` method can be called only once. The thread continues running until the `run` method completes or the `stop` method of the thread is called.

User Interfaces

18.1 AWT

18.2 Web Applets using AWT

Web applets can be written one of two styles:

- Lean and mean, where binary arithmetic is used, and only core Java classes (such as *java.lang.String*) are used. This is recommended for optimizing webpages which may be accessed by people using a slow internet connection. Several examples using this style are included in the NetRexx package like the two listed below.

Listing 18.1: Nervous Tetxt

```

1  /* NervousText applet in NetRexx: Test of text animation.
2     Algorithms, names, etc. are directly from the Java version by
3     Daniel Wyszynski and kwalrath, 1995
4  */
5  options binary
6
7  class NervousTetxt extends Applet implements Runnable
8
9      separated = char[]
10     s = String
11     killme = Thread
12     threadSuspended = boolean 0
13
14     method init
15         resize(300,50)
16         setFont(Font("TimesRoman", Font.BOLD, 30))
17         s = getParameter("text")
18         if s = null then s = "NetRexx"
19
20         separated = char[s.length]
21         s.getChars(0, s.length, separated,0)
22
23     method start
24         if killme \= null then return
25         killme = Thread(this)
26         killme.start
27
28     method stop
29         killme = null
30
31     method run
32         loop while killme \= null
33             Thread.sleep(100)
34             this.repaint
35         catch InterruptedException
36         end
37         killme = null
38
39     method paint(g=Graphics)
40         loop i=0 to s.length-1

```

```

41     x_coord = int Math.random*10+15*i
42     y_coord = int Math.random*10+36
43     g.drawChars(separated, i, 1, x_coord, y_coord)
44 end
45
46 method mouseDown(evt=Event, x=int, y=int) returns boolean
47     if threadSuspended then killme.resume
48         else killme.suspend
49     threadSuspended = \threadSuspended
50     return 1

```

Listing 18.2: ArchText

```

1  /* ArchText applet: multi-coloured text on a white background */
2  /* Mike Cowlishaw April 1996, December 1996 */
3  options binary
4
5  class ArchText extends Applet implements Runnable
6
7  text = "NetRexx" /* default text */
8  tick = 0 /* display counter */
9  timer = Thread null /* timer thread */
10 shadow=Image /* shadow image */
11 draw =Graphics /* where we can draw */
12
13 method init
14     s=getParameter("text") /* get any provided text */
15     if s\=null then text=s
16     shadow=createImage(getSize.width, getSize.height) /* image */
17     draw=shadow.getGraphics
18     draw.setColor(Color.white) /* background */
19     draw.fillRect(0, 0, getSize.width, getSize.height) /* .. */
20     draw.setFont(Font("TimesRoman", Font.BOLD, 30)) /* font */
21
22 method start
23     if timer=null then timer=Thread(this) /* new thread */
24     timer.setPriority(Thread.MAX_PRIORITY) /* time matters */
25     timer.start /* start the thread */
26
27 method stop
28     if timer=null then return /* have no thread */
29     timer.stop /* else stop it */
30     timer=null /* .. and discard */
31
32 method run /* this runs as thread */
33     loop while timer\=null
34         tick=tick+1 /* next update */
35         hue=((tick+133)//191)/191
36         draw.setColor(Color.getHSBColor(hue, 1, 0.7))
37         draw.drawString(text, 0, 30)
38         this.repaint /* .. and redraw */
39         Thread.sleep(119) /* wait awhile */
40     catch InterruptedException
41     end
42     timer=null /* discard */
43
44 method update(g=Graphics) /* override Applet's update */
45     paint(g) /* method to avoid flicker */
46
47 method paint(g=Graphics)
48     g.drawImage(shadow, 0, 0, null)

```

- Full-function, where decimal arithmetic is used, and advantage is taken of the full power of the NetRexx runtime *Rexx* class.
An example using this style is the below *WordClock.nrx*.

Listing 18.3: WordClock

```

1  /* WordClock -- an applet that shows the time in English. */
2  /*

```

```

3  /* Parameters:                                     */
4  /*                                     */
5  /*   face -- the font face to use                 */
6  /*   size -- the font size to use                 */
7  /*                                     */
8  /* ----- */
9  /* Based on the ancient QTIME.REXX, and typical Java applets. */
10
11 class WordClock extends Applet implements Runnable
12
13 timer=Thread null          /* the timer thread */
14 offsetx; offsety          /* text position */
15 now                       /* current time */
16
17 method init
18 /* Get parameters from the <applet> markup */
19 face=getParameter("face") /* font face */
20 if face=null then face="TimesRoman"
21 size=getParameter("size")
22 if size=null then size="20" /* font size */
23
24 setFont(Font(face, Font.BOLD, size))
25 resize(size*20, size*2) /* set window size */
26 offsetx=size/2          /* and where text will start */
27 offsety=size*3/2        /* note Y is from top */
28 parse Date() . . . now . /* initial time is fourth word */
29
30 method start
31 if timer=null then timer=Thread(this) /* new thread */
32 timer.setPriority(Thread.MAX_PRIORITY) /* time matters */
33 timer.start /* start the thread */
34
35 method stop
36 if timer\=null then do /* have thread */
37     timer.stop /* .. so stop it */
38     timer=null /* .. and discard */
39 end
40
41 method run
42 /* Use the Java Date class to get the time */
43 loop while timer\=null
44     parse Date() . . . now . /* time is fourth word */
45     this.repaint /* redisplay */
46     parse now ':' ':'secs /* where in minute */
47     wait=30-secs /* calculate delay in seconds */
48     if wait<=0 then wait=wait+60
49     /* say 'secs, wait:' secs wait */
50     Thread.sleep(1000*wait) /* wait for milliseconds */
51 catch InterruptedException
52     say 'Interrupted...'
53 end
54 timer=null /* done */
55
56 method paint(g=Graphics)
57 g.drawString(wordtime(now), offsetx, offsety) /* show it */
58
59 /* WORDTIME -- a cut-down version of QTIME.REXX
60    Arg1 is the time string (hh:mm:ss)
61    Returns the time in english, as a Rexx string
62    */
63 method wordtime(arg) static returns Rexx
64 /* Extract the hours, minutes, and seconds from the time. */
65 parse arg hour ':' 'min' ':' 'sec'
66 if sec>29 then min=min+1 /* round up minutes */
67
68 /* Nearness phrases - this time using an array */
69 near=Rexx[5] /* five items */
70 near[0]='' /* exact */
71 near[1]=' just gone'; near[2]=' just after' /* after */
72 near[3]=' nearly'; near[4]=' almost' /* before */
73
74 mod=min//5 /* where we are in 5 minute bracket */
75 out="It's"near[mod] /* start building the result */

```

```

76 if min>32 then hour=hour+1 /* we are TO the hour... */
77 min=min+2 /* shift minutes to straddle a 5-minute point */
78
79 /* Now special-case the result for Noon and Midnight hours */
80 if hour//12=0 & min//60<=4 then do
81   if hour=12 then return out 'Noon.'
82   return 'Midnight.'
83 end
84
85 min=min-(min//5) /* find nearest 5 mins */
86 if hour>12
87 then hour=hour-12 /* get rid of 24-hour clock */
88 else
89   if hour=0 then hour=12 /* .. and allow for midnight */
90
91 /* Determine the phrase to use for each 5-minute segment */
92 select
93   when min=0 then nop /* add "o'clock" later */
94   when min=60 then min=0 /* ditto */
95   when min= 5 then out=out 'five past'
96   when min=10 then out=out 'ten past'
97   when min=15 then out=out 'a quarter past'
98   when min=20 then out=out 'twenty past'
99   when min=25 then out=out 'twenty-five past'
100  when min=30 then out=out 'half past'
101  when min=35 then out=out 'twenty-five to'
102  when min=40 then out=out 'twenty to'
103  when min=45 then out=out 'a quarter to'
104  when min=50 then out=out 'ten to'
105  when min=55 then out=out 'five to'
106 end
107
108 numbers='one two three four five six'- /* continuation */
109 'seven eight nine ten eleven twelve '
110 out=out numbers.word(hour) /* add the hour number */
111 if min=0 then out=out "o'clock" /* .. and o'clock if exact */
112
113 return out'.' /* return the final result */
114
115 /* Mike Cowlishaw, December 1979 - January 1985. */
116 /* NetRexx version March 1996; applet April 1996. */

```

If you write applets which use the NetRexx runtime (or any other Java classes that might not be on the client browser), the rest of this section may help in setting up your Web server.

A good way of setting up an HTTP (Web) server for this is to keep all your applets in one subdirectory. You can then make the NetRexx runtime classes (that is, the classes in the package known to the Java Virtual Machine as *netrexx.lang*) available to all the applets by unzipping NetRexxR.jar into a subdirectory *netrexx/lang* below your applets directory.

For example, if the root of your server data tree is

D:\mydata

you might put your applets into

D:\mydata\applets

and then the NetRexx classes (unzipped from NetRexxR.jar) should be in the directory

D:\mydata\applets\netrexx\lang

The same principle is applied if you have any other non-core Java packages that you want to make available to your applets: the classes in a package called *iris.sort.quicksorts* would

go in a subdirectory below *applets* called *iris/sort/quicksorts*, for example.

Note that since Java 1.1 or later it is possible to use the classes direct from the NetRexxR.jar file.

18.3 Swing

Swing is the most commonly used name for the second attempt from the SUN engineers to provide a graphical user interface library for the JVM. With AWT also acknowledged by SUN to be a quick attempt that was made just before release of the first Java package, it became clear that it was rather taxing on system resources without compensation by a pretty look. A case in point is the event mechanism, that indiscriminately sends around mouse and keyboard events even when nobody is listening to them. The architecture for Swing prescribes registering for events before they are produced, and tries to have the drawing done by the Java graphics engine instead of leaning heavily on the operating system's native GUI functionality. The user interface widgets that are produced by Java are called 'light' and their looks can be changed by applying different skins, called '*look-and-feel*' (LAF) libraries.

In the first months of its existence Swing gathered quite a bad reputation because it made the Java 1.2 releases that contained it very slow in starting up programs that used the library. Consequently, much was invested in performance studies by SUN engineers and these problems were solved. One of the things that came out is that dividing the libraries in a great many classes, done for performance reasons, worked counterproductive. All these problems were solved over the years, and developments in hardware and multi-threading took care of the rest, and nowadays Swing is a valid way of producing a rich client user interface.

For esthetical reasons, it is best to research a bit in the third party look-and-feel libraries that can be obtained. Swing can be made to look beautiful, but it takes some care and the defaults are not helping.

18.3.1 Creating NetRexx Swing interfaces with NetBeans

18.4 Web Frameworks

18.4.1 JSF

Network Programming

19.1 Using Uniform Resource Locators (URL)

19.2 TCP/IP Socket I/O

19.3 RMI: Remote Method Interface

Database Connectivity with JDBC

For interfacing with Relational Database Management Systems (RDBMS) NetREXX uses the Java Data Base Connectivity (JDBC) model. This means that all important database systems, for which a JDBC driver has been made available, can be used from your NetREXX program. This is a large bonus when we compare this to the other open source scripting languages, that have been made go by with specific, nonstandard solutions and special drivers. In contrast, NetREXX programs can be made compatible with most database systems that use standard SQL, and, with some planning and care, can switch database implementations at will.

