An Introduction to Procedural and Object-oriented Programming (ooRexx) 6

Object Rexx Environments (.local, .environment),
Class Methods, Class Attributes, Object Rexx Class "Class",
Defining Classes and Methods at Runtime, "One-off Objects",
"The Big Picture" (TBP)
Multithreading, Security Manager, Unknown, Forward

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Object Rexx Environment, 1

- Object Rexx Programs
  - Running a Rexx program: sequence of execution
    - Checking entire program for syntax errors
    - Carrying out directives
    - Start the Rexx program
  - Possible questions
    - How can the routines, methods and classes be made available?
    - How can public routines and public classes be made visible?
    - Is there a possibility to share (couple) objects created in different parts of the same Rexx program, or even created in different Rexx programs?

Object Rexx Environment, 2

- The runtime system (ie. the interpreter) creates four directory objects (instances of the Object Rexx class Directory)
  - The directory "source"
    - Contains all routines, methods and classes available within a program
      - Routines, methods and classes defined in the program itself
      - Public routines and public classes defined in other programs which got called (CALL or ::REQUIRES directive)
      - .METHODS, a directory containing all **"free running"** methods, if any
    - The runtime system does not make the directory object "source" available to programmers
    - For each program the runtime system creates an own (individual) "source" directory and maintains it!
      - The public routines and public classes of **the last called program replace all** of the previously accessible external public routines and external public classes

Object Rexx Environment, 3

- The directory object "local"
  - Accessible via the "environment symbol" **.LOCAL**
    - Created for each process in the operating system
  - Contains process related objects, e.g.

.error (monitor object for error/debug messages)
.input (monitor object for input)
.output (monitor object for output)

[monitors allow exchanging the monitored objects, hence one can use them for redirection at runtime!]

.stderr (stream object which gets monitored by .error)
.stdin (stream object which gets monitored by .input)
.stdout (stream object which gets monitored by .output)

Object Rexx Environment, 4

- The directory object "environment"
  - Accessible via the "environment symbol" **.ENVIRONMENT**
    - Created for each process in the operating system (system-wide under OS/2)
  - Contains important objects, e.g.
    - ***All*** public Object Rexx classes
    - Founding objects, e.g.

      .nil indicates that no object is available

      .true the value "1", i.e. the Boolean value for representing true

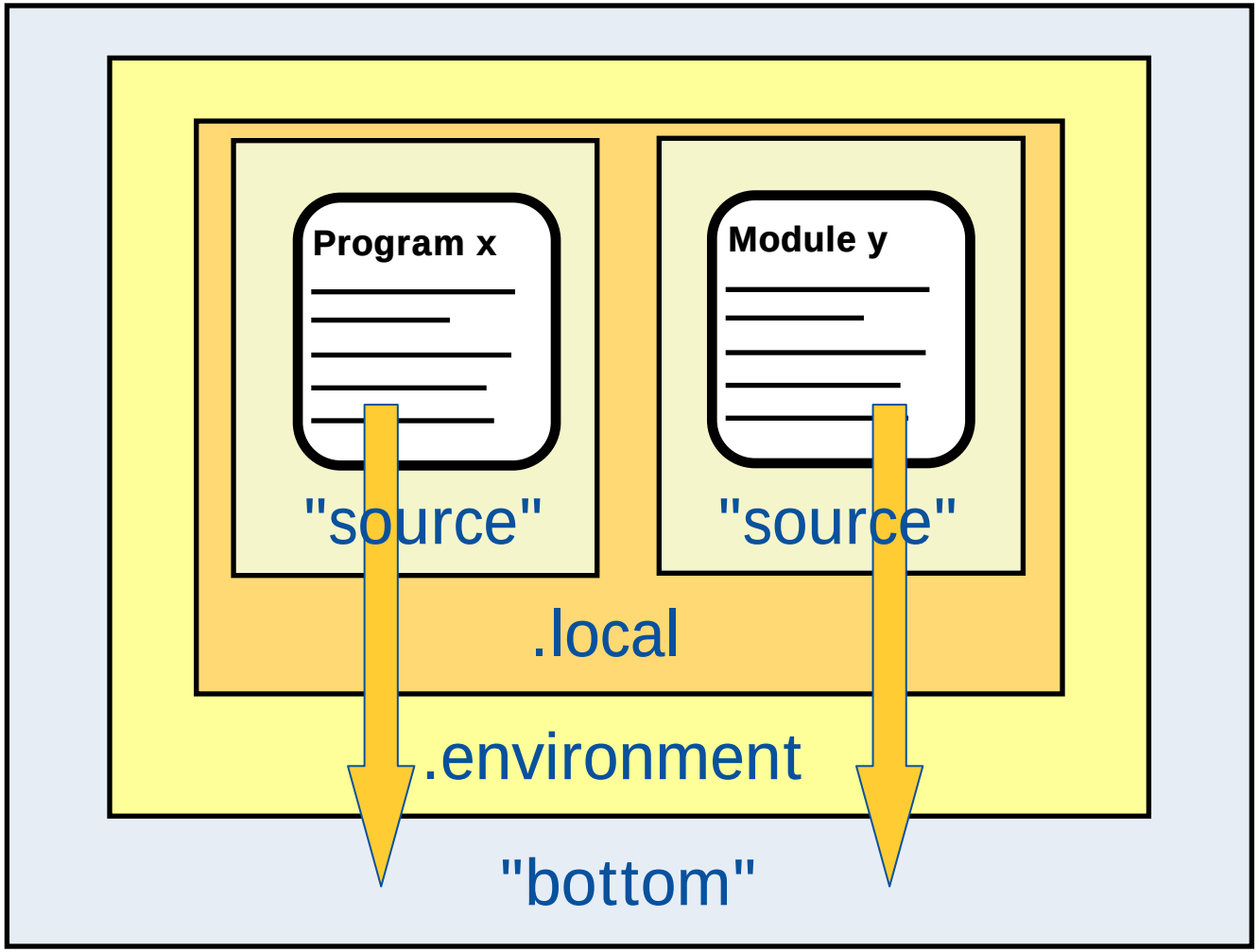
      .false the value "0", i.e. the Boolean value for representing false
- The directory object "bottom"
  - Additional object, that the runtime system needs
  - The runtime system does not make the directory object "bottom" available to programmers