Listing 20.1: A JDBC Query example

```

1  /* jdbc\JdbcQry.nrx
2
3  This NetRExx program demonstrate DB2 query using the JDBC API.
4  Usage: Java JdbcQry [<DB-URL>] [<userprefix>] */
5
6  import java.sql.
7
8  parse arg url prefix          -- process arguments
9  if url = '' then
10     url = 'jdbc:db2:sample'
11 else do                      -- check for correct URL
12     parse url p1 ':' p2 ':' rest
13     if p1 \= 'jdbc' | p2 \= 'db2' | rest = '' then do
14         say 'Usage: java JdbcQry [<DB-URL>] [<userprefix>]'
15         exit 8
16     end
17 end
18 if prefix = '' then prefix = 'userid'
19
20 do                          -- loading DB2 support
21     say 'Loading DB2 driver classes...'
22     Class.forName('COM.ibm.db2.jdbc.app.DB2Driver').newInstance()
23     -- Class.forName('COM.ibm.db2.jdbc.net.DB2Driver').newInstance()
24 catch e1 = Exception
25     say 'The DB2 driver classes could not be found and loaded !'
26     say 'Exception (' e1 ') caught : \n' e1.getMessage()
27     exit 1
28 end                          -- end : loading DB2 support
29
30 do                          -- connecting to DB2 host
31     say 'Connecting to:' url
32     jdbcCon = Connection DriverManager.getConnection(url, 'userid', 'password')
33 catch e2 = SQLException
34     say 'SQLException(s) caught while connecting !'
35     loop while (e2 \= null)
36         say 'SQLState:' e2.getSQLState()
37         say 'Message: ' e2.getMessage()
38         say 'Vendor: ' e2.getErrorCode()
39         say
40         e2 = e2.getNextException()
41     end
42     exit 1
43 end                          -- end : connecting to DB2 host

```

```

44
45 do                                     -- get list of departments with the managers
46   say 'Creating query...'
47   query = 'SELECT deptno, deptname, lastname, firstnme' -
48           'FROM' prefix'.DEPARTMENT dep,' prefix'.EMPLOYEE emp'-
49           'WHERE dep.mgrno=emp.empno ORDER BY dep.deptno'
50   stmt = Statement jdbcCon.createStatement()
51   say 'Executing query:'
52   loop i=0 to (query.length()-1)%75
53     say ' ' query.substr(i*75+1,75)
54   end
55   rs = ResultSet stmt.executeQuery(query)
56   say 'Results:'
57   loop row=0 while rs.next()
58     say rs.getString('deptno') rs.getString('deptname') -
59        'is directed by' rs.getString('lastname') rs.getString('firstnme')
60   end
61   rs.close()                               -- close the ResultSet
62   stmt.close()                             -- close the Statement
63   jdbcCon.close()                         -- close the Connection
64   say 'Retrieved' row 'departments.'
65 catch e3 = SQLException
66   say 'SQLException(s) caught !'
67   loop while (e3 \= null)
68     say 'SQLState:' e3.getSQLState()
69     say 'Message: ' e3.getMessage()
70     say 'Vendor: ' e3.getErrorCode()
71     say
72     e3 = e3.getNextException()
73   end
74 end                                     -- end: get list of departments

```

The first peculiarity of JDBC is the way the driver class is loaded. When most classes are 'pulled in' by the translator, a JDBC driver traditionally is loaded through the reflection API. This happens in line 22 with the `Class.forName` call. This implies that the library containing this class must be on the classpath.

In previous versions of JDBC, to obtain a connection, one first had to initialize the JDBC driver by calling the method `Class.forName`. Any JDBC 4.0 drivers that are found on the class path are automatically loaded. (However, one must manually load any drivers prior to JDBC 4.0 with the method `Class.forName`.)

In line 32 of the example we connect to the database using a url and a userid/password combination. This is an easy way to do and test, but for most serious applications we do not want plaintext userids and passwords in the sourcecode, so most of the time we would store the connection info in a file that we store in encrypted form, or we use facilities of J2EE containers that can provide data sources that take care of this, while at the same time decoupling your application source from the infrastructure that it will run on.

In line 47 the query is composed by filling in variables in a Rexx string and making a `Statement` out of it, in line 50. In line 55, the `Statement` is executed, which yields a `ResultSet`. This has a *cursor* that moves forward with each `next` call. The next call returns *true* as long as there are rows from the resultset to return.

The `ResultSet` interface implements *getter* methods for all JDBC Types. In the above example, all returned results are of type `String`.

Listing 20.2: A JDBC Update example

```

1  /* jdbc\JdbcUpd.nrx
2
3  This NetRexx program demonstrate DB2 update using the JDBC API.
4  Usage: Java JdbcUpd [<DB-URL>] [<userprefix>] [U] */
5
6  import java.sql.
7
8  parse arg url prefix lowup    -- process arguments
9  if url = '' then
10     url = 'jdbc:db2:sample'
11  else do                      -- check for correct URL
12     parse url p1 ':' p2 ':' rest
13     if p1 \= 'jdbc' | p2 \= 'db2' | rest = '' then do
14         say 'Usage: java JdbcUpd [<DB-URL>] [<userprefix>] [U]'
15         exit 8
16     end
17  end
18  if prefix = '' then prefix = 'userid'
19  if lowup \= 'U' then lowup = 'L'
20
21  do                          -- loading DB2 support
22     say 'Loading DB2 driver classes...'
23     Class.forName('COM.ibm.db2.jdbc.app.DB2Driver').newInstance()
24     -- Class.forName('COM.ibm.db2.jdbc.net.DB2Driver').newInstance()
25  catch e1 = Exception
26     say 'The DB2 driver classes could not be found and loaded !'
27     say 'Exception (' e1 ') caught : \n' e1.getMessage()
28     exit 1
29  end                          -- end : loading DB2 support
30
31  do                          -- connecting to DB2 host
32     say 'Connecting to:' url
33     jdbcCon = Connection DriverManager.getConnection(url, 'userid', 'password')
34  catch e2 = SQLException
35     say 'SQLException(s) caught while connecting !'
36     loop while (e2 \= null)
37         say 'SQLState:' e2.getSQLState()
38         say 'Message: ' e2.getMessage()
39         say 'Vendor: ' e2.getErrorCode()
40         say
41         e2 = e2.getNextException()
42     end
43     exit 1
44  end                          -- end : connecting to DB2 host
45
46  do                          -- retrieve employee, update firstname
47
48     say 'Preparing update...'    -- prepare UPDATE
49     updateQ = 'UPDATE' prefix'.EMPLOYEE SET firstnme = ? WHERE empno = ?'
50     updateStmt = PreparedStatement jdbcCon.prepareStatement(updateQ)
51     say 'Creating query...'      -- create SELECT
52     query = 'SELECT firstnme, lastname, empno FROM' prefix'.EMPLOYEE'
53     stmt = Statement jdbcCon.createStatement()
54     rs = ResultSet stmt.executeQuery(query) -- execute select
55
56     loop row=0 while rs.next()    -- loop employees
57         firstname = String rs.getString('firstnme')
58         if lowup = 'U' then firstname = firstname.toUpperCase()
59         else do
60             dChar = firstname.charAt(0)
61             firstname = dChar || firstname.substring(1).toLowerCase()
62         end
63         updateStmt.setString(1, firstname)    -- parms for update
64         updateStmt.setString(2, rs.getString('empno'))
65         say 'Updating' rs.getString('lastname') firstname ': \0'
66         say updateStmt.executeUpdate() 'row(s) updated' -- execute update
67     end
68
69     rs.close()                  -- close the ResultSet
70     stmt.close()                -- close the Statement
71     updateStmt.close()          -- close the PreparedStatement

```

```

72 jdbcCon.close()                -- close the Connection
73 say 'Updated' row 'employees.'
74 catch e3 = SQLException
75   say 'SQLException(s) caught !'
76   loop while (e3 \= null)
77     say 'SQLState:' e3.getSQLState()
78     say 'Message: ' e3.getMessage()
79     say 'Vendor: ' e3.getErrorCode()
80     say
81     e3 = e3.getNextException()
82   end
83 end                             -- end: employees

```

For database updates, we connect using the driver in the same way (line 23) and now prepare the statement used for the database update (line 50). In this example, we loop through the cursor of a select statement and update the row in line 66. The `executeUpdate` method of `PreparedStatement` returns the number of updated rows as an indication of success.

From JDBC 2.0 on, cursors are updateable (and scrollable, so they can move back and forth), so we would not have to go through this effort - but it is a valid example of an update statement.

WebSphere MQ

WebSphere MQ (also and maybe better known as MQ Series) is IBM's messaging and queuing middleware, and is in use at a great many financial institutions and other companies. It has, from a programming point of view, two API's: JMS (Java Messaging Services), a generic messaging API for the Java world, and MQI, which is older and proprietary to IBM's product. The below examples show the MQI; other examples might show JMS applications.

This is the sample Java application for MQI, translated (and a lot shorter) to NetRexx.

Listing 21.1: MQ Sample

```

1 import com.ibm.mq.MQException
2 import com.ibm.mq.MQGetMessageOptions
3 import com.ibm.mq.MQMessage
4 import com.ibm.mq.MQPutMessageOptions
5 import com.ibm.mq.MQQueue
6 import com.ibm.mq.MQQueueManager
7 import com.ibm.mq.constants.MQConstants
8
9 class MQSample
10 properties private
11
12 qManager = "rjtestqm";
13 qName = "SYSTEM.DEFAULT.LOCAL.QUEUE"
14
15 method main(args=String[]) static binary
16 m = MQSample()
17 do
18 say "Connecting to queue manager: " m.qManager
19 qMgr = MQQueueManager(m.qManager)
20
21 openOptions = MQConstants.MQOO_INPUT_AS_Q_DEF | MQConstants.MQOO_OUTPUT
22
23 say "Accessing queue: " m.qName
24 queue = qMgr.accessQueue(m.qName, openOptions)
25
26 msg = MQMessage()
27 msg.writeUTF("Hello, World!")
28
29 pmo = MQPutMessageOptions()
30
31 say "Sending a message..."
32 queue.put(msg, pmo)
33
34 rcvMessage = MQMessage()
35
36 gmo = MQGetMessageOptions()
37
38 say "...and getting the message back again"
39 queue.get(rcvMessage, gmo)
40
41 msgText = rcvMessage.readUTF()
42 say "The message is: " msgText
43
44 say "Closing the queue"
45 queue.close()
46

```

```

47     say "Disconnecting from the Queue Manager"
48     qMgr.disconnect()
49     say "Done!"
50 catch ex=MQException
51     say "A WebSphere MQ Error occurred : Completion Code " ex.completionCode "Reason
      Code " ex.reasonCode
52 catch ex2=java.io.IOException
53     say "An IOException occurred whilst writing to the message buffer: " ex2
54 end

```

This sample connects to the Queue Manager (called *rjtestqm*) in *bindings mode*, as opposed to *client mode*. Bindings mode is only a connection possibility for client programs that are running in the same OS image as the Queue Manager, on the server. Note that the application connects (line 19), accesses a queue (line 23), puts a message (line 32), gets it back (line 39) closes the queue (line 45) and disconnects (line 48) all without checking returncodes: the exceptionhandler takes care of this, and all irregularities will be reported from the catch MQException block starting at line 50).

The main method does in this case not follow the canonical form, but has 'binary' as an extra option. Option binary can be defined on the command line as an option to the translator, as a program option, as a class option and as a method option. Here the smallest scope is chosen. There is a good reason to make this method a binary method: accessing a queue in MQ Series requires some options that are set using a mask of binary flags - this works, in current NetREXX versions, only in binary mode, because the operators have other semantics in nobinary mode.

Listing 21.2: MQ Message Reader

```

1  import com.ibm.mq.
2
3  class MessageReader
4      properties private
5
6      qManager = "rjtestqm";
7      qName    = "TESTQUEUE1"
8
9      method main(args=String[]) static binary
10
11         m = MessageReader()
12         do
13             MQEnvironment.hostname = 'localhost'
14             MQEnvironment.port = int 1414
15             MQEnvironment.channel = 'CHANNEL1'
16
17             -- exit assignment
18             exits = TimeoutChannelExit()
19             MQEnvironment.channelReceiveExit = exits
20             MQEnvironment.channelSendExit = exits
21             MQEnvironment.channelSecurityExit = exits
22
23             say "Connecting to QM: " m.qManager
24             qMgr = MQQueueManager(m.qManager)
25
26             openOptions = MQConstants.MQOO_INPUT_AS_Q_DEF
27
28             say "Accessing Queue : " m.qName
29             queue = qMgr.accessQueue(m.qName, openOptions)
30
31             gmo = MQGetMessageOptions() -- essential here is that we have MQGMO_WAIT;
32             gmo.Options = MQConstants.MQGMO_WAIT | MQConstants.MQGMO_FAIL_IF_QUIESCING |
33             MQConstants.MQGMO_SYNCPOINT
34             gmo.WaitInterval = MQConstants.MQWI_UNLIMITED
35
36             loop forever
37                 rcvMessage = MQMessage()

```

```

37 queue.get(rcvMessage, gmo)
38 msgText = rcvMessage.readUTF()
39 say "Got a message; the message is: " msgText
40 say
41 end
42
43 catch ex=MQException
44   say "A WebSphere MQ Error occured : Completion Code " ex.completionCode "Reason
      Code " ex.reasonCode
45   say "Closing the queue"
46   queue.close()
47   say "Disconnecting from the Queue Manager"
48   qMgr.disconnect()
49   say "Done!"
50 end

```

In contrast to the previous sample the MessageReader sample only has one import statement. This is always hotly debated in project teams, one school likes the succinctness of including only the top level import, and only goes deeper when there is ambiguity detected; another school spells out the all imports to the bitter end.

The MessageReader sample connects to another queue, called TESTQUEUE1 (specified in line 7) but here we connect in *client mode*, as indicated by lines 13-15 which specify an MQEnvironment. Other options are using an MQSERVER environment variable or a *Channel Definition Table*.

This program is also uncommon in that it uses MQConstants.MQGMO_WAIT as an option instead of being triggered as a process by a message on a trigger queue. Using this option means that the program waits (stays active, not really busy polling but depending on an OS event) until a new message arrives, which will be processed immediately.

In lines 18-21 a *Channel Exit* is specified. This exit is show in the following example.

Listing 21.3: MQ Java Channel Exit

```

1 import com.ibm.mq.
2 import java.nio.
3
4 class TimeoutChannelExit implements WMQSendExit, WMQReceiveExit, WMQSecurityExit
5
6   properties
7
8   tTask = WatchdogTimer
9   t = java.util.Timer
10  timeout = long
11  initialized = boolean
12
13  method TimeoutChannelExit()
14    say "TimeoutChannelExit Constructor Called"
15    t = java.util.Timer()
16    timeout = long 15000
17
18  method channelReceiveExit(channelExitParms=MQCXP, -
19    channelDefinition=MQCD, -
20    agentBuffer=ByteBuffer) returns ByteBuffer
21  do
22    this.tTask.cancel() -- cancel the timer task whenever a message is read
23  catch NullPointerException -- but catch the null pointer the first time
24  end
25  this.tTask = WatchdogTimer()
26  this.t.schedule(this.tTask,this.timeout)
27  return agentBuffer
28
29  method channelSecurityExit(channelExitParms=MQCXP, -
30    channelDefinition=MQCD, -
31    agentBuffer=ByteBuffer) returns ByteBuffer
32  return agentBuffer

```



```

33
34 method channelSendExit(channelExitParms=MQCXP, -
35     channelDefinition=MQCD, -
36     agentBuffer=ByteBuffer) returns ByteBuffer
37     return agentBuffer

```

Listing 21.4: WatchdogTimer

```

1 class WatchdogTimer extends TimerTask
2
3 method WatchdogTimer()
4 method run()
5     say 'WATCHDOG TIMER TIMEOUT: HPOpenView Alert Issued' Date()

```

MQ Series has traditional channel exits (programs that can look at the message contents before the application gets to it). In the MQI Java environment there is something akin to this functionality, but a Java channel exit for MQ Series has to be defined in the application, as shown in the previous example. The function of this particular exit is to implement a *Watchdog timer* - on a separate thread, as shown in the sample that follows the sample channel exit. The timer threatens here to have issues a HP OpenView alert, but that part has been left out.

This particular sample has been designed to do something that is normally a bit harder to do: signal the operations department when something does NOT happen - here the assumption is that there is a payment going over the queue at least once every 20 minutes - when that does not happen, an alert is issued. With every message that goes through, the timer thread is reset, and only when it is allowed to time out, action is undertaken.

Listing 21.5: Publish/Subscribe

```

1 import com.ibm.mq.
2
3 class MQPubSubSample
4
5     properties inheritable
6     queueManagerName = String
7     syncPoint = Object()
8     props = Hashtable
9     topicString = String
10    topicObject = String
11    subscribers = Thread[]
12    subscriberCount = int
13
14    properties volatile inheritable
15    readySubscribers = int 0 --must be defined volatile
16
17    method MQPubSubSample()
18        topicString = null
19        topicObject = System.getProperty("com.ibm.mq.pubSubSample.topicObject", "
20            TESTTOPIC")
21        queueManagerName = System.getProperty("com.ibm.mq.pubSubSample.queueManagerName", "
22            rjtestqm")
23        subscriberCount = Integer.getInteger("com.ibm.mq.pubSubSample.subscriberCount",
24            100).intValue()
25        this.props = Hashtable()
26        this.props.put("hostname", "127.0.0.1")
27        this.props.put("port", Integer(1414))
28        this.props.put("channel", "SYSTEM.DEF.SVRCONN")
29
30    method main(agr=String[]) static binary
31        sample = MQPubSubSample()
32        sample.launchSubscribers()
33
34    /*
35    * wait until all the subscriber threads have finished the subscription
36    */

```

```

33  */
34  do protect sample.syncPoint
35    loop while sample.readySubscribers < sample.subscriberCount
36      do
37        sample.syncPoint.wait()
38        catch InterruptedException
39          end
40        end -- loop while sample
41      end -- do
42
43      sample.doPublish()
44
45  method launchSubscribers()
46    say "Launching the subscribers"
47    subscribers = Thread[subscriberCount]
48
49    threadNo = int 0
50    loop while threadNo < this.subscribers.length
51      this.subscribers[threadNo] = MQPubSubSample.Subscriber("Subscriber" threadNo)
52      this.subscribers[threadNo].start()
53      threadNo = threadNo + 1
54    end
55
56  method doPublish() signals IOException
57    say "method doPublish started"
58    destinationType = int CMQC.MQOT_TOPIC
59    do
60      queueManager = MQQueueManager(this.queueManagerName, this.props)
61      messageForPut = MQMessage()
62      say "***Publishing ***"
63      messageForPut.writeString("Hello world!")
64      queueManager.put(destinationType, topicObject, messageForPut)
65    catch e=MQException
66      say "Exception while publishing " e
67    end
68
69  class MQPubSubSample.Subscriber binary dependent extends Thread
70
71    properties private
72    myName = String
73    openOptionsForGet = int CMQC.MQSO_CREATE | CMQC.MQSO_FAIL_IF QUIESCING | CMQC.
      MQSO_MANAGED | CMQC.MQSO_NON_DURABLE
74
75  method Subscriber(subscriberName=String)
76    super(subscriberName)
77    myName = subscriberName
78
79  method run()
80    do
81      say myName " - ***Subscribing***"
82      queueManager = MQQueueManager(parent.queueManagerName, parent.props)
83      destinationForGet = queueManager.accessTopic(parent.topicString, parent.
        topicObject, CMQC.MQTOPIC_OPEN_AS_SUBSCRIPTION, openOptionsForGet)
84
85      do protect parent.syncpoint
86        parent.readySubscribers = parent.readySubscribers + 1
87        parent.syncPoint.notify()
88      end
89
90      mgmo = MQGetMessageOptions()
91      mgmo.options = CMQC.MQGMO_WAIT
92      mgmo.waitInterval = 30000
93      say myName " - ***Retrieving***"
94      messageForGet = MQMessage()
95
96      do protect getClass()
97        destinationForGet.get(messageForGet, mgmo)
98      end
99
100      messageDataFromGet = String messageForGet.readLine()
101      say myName " - Got [" messageDataFromGet "]"
102
103    catch e=Exception

```

```
104     say myName " " e
105     e.printStackTrace()
106 end
107 parent.readySubscribers = parent.readySubscribers - 1
```

This sample shows the publish-subscribe interfaces that at some time have been added to the product. This specific sample shows some Java thread complexity but is a good example of doing publish/subscribe work in a multithreaded way, which is a natural fit for this type of work.

MQTT

22.1 Pub/Sub with MQ Telemetry

Publish/subscribe (pub/sub) is a model that lends itself very well to a number of one publisher, many subscriber type of applications; the tools to enter this technology have never been as available as they are now. Also, MQTT is a small protocol that needs to be taken seriously: Facebook has recently become one of the largest users.

Designed as a low-overhead on-the-wire protocol for brokers in the Internet-of-things age, MQTT is an exciting new development in the Messaging and Queueing realm. It is a good choice for any broker functionality, as the minimal message overhead is 2 bytes, but the maximum messages size, in one of the more popular open source brokers is a good 250MB, which give you a message size that is a lot higher than anything possible in the early years of MQ Series back in the nineties. It is now possible to do development with an entry level, entirely open source suite, and scale up to commercial, clustered and highly available implementations when needed, since the protocol has is supported by the base IBM WebSphere MQ product and is an added deliverable in WSMQ 7.5, after being available as an installable add-on for several years.

Here I will show how extremely straightforward it is to create a pub/sub application using this technology. These examples use NetRexx, the Eclipse PAHO Java client library and the open source Mosquitto broker; all these components are completely free and open source. I have installed Mosquitto on my MacBook using the brew system(fn), which makes it as much trouble as “sudo brew install mosquitto”. NetRexx is an excellent language for these examples, as it is compact and avoids the C-inspired ceremony of Java language syntax; if your project requires Java, you can just save the generated Java source (using the new `-keepasjava` option).

Mosquitto(fn) is written by Roger Light as an open source equivalent of IBM’s rsmb (real small message broker) example application, which is free but lacks source code. It is a small broker application that nevertheless runs production sized workloads. As MQTT, as opposed to the MQI or JMS API’s you use when developing a messaging application, is an on-the-wire protocol (commercial messaging systems tend to have their own, unpublished, on-the-wire protocols), we need an API to use it. This API consists of a set of calls that do the formatting of the messages to the requirements of the on-the-wire protocol for you. The messages themselves are just byte-arrays, which gives you the ultimate freedom in designing their content. It is not unusual for connected devices to encode their information in a few bits; on the other hand, there is no reason not to use extreme verbosity in messages; as long as you send the `.getBytes` that your String yields, MQTT will send it. When encoding information in a compact way, the protocol design

will really pay off, because the protocol overhead, in comparison with http and other chatty protocols, is very low. A limited set of quality of service options (qos) will indicate if you want send and pray, acknowledged delivery or acknowledged one-time-only delivery.