Environment Symbols, 1

- Identifiers always begin with a dot
  - Runtime system environment symbols do not contain a dot in the remaining characters of the identifier
  - User defined environment symbols should contain one additional dot in the rest of the identifier to distinguish them from the runtime system ones
- "Searching the environment"
  - **The runtime system** removes the first dot and uses the remainder as the identifier (name) for **looking up the aforementioned directory objects** in the following, fixed searching order:
    1. Source directory
    2. Local directory (accessible as .local)
    3. Environment directory (accessible as .environment)
    4. Bottom directory

    → A nice runtime system "service" one can employ for ones own purposes...

Environment Symbols, 2



Environment Symbols, 3

  - If there is no entry in the environment, then the name of the environment symbol (including the leading dot and uppercased) is used as the value (like an uninitialized Rexx variable)

- **Warning!**
  - Do not define classes, which possess the same name as the built-in ones ("source" directory will be looked up *before* the .Environment directory)
  - Do ***not*** redefine **.nil**, **.true** and **.false** !
- Further information, e.g.

  `http://wi.wu-wien.ac.at/rgf/rexx/orx07/Local.pdf`

Object Rexx Environment
Example Output of .LOCAL

```
/* Output the entries of the local environment */
 tmpArr = sort(.local)
 DO entry OVER tmpArr
    SAY LEFT(entry, 25, '.') .local~at(entry)~string
 END
 ::REQUIRES sort_util.cmd /* get the sort routine from "ORX8.ZIP" */
```

Output:

```
ERROR..................... a Monitor
INPUT..................... a Monitor
LOCALSERVER............... a server
NLS.DEFAULT.ALIAS........ iso8859-1
OUTPUT.................... a Monitor
STDERR.................... STDERR
STDIN..................... STDIN
STDOUT.................... STDOUT
STDQUE.................... SESSION
```

Module containing sort routine available from:

<http://wi.wu-wien.ac.at/rgf/rexx/orx08/>

Metaclasses
Class Attributes, Class Methods

- Metaclasses
  - Object Rexx class **Class** and all of its subclasses, if any
  - Allow maintaining the methods, instances of such a class should get assigned to (Methods DEFINE, DELETE, METHOD, METHODS)
  - Allows creating objects (instances) from a class (Method NEW)
  - Instance of a metaclass is called "class object"
  - It is *always* possible to get access to the class object, which created an instance/object by sending it the message "CLASS"
    - Method CLASS defined in the root class "Object" will get invoked and will return the appropriate class object
- "Class attributes"
  - Attributes of a metaclass
- "Class methods"
  - Methods of a metaclass