The API library that was chosen for these examples is that from the Eclipse PAHO project. This project, which is in its early stages, has C, Javascript and Java client libraries available. I chose the Java client because the JVM environment is where most of the organizations that I work for will use it. The PAHO Java client library is donated by IBM and written by Dave Locke; it is in active development. If you want to see how the protocol moves in packets over the network, I can recommend Wireshark, which does a good job of recognizing them (if you run on the standard port 1883) and showing you the message types (like ACK) and their bytes.

After having put the NetRexx(.jar) and paho client jars on your classpath, you are good to go. The first example here is the publisher – this is not a fragment, but the complete code. For production code we might add some more checks, as enterprise environments always are prone to suddenly run low on disk space and suffer missing authorizations, but it works as it stands. Do note that you do not have to define a message topic in advance – just think of one any use it, at least if you are in your own environment. With Mosquitto, there wasn't anything to define in advance, and the running Publisher (happily lifted from the Java example) in NetRexx was actually the first time I talked to Mosquitto on my MacBook.

Listing 22.1: MQTT Publish Sample

```
1 import java.sql.Timestamp
2 import org.eclipse.paho.client.mqttv3.
3
4 class Publish implements MqttCallback
5
6   method Publish()
7     conOpt = MqttConnectOptions()
8     conOpt.setCleanSession(0)
9     tmpDir = System.getProperty("java.io.tmpdir")
10    dataStore = MqttDefaultFilePersistence(tmpDir)
11    clientId = MqttClient.generateClientId()
12    topicName = "/world"
13    payload = "hello".toString().getBytes()
14    qos = 2
15
16    do
17      broker = "localhost"
18      port = "1883"
19      brokerUrl = "tcp://"broker":"port
20      client = MqttClient(brokerUrl,clientId, dataStore)
21      client.setCallback(this)
22    catch e=mqttException
23      say e.getMessage()
24      e.printStackTrace()
25    end -- do
26
27    client.connect()
28    log("Connected to "brokerUrl" with client ID "clientId)
29
30    -- Get an instance of the topic
31    topic = client.getTopic(topicName)
32
33    message = MqttMessage(payload)
34    message.setQos(qos)
35
36    -- Publish the message
37    time = Timestamp(System.currentTimeMillis()).toString()
```

```

38 log('Publishing at: 'time' to topic "'topicName'" with qos 'qos')
39 token = topic.publish(message)
40
41 -- Wait until the message has been delivered to the server
42 token.waitForCompletion()
43
44 -- Disconnect the client
45 client.disconnect()
46 log("Disconnected")
47
48
49 method log(line)
50   say line
51
52 method messageArrived(t=String,m=MqttMessage)
53   log("Message Arrived: " t m)
54
55 method deliveryComplete(t=IMqttDeliveryToken)
56   log("Delivery Complete: " t)
57
58 method connectionLost(t=Throwable)
59   log("Connection Lost:" t.getMessage())
60
61 method main(args=String[]) static
62   Publish()

```

Topics can have a hierarchical organization; this structure is put in by composing trees of topics, which are strings separated by '/'. In this way, it is easy to compose a /news/economics/today topic string that gives some structure to the publication. The classification is entirely up to the designer.

Messaging in its original form is an asynchronous technology, and for this reason the API offers a callback option, where the callback receives the results of your publish action in an asynchronous way. The broker assigns a message id which you receive back.

The second source fragment (and again, it is no fragment but the entire application program) shows the subscriber.

Listing 22.2: MQTT Subscribe Sample

```

1 import java.sql.Timestamp
2 import org.eclipse.paho.client.mqttv3.
3
4 class Subscribe implements MqttCallback
5
6   properties private
7   client = MqttClient
8   conOpt = MqttConnectOptions()
9   tmpDir = System.getProperty("java.io.tmpdir")
10  clientId = MqttClient.generateClientId()
11  topicName = "/world"
12  qos = 2
13
14  method Subscribe()
15    do
16      connectAndSubscribe()
17    catch mx=MqttException
18      log(mx.getMessage())
19    end
20    -- Block until Enter is pressed
21    log("Press <Enter> to exit");
22    do
23      System.in.read()
24    catch IOException
25    end
26
27    -- Disconnect the client
28    client.disconnect()
29    log("Disconnected")

```

```

30
31 method connectAndSubscribe() signals MqttSecurityException,MqttException
32 conOpt.setCleanSession(1)
33 dataStore = MqttDefaultFilePersistence(tmpDir)
34 do
35     broker = "localhost"
36     port = "1883"
37     brokerUrl = "tcp://"broker":"port
38     client = MqttClient(brokerUrl,clientId, dataStore)
39     client.setCallback(this)
40 catch e=mqttException
41     say e.getMessage()
42     e.printStackTrace()
43 end -- do
44
45 this.client.connect()
46 log("Connected to "brokerUrl" with client ID "client.getClientId())
47
48 -- Subscribe to the topic
49 log('Subscribing to topic "'topicName'" qos 'qos)
50 this.client.subscribe(topicName, qos)
51
52 method log(line)
53     say line
54
55 method messageArrived(t=String,m=MqttMessage)
56     log("Message Arrived: " t m)
57
58 method deliveryComplete(t=IMqttDeliveryToken)
59     log("Delivery Complete: " t)
60
61 method connectionLost(t=Throwable)
62     do
63         connectAndSubscribe()
64     catch mx=MqttException
65         log(mx.getMessage())
66     end
67
68 method main(args=String[]) static
69     Subscribe()

```

In the home setup, there is a Raspberry PI running the client while a server in the attic runs the Mosquitto broker. On the Raspberry, which runs Debian wheezy with the soft-float ABI that, at the moment of writing, is still necessary for the Oracle ARM Java implementation; everything done in NetRexx runs unchanged; I just move the classes to it using scp. The broker on the laptop takes care of the scenario in which I suddenly can do some development while not connected to the net, like when I have some moments to reflect on the code in the IKEA restaurant while my spouse runs the serious shopping business.

Security is outside of the scope of this introduction which shows you the sourcecode of a simple pub/sub application, but in Mosquitto the traffic can be secured using SSL certificates and userid/password combinations; also, the access to topics can be limited. In terms of availability, the Mosquitto configuration file offers an opportunity to send all messages for a defined set of topics to another connected broker, which might be in a different part of the world, or your home, to enable a redundant setup. While the broker does not offer the queue – transmission queue - channel setup with retrying channels that MQ does, the client API has some facilities to locally save the messages and retry if the communication was lost. Also, the last-will-and-testament facility is something that traditional MQ does not have.

Component Based Programming: Beans

JavaBeans is the name for the Java component model. It consists of two conventions, for the naming of *getter* and *setter* methods for properties, and the *event* mechanism for sending and receiving events. NetREXX adds support for the automatic generation of getter and setter methods, through the **properties indirect** option on the properties statement.

Using the NetRexxA API

As described elsewhere, the simplest way to use the NetRexx interpreter is to use the command interface (NetRexxC) with the *-exec* or *-arg* flags. There is also a more direct way to use the interpreter when calling it from another NetRexx (or Java) program, as described here. This way is called the *NetRexxA Application Programming Interface* (API).

The *NetRexxA* class is in the same package as the translator (that is, *org.netrexx.process*), and comprises a constructor and two methods. To interpret a NetRexx program (or, in general, call arbitrary methods on interpreted classes), the following steps are necessary:

1. Construct the interpreter object by invoking the constructor *NetRexxA()*. At this point, the environment's classpath is inspected and known compiled packages and extensions are identified.
2. Decide on the program(s) which are to be interpreted, and invoke the *NetRexxA parse* method to parse the programs. This parsing carries out syntax and other static checks on the programs specified, and prepares them for interpretation. A stub class is created and loaded for each class parsed, which allows access to the classes through the JVM reflection mechanisms.
3. At this point, the classes in the programs are ready for use. To invoke a method on one, or construct an instance of a class, or array, etc., the Java reflection API (in *java.lang* and *java.lang.reflect*) is used in the usual way, working on the *Class* objects created by the interpreter. To locate these *Class* objects, the API's *getClassObject* method must be used.

Once step 2 has been completed, any combination or repetition of using the classes is allowed. At any time (provided that all methods invoked in step 3 have returned) a new or edited set of source files can be parsed as described in step 2, and after that, the new set of class objects can be located and used. Note that operation is undefined if any attempt is made to use a class object that was located before the most recent call to the *parse* method.

Here's a simple example, a program that invokes the *main* method of the *hello.nrx* program's class:

Listing 24.1: Try the NetRexxA interface

```

1 options binary
2 import org.netrexx.process.NetRexxA
3
4 interpreter=NetRexxA()      -- make interpreter
5
6 files=['hello.nrx']         -- a file to interpret
7 flags=['nocrossref', 'verbose0'] -- flags, for example
8 interpreter.parse(files, flags) -- parse the file(s), using the flags
9

```

```

10 helloClass=interpreter.getClassObject(null, 'hello') -- find the hello Class
11
12 -- find the 'main' method; it takes an array of Strings as its argument
13 classes=[interpreter.getClassObject('java.lang', 'String', 1)]
14 mainMethod=helloClass.getMethod('main', classes)
15
16 -- now invoke it, with a null instance (it is static) and an empty String array
17 values=[Object String[0]]
18
19 loop for 10 -- let's call it ten times, for fun...
20   mainMethod.invoke(null, values)
21 end

```

Compiling and running (or interpreting!) this example program will illustrate some important points, especially if a **trace all** instruction is added near the top. First, the performance of the interpreter (or indeed the compiler) is dominated by JVM and other start-up costs; constructing the interpreter is expensive as the classpath has to be searched for duplicate classes, etc. Similarly, the first call to the parse method is slow because of the time taken to load, verify, and JIT-compile the classes that comprise the interpreter. After that point, however, only newly-referenced classes require loading, and execution will be very much faster.

The remainder of this section describes the constructor and the two methods of the NetRexxA class in more detail.

24.1 The NetRexxA constructor

Listing 24.2: Constructor

```

1 NetRexxA()

```

This constructor takes no arguments and builds an interpreter object. This process includes checking the classpath and other libraries known to the JVM and identifying classes and packages which are available.

24.2 The parse method

Listing 24.3: parse

```

1 parse(files=String[], flags=String[]) returns boolean

```

The parse method takes two arrays of Strings. The first array contains a list of one or more file specifications, one in each element of the array; these specify the files that are to be parsed and made ready for interpretation.

The second array is a list of zero or more option words; these may be any option words understood by the interpreter (but excluding those known only to the NetRexxC command interface, such as *time*).¹³ The parse method prefixes the *nojava* flag automatically, to prevent *.java* files being created inadvertently. In the example, *nocrossref* is supplied to stop a cross-reference file being written, and *verbose0* is added to prevent the logo and other progress displays appearing.

The *parse* method returns a boolean value; this will be 1 (true) if the parsing completed without errors, or 0 (false) otherwise. Normally a program using the API should test this

¹³Note that the option words are not prefixed with a -.

result an take appropriate action; it will not be possible to interpret a program or class whose parsing failed with an error.

24.3 The getClassObject method

Listing 24.4: getClassObject

```
1 getClassObject(package=String, name=String [,dimension=int]) returns Class
```

This method lets you obtain a Class object (an object of type *java.lang.Class*) representing a class (or array) known to the interpreter, including those newly parsed by a parse instruction.

The first argument, *package*, specifies the package name (for example, *com.ibm.math*). For a class which is not in a package, *null* should be used (not the empty string, "").

The second argument, *name*, specifies the class name (for example, *BigDecimal*). For a minor (inner) class, this may have more than one part, separated by dots.

The third, optional, argument, specifies the number of dimensions of the requested class object. If greater than zero, the returned class object will describe an array with the specified number of dimensions. This argument defaults to the value 0.

An example of using the *dimension* argument is shown above where the *java.lang.String[]* array Class object is requested.

Once a Class object has been retrieved from the interpreter it may be used with the Java reflection API as usual. The Class objects returned are only valid until the parse method is next invoked.

24.4 The exiting method

Syntax:

Listing 24.5: exiting

```
1 exiting() returns boolean
```

If this method returns true, an interpreted program has invoked the NetRexx "exit" instruction to shut down the interpreter. If more programs need to be interpreted, a new instance of the interpreter will need to be created with the NetRexxA() constructor.

24.5 Interpreting programs contained in memory strings

Programs can be interpreted directly from memory strings. The first extension adds an optional array of strings containing programs to the standard parse API. It is mainly useful to IDE developers. It also serves as the basis to support two other extensions documented below.

3.01

Listing 24.6: parse program in memory buffer

```
1 method parse(filestrings=String[], programstrings=String[], flagstrings=String[],  
    logfile=PrintWriter null, outfile=PrintStream System.out) returns boolean
```

Parses a set of files, under specified flags:

- filestrings is a list of program names,
- programstrings is a list of program strings¹⁴,
- flagstrings is a list of flags,
- logfile is a PrintWriter for parse output messages (optional),
- outfile is a PrintStream for console output messages (optional),

This method returns 1 if no error

The second extension is a new easy to use method to parse and interpret a program contained in a string.

Listing 24.7: parse program in string

```
1 method interpret(programname=String, programstring=String, argstring=String "",
    flagstring=String "", logfile=PrintWriter null, outfile=PrintStream System.out)
    returns boolean
```

A convenience method to interpret a single NetRexx program in a string:

- programname is the program name,
- programstring is the program string,
- argstring is the argument string (optional),
- flagstring is the translator flags string (optional),
- logfile is a PrintWriter for parse output messages (optional),
- outfile is a PrintStream for console output messages (optional),

This method returns 1 if no parse error. The default flag is -verbose0

Here is a simple example using the interpret method:

Listing 24.8: interpret from string

```
1 import org.netrexx.process.
2 netrexxapi=NetRexxA()
3 myprog="say 'argument string is' arg"
4 netrexxapi.interpret("myprog",myprog,"a passed argument")
```

The third extension is a slightly more complex “eval” method that allows a program to call a static method in a program string and receive an object back.

Listing 24.9: eval

```
1 method eval(programname=String, programstring=String, methodname=String, argstring=
    String "", flagstring=String "", logfile=PrintWriter null, outfile=PrintStream
    System.out) returns Object
```

A convenience method to interpret a method from a NetRexx program in a string and return an object:

- programname is the program name,
- programstring is the program string,
- methodname is the method name to call - the method must accept a String array like main methods,
- argstring is the argument string (optional),
- flagstring is the translator flags string (optional),

¹⁴Note that program strings which are not named in the name list are ignored.

- logfile is a PrintWriter for parse output messages (optional),
- outfile is a PrintStream for console output messages (optional),

This method returns an object if no error. The default flag is -verbose0

Here is a simple example using the eval method:

Listing 24.10: eval example

```
1 import org.netrexx.process.  
2 netrexxapi=NetRexxA()  
3 termpgmstring='method term(sa=String[]) static returns rexx;i=Rexx(sa);return 1/i'  
4 say netrexxapi.eval("termpgm",termpgmstring,"term",99)
```

Interfacing to Scripting Languages

NetREXX contains standardized Java Scripting support, and the NetRexxC.jar file is a self-contained JSR223 scripting engine. This facility opens up a number of possibilities to interface in a standardized manner with several scripting languages and other infrastructure, and offers an easy way for including interpreted NetREXX code in JVM applications. JSR223 is a standard for interacting with scripting languages that consists of:

1. A mechanism to find out for which scripting languages support is available
2. A way to choose one of them
3. An `eval()` call to dynamically specify and execute a program
4. A *bindings* mechanism to bind variable names to values, to exchange objects with scripts
5. Optionally, a way to execute methods, functions or routines from larger programs
6. Optionally, a way to keep already compiled scripts around for repeated execution (with associated higher performance)

The JSR223 specification¹⁵ details the calls that are available in the `javax.scripting` package. To use the JSR223 interface, Java 6 or higher is required. The JAR file specification defines a service as a well-known set of interfaces and (usually) abstract classes. A service provider is a specific implementation of such a service. For scripting, the service consists of `javax.script.ScriptEngineFactory`. All classes that implement this interface are service providers. Service providers identify themselves by placing a so-called provider-configuration file in `META-INF/services`. Its filename corresponds to the fully qualified name of the service class, which is `javax.script.ScriptEngineFactory`. Each line of this file contains the fully qualified name of a service provider. The factory class of the NetREXX connector is `org.netrexx.jsr223.NetRexxScriptEngineFactory`. So the file `META-INF/services/javax.script.ScriptEngineFactory` contains one line with exactly this class name.

25.1 Which JSR223 engines are on my system?

The number of JSR223 engines available varies per JVM implementation. The following code can be used to list these.

Listing 25.1: Enumerate the JSR223 Engines on a JVM

```
1 import javax.script.ScriptEngine
2 import javax.script.ScriptEngineFactory
```

¹⁵<http://www.jcp.org/en/jsr/detail?id=223>

```

3 import javax.script.ScriptEngineManager
4
5 method main(args=String[]) static
6     manager = ScriptEngineManager()
7     factories = manager.getEngineFactories()
8     it=factories.iterator()
9     loop while it.hasNext()
10         factory=ScriptEngineFactory it.next()
11         f=ScriptEngine factory.getScriptEngine()
12         say "className = " f.getClass.getName
13         engineName = factory.getEngineName()
14         engineVersion = factory.getEngineVersion()
15         if engineVersion = null then engineVersion = ''
16         langName = factory.getLanguageName()
17         langVersion = factory.getLanguageVersion()
18         say "engineName = " engineName engineVersion langName langVersion
19         say
20     end

```

For example, the Java 8 SE version by Oracle on macOS delivers out of the box:

```

1 className = com.oracle.truffle.js.scriptengine.GraalJSScriptEngine
2 engineName = Graal.js 20.0.0 ECMAScript ECMA - 262 Edition 9
3
4 className = jdk.nashorn.api.scripting.NashornScriptEngine
5 engineName = Oracle Nashorn 1.8.0_242 ECMAScript ECMA - 262 Edition 5.1
6
7 className = org.netrexx.jsr223.NetRexxScriptEngine
8 engineName = NetRexx Script Engine V1.0.0 NetRexx 3.09

```

As one can see, the name of the engine, the language and its release are standard features for this query. The NetRexxC.jar file on the classpath adds the NetREXX implementation. There can be any number of additional jar archives on the classpath to deliver engines for different JSR223 implementations for different languages.

25.2 Selecting an engine

When developing a program one is probably interested in using a specific implementation, and it is possible to request the loading of a specific JSR223 engine by name.

Listing 25.2: Choosing an engine

```

1 import javax.script.
2
3 manager = ScriptEngineManager()
4 nrEngine = manager.getEngineByName("NetRexx")

```

The language engine can be selected by its short name, so there is no need to specify the longer name or its version.

25.3 Evaluating a script

This example shows how to do a simple thing that illustrates the value of being able to do this from other environments: calculating some number with *numeric precision* set to some value that other languages cannot handle.

Listing 25.3: Evaluating a script

```
1 /* simple script invocation */
2 nrEngine.eval('numeric digits 17; say 111111111 * 111111111')
```

The output from this script would be:

12345678987654321

25.4 Bindings

Bindings are name-value pairs whose keys are strings - they can be of REXX type. Their behavior is defined through the `javax.script.Bindings` interface. As for `ScriptContext`, a basic implementation is provided called `SimpleBindings`. Although bindings belong to script contexts, `ScriptEngine` provides `createBindings()`, which returns an uninitialized binding. Another method, `getBindings()`, exists to return the bindings of a certain scope. There are at least two scopes, `ScriptContext.GLOBAL_SCOPE` and `ScriptContext.ENGINE_SCOPE`. They represent key-value pairs that are either visible to all instances of a script engine that have been created by the same `ScriptEngineManager`, or visible only during the lifetime of a certain script engine instance. The following program illustrates the use of bindings to store a value, 42, into the binding called `answer` and then using its retrieved value in the evaluation of the statement 'say "the answer is" answer '. The next action uses the handle one for a value of 1, and uses its retrieved value to add it to the value previously contained in the binding `answer`.

Listing 25.4: Object Bindings

```
1 import javax.script.
2
3 nrEngine = ScriptEngineManager().getEngineByName("NetRexx")
4
5 /* simple script invocation */
6 nrEngine.eval('numeric digits 17; say 111111111 * 111111111')
7
8 /* script invocation with bindings */
9 answer = 42
10 nrEngine.put("answer", answer)
11 nrEngine.eval('say "the answer is "answer')
12
13 one = 1
14 nrEngine.put("onemore", one)
15 nrEngine.eval('say "one more is "answer+onemore')
```

Note that in line two, the invocation is shortened a bit by getting rid of the intermediate manager object for instantiation of the language interface. Also note that in line 10, we chose, for illustration purposes, to store the one object into the bindings structure using a different name, `onemore`. This shows that the string used as identifier for the object is just a handle to it, and nothing more. This would yield:

```
1 12345678987654321
2 the answer is 42
3 one more is 43
```

The different possibilities and language combinations will be discussed in the paragraphs below.

25.4.1 Obtaining a returncode

The variable binding used for the return code from the NetRexx program is called `returnobject`. This program illustrates its use:

Listing 25.5: Obtaining a returncode

```
1 import javax.script.  
2  
3 nrEngine = ScriptEngineManager().getEngineByName("NetRexx")  
4  
5 /* check returncode */  
6 say nrEngine.eval('NetRexxScriptEngine.instance.put("returnobject", "99")')  
  
1 99
```

25.5 Interpreted execution of NetREXX scripts from jrunscript

Another way of calling any NetRexx program, for interpretation, is to use the standard `jrunscript` executable that is included in Java 1.6 and beyond. For example, in the `examples/rosettacode` directory, one could specify:

```
jrunscript -l netrexx -cp $CLASSPATH -f RCSortingHeapsort.nrx
```

The `-l` option instructs the `jrunscript` handler to choose NetRexx as its standard scripting language. For NetRexx to be eligible as a scripting language, `NetRexxC.jar` must be on the `jrunscript` classpath, which is a separate classpath from the standard one. In this setup, even NetREXX programs with a filename that is not valid as a classname, can be executed as an interpreted script.

25.6 Using JavaScript from NetREXX programs

JavaScript support is built in from Java 1.6 onwards, and using it does not require placing another library on the classpath. Using JavaScript from NetREXX can have benefits, for example when using types native to JavaScript, like the JSON data interchange format.