Class Methods, 1

- Class methods
  - Methods of a metaclass
    - All methods of the Object Rexx class **Class**, e.g.
      - ID, DEFINE, DELETE, METHODS
    - All methods of the Object Rexx root class **Object**, e.g.
      - STRING, HASMETHOD
    - All methods, which are defined with a ::METHOD directive containing the keyword CLASS are assigned to the class object
      - The interpreter uses SETMETHOD from the Object Rexx root class **Object**
  - Class methods can be invoked via the class object
    - Each object can retrieve its own class object by sending itself the message Class and thereafter sending the desired messages to the class object

Class Methods, 2

```
/**/
SAY COPIES("-", 50)
.Test~Hallo_1
SAY COPIES("-", 50)
o = .Test~New
o~Hallo_2
::CLASS  Test
::METHOD Init  CLASS
  SAY "New class [" || self~string || "] is being created..."
  self~init:super
::METHOD Hallo_1 CLASS
  SAY "Hallo, I am [" || self~string || "]..."
::METHOD Init
  SAY "New instance ["self~string"] is being created..."
  self~init:super
::METHOD Hallo_2
  SAY "Hallo, I am ["self~string"]..."
```

Output:

```
New class [The TEST class] is being created...
------------------------------------------------
Hallo, I am [The TEST class]...
------------------------------------------------
New instance [a TEST] is being created...
Hallo, I am [a TEST]...
```

Class Methods, 3

```
/**/
SAY COPIES("-", 50)
.Test~Hallo_1
SAY COPIES("-", 50)
o = .Test~New
o~Hallo_2
::CLASS  Test
::METHOD Init  CLASS
  SAY "New class [" || self~string || "] is being created..."
  self~init:super
::METHOD Hallo_1 CLASS
  SAY "Hallo, I am [" || self~string || "]..."
::METHOD Init
  SAY "New instance ["self~string"] is being created..."
  self~init:super
::METHOD Hallo_2
  SAY "Hallo, I am ["self~string"]..."
```

Output:

```
New class [The TEST class] is being created...
------------------------------------------------
Hallo, I am [The TEST class]...
------------------------------------------------
New instance [a TEST] is being created...
Hallo, I am [a TEST]...
```

Class Methods, 4

- Class attributes
  - Attributes of metaclasses
    - Access like any other attributes
      - Attribute methods
        - Method directive with the key word ATTRIBUTE
        - Allow getting and setting the value
      - Using the EXPOSE statement as the first statement in a method

Class Methods, 5

```
/**/
.Test ~~New ~~New ~~New ~~New ~~New ~~New
SAY "So far, there have been [".Test~Counter"] objects created."
o = .Test~New
SAY "So far, there have been ["o~class~Counter"] objects created."
SAY "class:" o~class~string", last instance was:" o~string
```

```
::CLASS  Test
::METHOD Init                 CLASS
  self~Counter = 0
  self~init:super
::METHOD Counter  ATTRIBUTE CLASS
::METHOD New                  CLASS
  EXPOSE Counter
  Counter = Counter + 1
  FORWARD CLASS (super)
```

Output:

```
So far, there have been [6] objects created.
So far, there have been [7] objects created.
class: The TEST class, last instance was: a TEST
```

Metaclass, 1

- If the runtime system (interpreter) finds a ::CLASS directive, it creates an instance of type **Class** ("class object") for it
- If the runtime system (interpreter) finds a ::METHOD directive, it creates an instance of type **Method** for it
  - Method objects which are defined for instances of a class are called "**instance** methods" and are stored in the class object with the help of its DEFINE method
    - One can retrieve a supplier of all defined instance methods by sending the METHODS message to the class object
  - Method objects, which are meant for the class object itself (method directive containing the keyword CLASS) are dubbed "**class** methods" and are attached to the class object with the help of SETMETHOD which is defined in the Object Rexx root class **Object**

Metaclass, 2

- Object Rexx programs can be devised, which create class objects and method objects at runtime ("dynamic")
  - Classes are represented as class objects (instances of the Object Rexx class **Class**)
  - Methods are represented as method objects (instances of the Object Rexx class **Method**)
    - Instance methods are stored with the class object using its DEFINE method (one could remove an instance method from it with DELETE)
      - One can retrieve a supplier of all defined instance methods by sending the METHODS message to the class object
    - Class methods can be directly assigned to class objects using SETMETHOD- defined in the Object Rexx root class **Object** (one could remove a class method with UNSETMETHOD)