Listing 25.6: Run JavaScript

```
1 import javax.script.  
2  
3 jsEngine = ScriptEngineManager().getEngineByName("JavaScript")  
4  
5 jsEngine.eval('var foo = {};')  
6 jsEngine.eval('foo.foundation = "RexxLA";')  
7 jsEngine.eval('foo.model = "open";')  
8 jsEngine.eval('foo.week = 42;')  
9 jsEngine.eval('foo.transport = "car";')  
10 jsEngine.eval('foo.month = 7;')  
11  
12 jsEngine.eval('bar = JSON.stringify(foo);')  
13  
14 jsonString = jsEngine.get('bar')  
15 say jsonString
```

which yields the following result:

```
1 {"foundation":"RexxLA","model":"open","week":42,"transport":"car","month":7}
```

25.7 Using AppleScript on macOS

On macOS you can run an AppleScript using NetREXX.

Listing 25.7: Run AppleScript

```
1 import javax.script.
2 -- does not work in recent macOS versions
3
4 /*
5 Instead of ScriptEngine engine = mgr.getEngineByName("AppleScript"); you must use:
6 ScriptEngine engine = mgr.getEngineByName("AppleScriptEngine");
7
8 In your src directory create directory META-INF
9 In your src directory create directory META-INF/services
10 Create file META-INF/services/javax.script.ScriptEngineFactory
11 In this file is one line:
12 apple.applescript.AppleScriptEngineFactory
13 */
14
15 appleEngine = ScriptEngineManager().getEngineByName("AppleScriptEngine")
16 context = appleEngine.getContext()
17 bindings = context.getBindings(ScriptContext.ENGINE_SCOPE)
18 bindings.put("javax_script_function", "getName")
19 bindings.put(ScriptEngine.ARGV, 'Stranger')
20
21 appleScript = 'on getName(default_) \n'-
22     'tell application "Finder" \n'-
23     'display dialog "What is your name?" default answer default_ with icon note \n'
24     '-
25     'set myName to the text returned of the result \n'-
26     'delay 0.5 \n'-
27     'display dialog "Hi there, " & myName & "! Welcome to AppleScript!" with icon
28     note \n'-
29     'end tell\n'-
30     'return myName\n'-
31     'end getName'
32
33 result = appleEngine.eval(appleScript,context)
34 say result
```

The AppleScript interpreter expects end-of-line characters at the end of every line, so make sure to include them in your script. The above script shows it is fairly straightforward to put a dialog box with a question on the screen. The example shows how to give an argument (ARGV) to a method, and how to put the method name in the bindings object in order to return the result upon evaluation.

25.8 Execution of NetREXX scripts from ANT tasks

The jsr223 engine enables us to execute NetREXX scripts from the ant¹⁶ building tool using the <script> tag. This was already possible using the BSF library, where NetREXX was one of the originally supported languages, but has become more straightforward with jsr223 scripting.

¹⁶<http://ant.apache.org>

Listing 25.8: Run a NetREXX script in Ant

```
1 <project name="MyProject" basedir=".">
2   <description>
3     demonstration of ant jsr223 netrexx scripting
4   </description>
5
6   <property name="divider" value="81" />
7   <script language="netrexx" manager="javax">
8     say "100/"divider '=' ' 100/divider
9   </script>
10 </project>
```

Note that properties can be set in other parts of the ant xml file and used in the ant script. This script yields the following output:

```
1 Buildfile: /Users/rvjansen/apps/netrexx-code/documentation/pg/antscript.
  xml
2 [script] 100/81 = 1.2345679
3
4 BUILD SUCCESSFUL
5 Total time: 0 seconds
```

The task may use the BSF scripting manager or the JSR 223 manager that is included in JDK6 and higher. This is controlled by the manager attribute. The JSR 223 scripting manager is indicated by "javax", as shown on line 7.

All items (tasks, targets, etc) of the running project are accessible from the script, using either their name or id attributes (as long as their names are considered valid Java identifiers, that is). This is controlled by the "setbeans" attribute of the task. The name "project" is a pre-defined reference to the Project, which can be used instead of the project name. The name "self" is a pre-defined reference to the actual <script>-Task instance. From these objects you have access to the Ant Java API.

A classpath for execution of the script can be set using the classpath attribute. A script contained in a separate file can be executed using the src attribute.

25.9 Integration of NetRExx scripting in applications

Several applications offer a facility to script functionality using the javax.scripting interface, akin to the way applications use the REXX_SAA interface for this purpose.

25.10 Interfacing between ooRExx and NetRExx using BSF4ooRExx

BSF is a system for language interaction that originated in a research project at IBM, and predates JSR223 (and certainly its implementation in Java 6) for a number of years. BSF 2.x has its own interface, while modern BSF versions are an implementation of the JSR223 interfaces. BSF4ooRExx enables a bidirectional interface between ooRExx and Java, and enables one to use the large class library support for Java in ooRExx programs, but likewise the execution of ooRExx code from Java (including NetRExx) programs. BSF4ooRExx contains some special support for JVM programs written in NetRExx.

25.11 General jsr-223 Implementation Notes

This section describes some notes pertaining to specific jsr223 for NetRexx design and implementation decisions.

- All engine scope bindings are passed to the script as variables - note that binding names containing periods have the periods changed to underscores to be legal variable names.
- The NetRexx script engine is reused unless the script returned via an "exit" statement and the bindings are persistent which means that scripts will see the bindings (Objects) created by previous scripts
- Arguments are passed both as the normal `arg` string and as the array binding `javax.script.argv` i.e. script variable `javax_script_argv`.
- Scripts are executed via the NetRexxA API for interpreting a program from a string so they are not written to files.
- The current version of the engine has no other optimization and only support for bare minimum JSR223 features (No compilable, invokeable, preparse or caching or user profiles or console, etc.).
- When running as an Ant Script task, properties whose names contain periods are not passed to the bindings and must be accessed via `project.getProperty('some.name')` The workaround is to define a local Ant property as a global first and the scriptengine will overlay the global value with the local value in the bindings map
- When running as an Ant Script task, properties can be set via `project.setProperty('some.name', 'some value')`
- Script parms can be passed in an "arg" binding. Parse flags can be passed with a "netrexxflags" binding or in Ant with the usual "ant.netrexx.verbose", etc properties.
- Ant scripts can use the nested classpath facility - It is automatically added to the classpath that NetRexx scans. Likewise any path segments from a thread context `URLClassLoader` are added.
- The engine will run programs (ie that have a main class) as well as scripts but bindings cannot then be auto added to the program namespace so programs have to load bindings like this: `NetRexxScriptEngine.getObject("objectname")`

NetREXX Tools

26.1 Editor support

This chapter lists editors that have plugin support for NetREXX, ranging from syntax coloring to full IDE support (specified), and REXX friendly editors, that are extensible using REXX as a macro language (which can be the first step to provide NetREXX editing support).

26.1.1 JVM - All Platforms

JEdit	Full support for NetREXX source code editing, to be found at http://www.jedit.org .
NetRExxDE	A revisions with additions of the NetREXX plugin for jEdit, moving to a full IDE for NetREXX. http://kenai.com/projects/netrexx-misc
Eclipse	Eclipse has a NetREXX plugin that provides a complete IDE environment for the development of NetREXX programs (in alpha release) by Bill Fenlason. The project is situated at SourceForge (http://eclipsenetrexx.sourceforge.net/). Chapter 27 on page 91 discusses the setup of Eclipse to build the translator itself; and has instructions for the setup of the NetREXX plugin.

26.1.2 Linux

Emacs	netrexx-mode.el (in the NetREXX package in the tools directory) runs on GNU Emacs, which is installed by default on most Linux developer distributions.
vim	vi with extensions

26.1.3 MS Windows

Emacs	netrexx-mode.el (in the NetREXX package in the tools directory) runs on GNU Emacs for Windows. http://www.gnu.org/software/emacs/windows/faq.html .
vim	vi with extensions

26.1.4 macOS

Aquamacs	A version of Emacs that is integrated with the macOS Aqua look and feel. (http://www.aquamacs.org). NetREXX mode is included in the NetREXX package in the <code>tools</code> directory.
Emacs	<code>netrexx-mode.el</code> (in the NetREXX package) runs on GNU Emacs for macOS. http://www.gnu.org/software/emacs .
Vim	Vi with extensions

26.2 Java to Nrx (`java2nrx`)

When working on a piece of Java code, or an example written in the language, sometimes it would be good if we could see the source in NetREXX to make it more readable. This is exactly what `java2nrx` by Marc Remes does. It has a Java 1.5 parser and an Abstract Syntax Tree that delivers a translation to NetRExx, to the extend of what is currently supported under NetRExx.

At the moment it is to be found at `gitclonegit://git.code.sf.net/p/netrexx/codenetrexx-code` in the `tools` directory.

It is started by the `java2nrx.sh` script; for convenience, place `java2nrx.sh` and `java2nrx.jar` in the same directory. NetRExxC and `java` must be available on the path.

Usage: Alternatively:

FIGURE 5: `Java2nrx` 1



FIGURE 6: `Java2nrx` 2



- nrc** runs NetRExxC compiler on output `nrx` file
- stdout** prints NetRExx file on stdout
- run** runs generated translated NetRExx output file

Using Eclipse for NetRexx Development

This is a guide for first time Eclipse users to set up a NetRexx development project. It is not a beginners guide to Eclipse, but is intended to explain how to download the NetRexx compiler source from SVN to be able to modify and build it using Eclipse¹⁷.

It is detailed and hopefully foolproof for someone who has never used Eclipse. It assumes a Windows user, but if you are a Linux or Mac user, you will no doubt understand what to do.

This guide is for Eclipse 4.2 (Juno), written August, 2012. New Eclipse releases occur every 4 months, so there may be differences depending on what the current version is.

27.1 Downloading Eclipse

There are many different preconfigured versions of Eclipse. As you become more experienced with it you may wish to use a different distribution, but the one specified here makes some things simple. It does contain some things that you may never use.

1. Make a new folder for the project. Name it appropriately (e.g. EclipseNetRexx)
2. Browse to eclipse.org, and click on “Download”.
3. Download the version named ECLIPSE IDE FOR JAVA DEVELOPERS for your your operating system.
4. The download is about 150 MB.
5. Unzip the downloaded file into your project folder.

27.2 Setting up the workspace

There are different strategies for managing Eclipse workspaces. Eclipse defaults to putting the workspace in your Windows documents folder - probably not what you want to do. The following is perhaps the most simple way.

1. Open the project folder. It will now contain a folder named eclipse.
2. Add a new folder named “workspace” in the project folder to go along with the eclipse folder.
3. Open the eclipse folder, and create a shortcut to `eclipse.exe`.
4. Move the shortcut to the desktop and rename it to something like “Eclipse NetRexx”.

¹⁷If you have questions or comments, feel free to contact Bill Fenlason at billfen@hvc.rr.com.

5. Close the project folder, and double click the shortcut to start Eclipse.
6. The “Select a workspace” dialog comes up - don’t use the default.
7. Browse to the workspace folder that you just created and select it.
8. Click (check) the “Use this as the default” box, and click OK.

27.3 Shellshock

If you have never used Eclipse, it can be a bit overwhelming. It is rather complicated, and has endless options, etc. In addition there are at least a thousand different plugins.

You will be greeted by a Welcome screen - you may find it interesting or boring. Exit from it via tback to the welcome screen from: Main Menu -> Help -> Welcome.

27.4 Installing Git

Modern versions of Eclipse come with Git support built in. If not, install it from the Eclipse Marketplace.

27.5 Downloading the NetRexx project from the SVN repository

The Git repository on SourceForge contains the NetRexx compiler/translator, documentation, examples, etc. These instructions assume you want only the compiler project.

1. The NetRexx Git repository clone command is: `git clone git://git.code.sf.net/p/netrexx/codenetrexx-code`
2. Copy it (for pasting) from above, or get it from the kenai or netrexx.org site.

27.6 Setting up the builds

Ant support is built into Eclipse, but it must be configured to be able to access the bootstrap NetRexx compiler.

1. Double click on the build.xml file name in the package explorer. Note that its icon is an ant.
2. The build file will open in an editor window.
3. Right click in the window to bring up a context menu, and select Run As -> 2 Ant Build
4. Do NOT select 1 Ant Build.
5. The Ant configuration dialog comes up - it will show you all the targets, etc.
6. Click on the Classpath tab, and then click on User Entries.
7. Now click on Add External Jars to bring up the Jar Selection dialog.
8. Navigate to the lib folder in the project folder. Make sure you are not in the build folder.
9. Double click on NetRexxC.jar to select it.

10. Click on the Refresh tab, and check the Refresh resources on completion box.
11. Click Run to build the distribution. The messages will appear in the console listing below.
12. The java doc step may fail.
13. Close the build.xml file (X on the tab).

You can configure the ant build by using the configuration dialog in Run As -> 2 Ant Build. You may want to check “compile” and “jars” to run those steps. Use Apply to save the configuration.

There are two different builds. The second build.xml file is in the project -> tools -> ant-task folder. Open it up and repeat the above steps for that build.xml file. Each build file has its own ant configuration, and once set selecting Run As -> 1 Ant Build will run it. Or just hit F11.

27.7 Using the NetRexx version of the NetRexx Ant task

The above process uses the standard NetRexx Ant task, not the new one. To use the new one:

1. Main Menu -> Window -> Preferences -> Ant -> Runtime.
2. Open up and select Ant Home Entries. Then click on Add External Jars
3. Navigate to the lib folder in the project and select ant-netrexx.jar
4. The jar will appear at the bottom of the list.
5. Use the UP button to move it up (ahead) of the apache ant version, click OK

27.8 Setting up the Eclipse NetRexx Editor Plugin (Optional)

The NetRexx Editor plugin provides syntax coloring and error checking for nrx files, as well as one click compiling and translating.

1. Click on Main Menu -> Help -> Eclipse Marketplace.
2. Type NetRexx in the search box and hit enter.
3. Click the Install button next to the Eclipse NetRexx package.
4. Click Next, Accept the License, Finish, OK to unsigned content, and Yes to restart Eclipse.
5. Click Main Menu -> Window -> Preferences -> NetRexx Editor to explore it

Platform dependent issues

28.1 Mobile Platforms

Android™ is a version of Linux and friendly to NetREXX programs. Indeed, with NetREXX performing so much better than the closest competition (jRuby, jython) on these devices, there might be a bright future for NetREXX in these environments.

However, there are some drawbacks, caused by the security architecture put in place. Free, unfettered programming like one can do on a desktop machine is a rare occurrence on these devices, and to get programs running on them requires some knowledge of the security architecture that has been put in place for mobile operating systems.

While Apple development still employs a closed model that allows programming only by buying a license with accompanying certificates, and vetting by the App Store employees, and an assumption you will program in Objective-C, Android allows programming but not as straightforward as we know it. To make simple command-line NetREXX programs, both device types need to be *rooted* to allow optimal access. Android allows the installation of applications without vetting by third parties, but dictates a programming model that incurs some overhead - which is a drawback for the occasional scripter.

28.1.1 Android

The security model of Android is based on *least needed privilege* and is implemented by assigning each application a different userid, so that applications on the same device (be it a phone or a tablet) cannot get to each others data. The consequence of this is that simple NetREXX programming and scripting

28.1.2 Apple IOS

Note: this chapter is out of date. Nonwithstanding the current intention of Apple to only allow Swift and Objective-C as programming languages on the iPhone and iPad, NetREXX on IOS works fine. This is what one should do to make it work:

1. Jailbreak¹⁸ the device. This is necessary until a more sensible setup is used. I used Spirit; it synchs the phone with the hack and then Cydia is installed, an application that does package management the Debian way
2. Choose the "developer profile" on Cydia when asked. This applies a filter to the packages shown (or rather it doesn't) - but you need to do it in order to see the

¹⁸Note that jailbreaking an iPhone is against Apple's End Use License Agreement) and might be illegal in some jurisdictions.

prerequisites

3. OpenTerminal will help you to do command line operations on the phone itself
4. The prerequisites are a Java VM (JamVM installs a VM and ClassPath, the open Java implementation) and Jikes, the Java compiler written in C and compiled to the native instruction set of the phone, which is ARM - most processors implementing this have *Jazelle*, a special instruction set to accelerate Java bytecode. However, this feature is seldom used.

The phone can also be logged on to using ssh from your desktop. Do not forget to change the password for the 'root' user and the 'mobile' user, as instructed in the Cydia package. Note that this type of information will can be made inaccurate very swiftly.

When this is done, NetRexxC.jar can be copied to the phone. I did this using 'scp NetRexxC.jar mobile@10.0.0.76:' (use the password you just set for this userid) (and because my router assigned 10.0.0.76 to the phone today). I crafted a small 'nrc' script that does a translate and then a Java compile using jikes (and I actually wrote this on the phone using an application called 'iEdit' - nano, vim and other editors are also available but I found the keyboard scheme to type in ctrl-characters a bit tedious - you type a 'ball' character and then the desired ctrl char, while shifting the virtual keyboard through different modes):

nrc:

```
java -cp ~/NetRexxC.jar COM.ibm.netrexx.process.NetRexxC $*
```

Now we can do a compile of the customary hello.nrx with './nrc -keep -nocompile hello' (notice that this is all in the home directory of the 'mobile' user, just like the jar that I just copied. The resulting hello.java.keep can then be mv'ed to hello.java and compiled with 'jikes hello.java'. This produces a class that can be run with 'java -cp NetRexxC.jar hello'

28.2 IBM Mainframe: Using NetREXX programs in z/OS batch

Traditionally the mainframe was a batch oriented environment, and much of the workload that counts still executes in this way. To be able to use NetREXX with Job Control Language (JCL) in batch address spaces, accessing traditional datasets and interacting with the console when needed, we need to know a bit more. This will be explained in these paragraphs.

A standard component of z/OS since version 1.8 or so is jzos, which acts as glue between the unix-like abstractions the JVM works with and the time tested way of working on z/OS, with its SAM and VSAM datasets, its Partitioned Data Set (PDS) file organization, the ICF Catalogs and console address space; all of which in existence long before Java reared its head in our IT environments.

The manuals will teach you that there are several ways to interact with HFS/OMVS resources in JCL, but the alternatives to jzos have so many drawbacks that it is the only sensible way to run NetREXX programs in the batch environment.

Building the NetREXX translator

It is easy to build the NetREXX translator from source. Prerequisites are:

1. A Java Virtual Machine
2. A Git client

NetREXX can be built on all platforms that it runs on. NetRexx has been bootstrapped since 1996 and subsequently has been used to compile itself. Every checkout of the source code contains the 'bootstrap' compiler, which is normally the previous release version. Only the official release branches contain the same release of the compiler - to prove that it still can compile itself on release. Theoretically, it is possible to break things by introducing changes that preclude the compiler to compile itself - it is our job that these changes are not released to a wider audience, but rolled back in time.

29.1 Repository

The NetREXX source code repository is hosted at the SourceForge Git repository. To get the code on your system, you should register at the NetRexx project at SourceForce and clone the repository using Git. For this version management package there are many graphical user interfaces, but what is shown here, is the command line version. Choose a suitable place as working directory - you can later move it around as you please.

```
git clone git://git.code.sf.net/p/netrexx/code netrexx-code
```

Note: This will checkout the whole repository to your local system; including previous versions, experimental branches and personal sandboxes of other developers.

The master branch contains the most current version of the source code, including the documentation, examples and test cases.

29.2 The buildfile

The official buildfile is called `build.xml` and the ant utility is used for building NetREXX from source. This file contains a number of tasks. To build the translator, make sure that the top level directory that is cloned from git is the current directory, and issue the command:

```
java -jar ant/ant-launcher.jar compile
```

followed by

```
java -jar ant/ant-launcher.jar jars
```

This will build the compiler from source and create a `build` directory in the current directory. In `build/lib` the NetRexxC and NetRexxR jars are put by the archiving process that is started by the `jar` task. These new jars can be used immediately, by having them (NetRexxC will suffice) on the classpath.

29.3 Testing

Currently, there are two locations that contain the tests. The first is the `org.netrexx.process.diag` package, which currently is being integrated into the `trunk/test` directory. This directory contains, in addition to the traditional “diag” tests that have been modified to run under jUnit, some of the tests for the newer functionality. These tests are accessible using a `make` process that uses `makefile` as its build build file. The command

```
make test
```

will compile and run the tests; jUnit will report on progress and results.

Translator inner workings

This chapter includes all documentation on the inner workings of the translator that is available. Its purpose is to assist with debugging serious problems or ease the introduction to the toolset for programmers who want to help the open source effort forwards.

30.1 Translator source files

The translator source is part of the package `org.netrexx.process`. The runtime support, including the `Rexx` type, is in the package `netrexx.lang`.

The source files in table 3 all correspond to a specific NetRexx clause, all created by `RxParser`, and all implementing `RxClauseParser`. Each is responsible for syntax checking, semantic processing, and code generation for the corresponding clause. `RxClass` and `RxMethod` are the critical classes. `RxNop` is the simplest. Method-term instructions are currently handled in `RxParser` but should have a separate class in this list.

TABLE 2: Translator source files

NetRexxC.nrx	The 'main program'
nrc.prp	Error messages (becomes NetRexxC.properties resource bundle)
RxArray.nrx	Parsed array reference
RxClasser.nrx	The class 'factory'; finds classes and packages, loads classes, finds fields in packages, etc.
RxClassImage.nrx	Loads and parses a .class file (from zip or directory byte stream)
RxClassInfo.nrx	Known information about a class
RxClassPool.nrx	Collection of known classes (maintained by RxClasser)
RxClause.nrx	The tokens and object corresponding to a clause
RxClauseParser.nrx	Interface: all clause objects implement this
RxClauser.nrx	Tokenizer (lexical analysis/parse)
RxCode.nrx	Represents encoded piece of program (e.g., an expression or clause). Holds information about the source of the code, and the code itself (currently only Java source code). At present, RxCode is only used for terms and expressions; clauses will probably evolve to use RxCode objects too.
RxConvert.nrx	Holds the cost and type of a conversion
RxConverter.nrx	Determines and costs a conversion/coercion, and effects a particular conversion
RxError.nrx	Handle an Error (see also RxQuit and RxWarn)
RxException.nrx	Represents a Java exception
RxExprParser.nrx	Parse and generate RxCode for an expression
RxField.nrx	Represents a field (property or method)
RxFixup.nrx	Changes the sourcefile attribute in a .class file to point to Foo.nrx constant instead of Foo.java
RxFlag.nrx	Represents option flags
RxLanguage.nrx	Language version and date, and major change list
RxLevel.nrx	Represents a level of semantic nesting. 0=class, 1=method, 2 is method body (do groups, etc.)
RxMessage.nrx	Displays/queues an error or warning message. (Offspring of RxError, RxQuit, RxWarn)
RxPackageInfo.nrx	Describes a known package
RxParser.nrx	NetRexx-specific program/clause parser
RxProgram.nrx	Represents a compilation unit (==Program)
RxQuit.nrx	Handles severe errors (see also RxError, RxWarn)
RxSignature.nrx	Represents a type
RxStreamer.nrx	Handles input and output streams (files), including formatting of output Java source
RxTermParser.nrx	Parses terms in expressions
RxToken.nrx	Represents a lexical token (see RxClauser)
RxTracer.nrx	Generates code for tracing of various types
RxTranslator.nrx	'top-level' controller for parsing and compilation.