Metaclass, 3

- The metaclass **Class** *normal* Object Rexx class
  - Therefore it can be subclassed (specialized)
  - *All subclasses of **Class** are metaclasses themselves !*
  - Should a specialized metaclass be used for creating the class object, then the ::CLASS directive must contain the keyword METACLASS followed by the name of the desired metaclass
    - The default is: METACLASS Class
- Sending a message by the name Class (available as method in the root class **Object**) to an object will always return the its class object (instance of a metaclass)
  - Hence all public methods of the metaclass are *always* available to an object via its class object

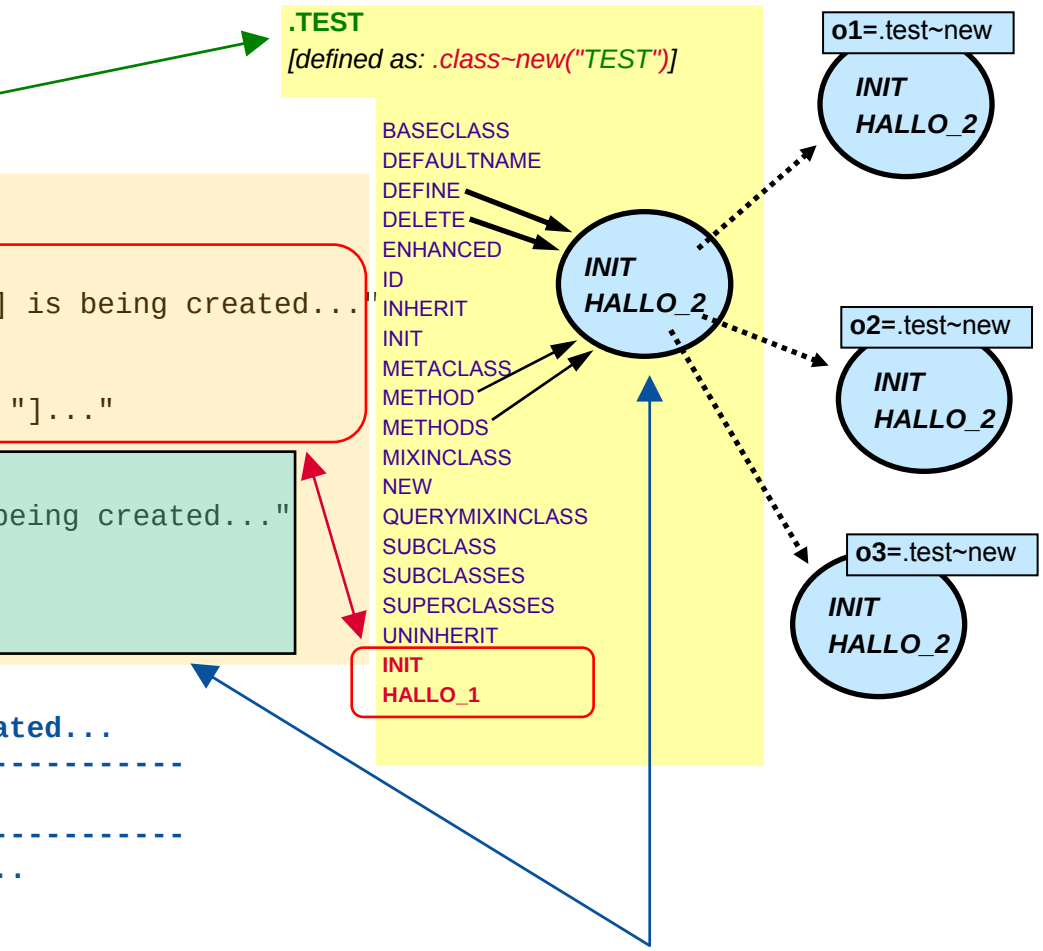
Class Methods vs. Instance Methods, 1
Example: Creating the Class Object ".TEST"

```
/**/
SAY COPIES("-", 50)
.Test~Hallo_1
SAY COPIES("-", 50)
o = .Test~New
o~Hallo_2
```

```
::CLASS  Test

::METHOD Init  CLASS
  SAY "New class [" || self~string || "] is being created..."
  self~init:super
::METHOD Hallo_1 CLASS
  SAY "Hallo, I am [" || self~string || "]..."

::METHOD Init
  SAY "New instance ["self~string"] is being created..."
  self~init:super
::METHOD Hallo_2
  SAY "Hallo, I am ["self~string"]..."
```



Output:

```
New class [The TEST class] is being created...
------------------------------------------------
Hallo, I am [The TEST class]...
------------------------------------------------
New instance [a TEST] is being created...
Hallo, I am [a TEST]...
```

Class Methods vs. Instance Methods, 2
Example: Creating the Class Object ".TEST"

Directives are encountered by the runtime system (interpreter)

Directives are carried out by the runtime system (interpreter)

```
::CLASS  Test                                  -- class
```

```
::METHOD Init  CLASS                           -- method #1
  SAY "New class [" || self~string || "] is being created..."
  self~init:super

::METHOD Hallo_1 CLASS                         -- method #2
  SAY "Hallo, I am [" || self~string || "]..."
```

```
::METHOD Init                                  -- method #3
  SAY "New instance ["self~string"] is being created..."
  self~init:super

::METHOD Hallo_2                               -- method #4
  SAY "Hallo, I am ["self~string"]...“
```

```
.source~test=.class~new("TEST")  -- class(object) erzeugen
```

```
meth1=.method~new("INIT", source1)     -- create method #1
.test~setmethod("INIT", meth1)         -- add to class object

meth2=.method~new("HALLO_1", source2) -- create method #2
.test~setmethod("HALLO_1", meth2)      -- add to class object
```

```
meth3=.method~new("INIT", source3)     -- create method #3
.test~define("INIT", meth3)            -- define as instance method

meth4=.method~new("HALLO_2", source4) -- create method #4
.test~define("HALLO_2", meth4)         -- define as instance method
```

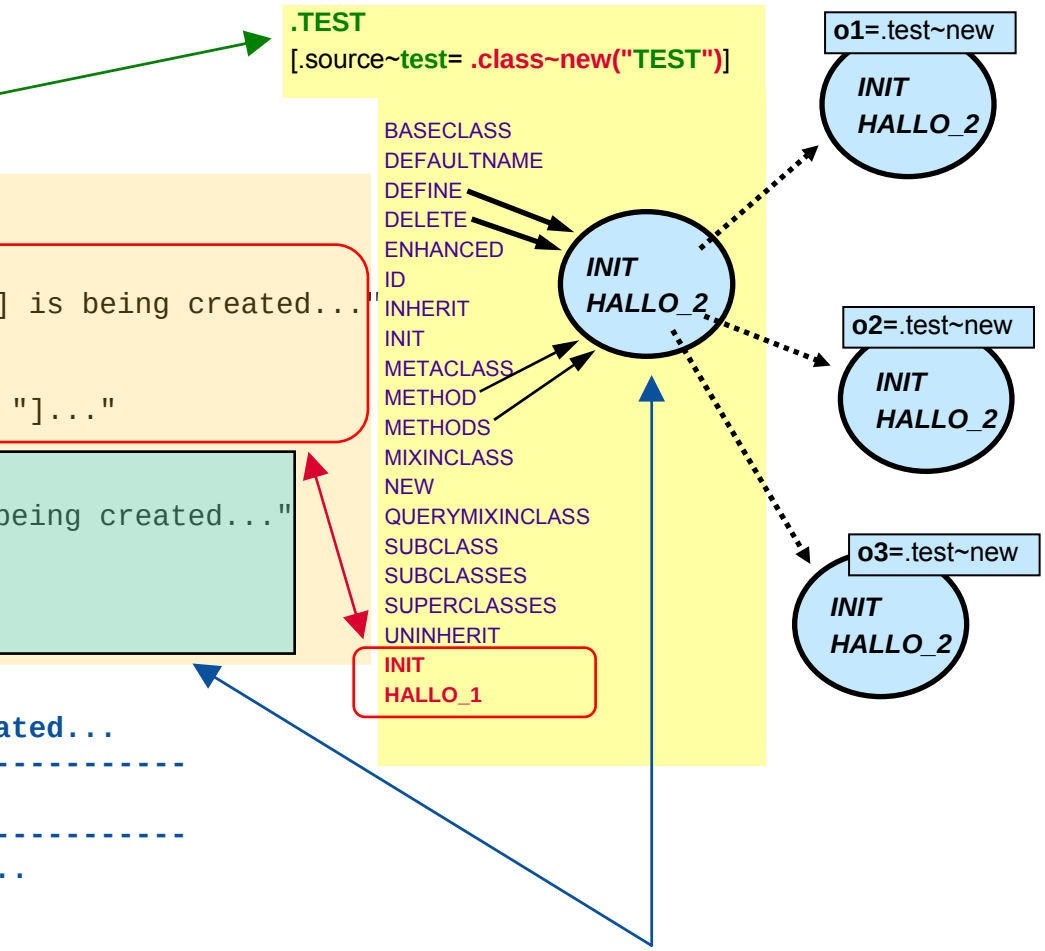
Class Methods vs. Instance Methods, 3
Example: Creating the Class Object ".TEST"

```
/**/
SAY COPIES("-", 50)
.Test~Hallo_1
SAY COPIES("-", 50)
o = .Test~New
o~Hallo_2
```

```
::CLASS  Test

::METHOD Init  CLASS
  SAY "New class [" || self~string || "] is being created..."
  self~init:super
::METHOD Hallo_1 CLASS
  SAY "Hallo, I am [" || self~string || "]..."

::METHOD Init
  SAY "New instance ["self~string"] is being created..."
  self~init:super
::METHOD Hallo_2
  SAY "Hallo, I am ["self~string"]..."
```