TABLE 3: Translator source files -2

RxVariable.nrx	Represents a local or class variable, and its cross-reference list
RxVarpool.nrx	Collection of known RxVariables
RxWarn.nrx	Handles Warnings
RxChunk.nrx	A chunk of Java sourcecode, destined for the output file (planned to be replaced by RxCode objects, long term)

TABLE 4: Translator source files -3

RxAssign.nrx	handles all assignment clauses
RxCatch.nrx	
RxClass.nrx	
RxDo.nrx	
RxElse.nrx	
RxEnd.nrx	
RxExit.nrx	
RxFinally.nrx	
RxIf.nrx	
RxImport.nrx	
RxIterate.nrx	
RxLeave.nrx	
RxLoop.nrx	
RxMethod.nrx	
RxNop.nrx	
RxNumeric.nrx	
RxOptions.nrx	
RxOtherwise.nrx	
RxPackage.nrx	
RxParse.nrx	
RxProperties.nrx	
RxReturn.nrx	
RxSay.nrx	
RxSelect.nrx	
RxSignal.nrx	
RxThen.nrx	
RxTrace.nrx	
RxWhen.nrx	

30.2 Method resolution

Method resolution in NetRexx proceeds as follows:

- If the method invocation is the first part (stub) of a term, then:
 1. The current class is searched for the method (see below for details of searching).
 2. If not found in the current class, then the superclasses of the current class are searched, starting with the class that the current class extends.
 3. If still not found, then the classes listed in the uses phrase of the class instruction are searched for the method, which in this case must be a static method. Each class from the list is searched for the method, and then its superclasses are searched upwards from the class; this process is repeated for each of the classes, in the order specified in the list.
 4. If still not found, the method invocation must be a constructor (see below) and so the method name, which may be qualified by a package name, should match the name of a primitive type or a known class (type). The specified class is then searched for a constructor that matches the method invocation.
- If the method invocation is not the first part of the term, then the evaluation of the parts of the term to the left of the method invocation will have resulted in a value (or just a type), which will have a known type (the continuation type). Then:
 1. The class that defines the continuation type is searched for the method (see below for details of searching).
 2. If not found in that class, then the superclasses of that class are searched, starting with the class that that class extends. If the search did not find a method, an error is reported. If the search did find a method, that is the method which is invoked, except in one case:
 3. If the evaluation so far has resulted in a value (an object), then that value may have a type which is a subclass of the continuation type. If, within that subclass, there is a method that exactly overrides the method that was found in the search, then the method in the subclass is invoked.

This case occurs when an object is earlier assigned to a variable of a type which is a superclass of the type of the object. This type simplification hides the real type of the object from the language processor, though it can be determined when the program is executed. Searching for a method in a class proceeds as follows:

1. Candidate methods in the class are selected. To be a candidate method:
 - the method must have the same name as the method invocation (independent of the case (see page 44) of the letters of the name)
 - the method must have the same number of arguments as the method invocation (or more arguments, provided that the remainder are shown as optional in the method definition)
 - it must be possible to assign the result of each argument expression to the type of the corresponding argument in the method definition (if strict type checking is in effect, the types must match exactly).
2. If there are no candidate methods then the search is complete; the method was not found.

3. If there is just one candidate method, that method is used; the search is complete.
4. If there is more than one candidate method, the sum of the costs of the conversions from the type of each argument expression to the type of the corresponding argument defined for the method is computed for each candidate method.
5. The costs of those candidates (if any) whose names match the method invocation exactly, including in case, are compared; if one has a lower cost than all others, that method is used and the search is complete.
6. The costs of all the candidates are compared; if one has a lower cost than all others, that method is used and the search is complete.
7. If there remain two or more candidates with the same minimum cost, the method invocation is ambiguous, and an error is reported. Note: When a method is found in a class, superclasses of that class are not searched for methods, even though a lower-cost method may exist in a superclass.

Note that until version 3.01 of the NetRexx translator a slightly different way of method resolution was used. There is a very small (and almost improbable) chance of encountering differences when recompiling very old sources.

Index

Class, 19, 62, 64, 79
Options, 67
Properties, 54, 55
Rexx, 22, 23, 32, 38, 41, 50, 58
arg, 18, 19, 21, 37, 42, 43, 50, 58, 62, 64
binary, 9, 56, 57, 66, 67, 69, 70, 77
catch, 19, 21, 23, 32, 38, 41, 55-58, 62-65, 67, 68, 70, 73-75
class, 9, 19, 22, 24, 30-32, 42, 49, 54-58, 66-70, 73, 74
constant, 18
dependent, 70
digits, 9, 41, 42
do, 19, 21, 23, 30, 32, 37, 38, 41, 42, 55, 58, 59, 62, 64, 66-68, 70, 73-75
else, 3, 21, 30, 32, 42, 43, 57, 59, 62, 64
end, 7, 8, 19, 21-23, 30, 32, 34, 37, 38, 41-43, 45, 47, 54-59, 62-65, 67, 68, 70, 71, 73-75, 78, 83
exit, 21, 37, 38, 43, 62, 64
extends, 24, 32, 55-58, 69, 70
finally, 38
for, 8, 54, 55, 78
forever, 8, 32, 45, 67
form, 9
if, 3, 8, 21-23, 30, 32, 37, 38, 41-43, 45, 56-59, 62, 64, 83
implements, 24, 31, 32, 54, 56-58, 68, 73, 74
import, 18, 19, 24, 32, 62, 64, 66-69, 73, 74, 77, 80-86
indirect, 22, 24
inheritable, 54, 55, 69
interface, 24
interpret, 80
leave, 8, 38, 45
loop, 7, 8, 21-23, 32, 34, 38, 41-43, 45, 47, 54-58, 62-65, 67, 70, 78, 83
method, 9, 18, 22-24, 30, 32, 33, 41-43, 49, 50, 54-58, 66-70, 73-75, 79, 80, 83
nop, 32, 59
numeric, 41, 42
options, 9, 41, 42, 56, 57, 70, 77
otherwise, 41
over, 34
package, 79
parent, 70, 71
parse, 21, 22, 32, 37, 38, 42-47, 58, 62, 64, 77-79
private, 22, 30, 32, 41, 43, 66, 67, 70, 74
properties, 22, 24, 30, 32, 49, 66-70, 74
protect, 30, 33, 70
public, 9, 32, 41
queue, 66-68
return, 9, 22-24, 30, 41-43, 56, 57, 59, 68, 69
returns, 18, 22, 23, 30, 41, 57, 58, 68, 69, 78-80
say, iii, 3, 6-9, 19, 21, 23, 24, 32, 34, 37, 38, 41-47, 50, 54, 55, 58, 62-70, 73-75, 81, 83, 85-87
select, 41, 59
signal, 41
signals, 30, 32, 41, 70, 75
sourceline, 9
static, 9, 18, 30, 32, 41-43, 50, 58, 66, 67, 69, 74, 75, 83
super, 9, 24, 55, 70
then, 3, 8, 21-23, 30, 32, 37, 38, 41-43, 45, 56-59, 62, 64, 83
this, 9, 22-24, 32, 56-58, 68-70, 73, 75
to, 7, 8, 41, 43, 47, 56, 63
trace, 9, 49, 52
until, 22
upper, 41
volatile, 69
when, 41, 59
while, 21, 23, 56-58, 62-65, 70, 83

applets for the Web, writing, 56
application programming interface, for interpreting, 77
ArchText example, 56
arg words option, 14

binary arithmetic, used for Web applets, 56
binary option, 12

classpath option, 14
comments option, 12
compact option, 12
constructor, in NetRexxA API, 78
crossref option, 12

- decimal option, 12
- diag option, 12
- exec option, 14
- exiting method, in NetRexxA API, 79
- explicit option, 12
- flag, binary, 12
- flag, nocompile, 14
- flag, noconsole, 15
- flag, run, 15
- flag, savelog, 15
- flag, time, 15
- flag,arg words, 14
- flag,classpath, 14
- flag,comments, 12
- flag,compact, 12
- flag,crossref, 12
- flag,decimal, 12
- flag,diag, 12
- flag,exec, 14
- flag,explicit, 12
- flag,format, 13
- flag,java, 13
- flag,keep, 14
- flag,keepasjava, 14
- flag,logo, 13
- flag,sourcedir, 13
- flag,strictargs, 13
- flag,strictassign, 13
- flag,strictcase, 13
- flag,strictimport, 13
- flag,strictmethods, 13
- flag,strictprops, 13
- flag,strictsignal, 13
- flag,symbols, 13
- flag,trace, traceX, 13
- flag,utf8, 13
- flag,verbose, verboseX, 14
- flag,warnexit0, 15
- format option, 13
- getClassObject method, in NetRexxA API, 79
- HTTP server setup, 59
- interpreting,API, 77
- interpreting,using the NetRexxA API, 77
- interpreting/API example, 77
- java option, 13
- javac option, 14
- keep option, 14
- keepasjava option, 14
- logo option, 13
- NervousTexxt example, 56
- NetRexxA, API, 77
- NetRexxA, class, 77
- NetRexxA/constructor, 78
- nocompile option, 14
- noconsole option, 15
- option, binary, 12
- option, nocompile, 14
- option, noconsole, 15
- option, run, 15
- option, savelog, 15
- option, time, 15
- option,arg words, 14
- option,classpath, 14
- option,comments, 12
- option,compact, 12
- option,crossref, 12
- option,decimal, 12
- option,diag, 12
- option,exec, 14
- option,explicit, 12
- option,format, 13
- option,java, 13
- option,keep, 14
- option,keepasjava, 14
- option,logo, 13
- option,sourcedir, 13
- option,strictargs, 13
- option,strictassign, 13
- option,strictcase, 13
- option,strictimport, 13
- option,strictmethods, 13
- option,strictprops, 13
- option,strictsignal, 13
- option,symbols, 13
- option,trace, traceX, 13
- option,utf8, 13
- option,verbose, verboseX, 14
- option,warnexit0, 15
- parse method, in NetRexxA API, 78
- ref /API/application programming interface, 77
- run option, 15
- runtime/web server setup, 59
- savelog option, 15
- sourcedir option, 13
- strictargs option, 13
- strictassign option, 13
- strictcase option, 13
- strictimport option, 13
- strictmethods option, 13
- strictprops option, 13
- strictsignal option, 13
- symbols option, 13
- time option, 15
- trace, traceX option, 13
- utf8 option, 13
- verbose, verboseX option, 14

warnexit0 option, 15
Web applets, writing, 56
Web server setup, 59
WordClock example, 57

ISBN 978-90-819090-0-6