Output:

```
New class [The TEST class] is being created...
------------------------------------------------
Hallo, I am [The TEST class]...
------------------------------------------------
New instance [a TEST] is being created...
Hallo, I am [a TEST]...
```

Defining Metaclasses, 1

- Some problems can be elegantly solved with the help of metaclasses
  - Example: **Singleton**
    - Ensure that there is *only one instance created* from a class !

Defining Metaclasses, 2

- Creating objects is realized via the class object's NEW method
  - Hence, if it was possible to check in the appropriate NEW method whether it already created an returned an instance, then
    - One can inhibit the creation of additional instances by inhibiting the forwarding of the NEW message to the superclass, **and**
    - It becomes possible to return the already created (single) instance instead, if it got stored in a class attribute.
  - For this purpose a metaclass Singleton shall be defined
    - If one would need a class with this singleton behaviour, then it would be sufficient for it to merely extend the ::CLASS directive with the metaclass keyword and indicate the desired metaclass:

      METACLASS Singleton

Defining Metaclasses, 3

- Object Rexx implementation of the metaclass ***Singleton***

```
/**/
::CLASS Singleton SUBCLASS Class

::METHOD Init
  EXPOSE SingleInstance
  SingleInstance = .nil
  self~init:super

::METHOD New
  EXPOSE SingleInstance
  IF SingleInstance = .nil THEN
  DO
     FORWARD CLASS (super) CONTINUE
     SingleInstance = RESULT
  END
  RETURN SingleInstance
```

Defining Metaclasses, 4

- There is an abstract datatype defined for an *Easter bunny*
  - Attribute: **usageSite**
  - Methods: getting/setting values for the attribute usageSite
  - As there is can be *only one Easter bunny* it must be made sure, that only one instance can be created !
    - Therefore the class object for **EasterBunny** should be created from the metaclass **Singleton**, which makes sure that this behaviour is enforced

Defining Metaclasses, 5

```
/* EasterBunny */
  a = .EasterBunny~new("Vienna, Austria")
  b = .EasterBunny~new("Stumm im Zillertal")
  SAY "a==b:" (a==b) "usageSite of b:" b~usageSite
  ::CLASS  EasterBunny  METACLASS Singleton
  ::METHOD usageSite ATTRIBUTE
  ::METHOD Init
    self~usageSite = ARG(1)
    SAY "Init-method: usageSite is:" self~usageSite
    self~init:super
  ::CLASS Singleton SUBCLASS Class
  ::METHOD Init
    EXPOSE SingleInstance
    SingleInstance = .nil
    self~init:super
  ::METHOD New
    EXPOSE SingleInstance
    IF SingleInstance = .nil THEN DO
       FORWARD CLASS(super) CONTINUE
       SingleInstance = RESULT
    END
    RETURN SingleInstance
```

Output:

```
Init-method: usageSite is: Vienna, Austria
a==b: 1 usageSite of b: Vienna, Austria
```

Defining Metaclasses, 6

- In Example 2 there was a test class which counted the number of created objects
- Define a metaclass **Counter**, which
  - Counts how many objects have been created, and
  - Which can be interrogated for the total of the created instances

```
::CLASS  Counter   SUBCLASS Class

::METHOD Init
  self~Counter = 0
  self~init:super

::METHOD Counter  ATTRIBUTE

::METHOD New
  EXPOSE Counter
  Counter = Counter + 1
  FORWARD CLASS (super)
```

Defining Metaclasses, 7

```
/**/
.Test ~~New ~~New ~~New ~~New ~~New ~~New
SAY "So far, there have been [".Test~Counter"] objects created."
o = .Test~New
SAY "So far, there have been [" o~class~Counter"] objects created."
SAY "class:" o~class~string", last instance was:" o~string
```

```
::CLASS  Test      METACLASS Counter
```

```
::CLASS  Counter   SUBCLASS Class
::METHOD Init
  self~Counter = 0
  self~init:super
::METHOD Counter  ATTRIBUTE
::METHOD New
  EXPOSE Counter
  Counter = Counter + 1
  FORWARD CLASS (super)
```

Output:

```
So far, there have been [6] objects created.
So far, there have been [7] objects created.
class: The TEST class, last instance was: a TEST
```

"ENHANCED" Method of "CLASS", 1

- Sometimes there is a need to create an instance of a class, which possesses all attributes and methods laid out in the class, but differs slightly in a few methods
  - Problem solution
    - One needs to define a subclass implementing the different methods
    - If there is a need to create many different objects, each differing slightly in a few methods, then this approach may become a little cumbersome
- The ENHANCED method allows the creation of an instance from an existing class which receives those methods which need to behave differently
  - Such objects are called "**one-off objects**"

"ENHANCED" Method of "CLASS", 2

- The class **PERSON** has an attribute **Name** and the methods **your_name** and **from_where** which are language dependent, in addition to numerous other methods
  - The methods **your_name** and **from_where** shall be implemented in the national language of the individual persons
    - Default is the German language and the default country is Austria (Europe)
      - "Ich heiße ..."
      - "Ich komme aus Österreich."
    - English persons
      - "My name is ..."
      - "I am from ..."
    - Spanish persons
      - "Mi nom es ..."
      - "Soy de ..."

"ENHANCED" Method of "CLASS", 3

```
/**/
es = .directory~new
es ~your_name = "RETURN 'Mi nom es' self~Name'.'"
es ~from_where= "RETURN 'Soy de España.' "
en = .directory~new
en ~your_name = "RETURN 'My name is' self~Name'.'"
en ~from_where= "RETURN 'I am from America.'"
p1 = .Person~new("Hans")
p2 = .Person~enhanced(es, "Juan")
p3 = .Person~enhanced(en, "John")
SAY p1~your_name p1~from_where
SAY p2~your_name p2~from_where
SAY p3~your_name p3~from_where
::CLASS  Person
::METHOD Name      ATTRIBUTE
::METHOD Init
  self~Name = ARG(1)
::METHOD your_name
  RETURN "Ich heiße" self~Name"."
::METHOD from_where
  RETURN "Ich komme aus Österreich."
```

Output:

```
Ich heiße Hans. Ich komme aus Österreich.
Mi nom es Juan. Soy de España.
My name is John. I am from America.
```

"The Big Picture" (TBP)
Initializing Object Rexx

- Interpreter is started
- The Object Rexx environments **.environment** and **.local** are created
- The Rexx program given as argument
  - Is checked for syntax errors
  - Directives are carried out, the **source** directory is created
    - ::REQUIRES loads the specified program, its syntax is checked and its directives are carried out (a corresponding source directory is created), required program is executed starting at the first line
    - Class objects are created for the classes and are stored in the source directory
  - Execution of the program starts at the first line

Multithreading, 1

- Multithreading
  - Parallel execution of different parts of an Object Rexx program
    - Parallel execution of methods
      - Multihreading **between** different objects: **"inter**-multithreading**"**
      - Multithreading **within** one and the same object: **"intra**-multithreading**"**
  - Possible Problems
    - Accessing shared resources concurrently, e.g.
      - Concurrent alteration of attributes,
      - Concurrent alteration of files etc.
    - "Deadlocks", e.g.
      - Object 1 reserves: resource **A** and then **B**
      - Object 2 reserves: resource **B** and then **A**

Multithreading, 2

- Object Rexx default behaviour (continued)
  - All methods are **GUARD**ed by default, hence access to attributes is serialized
    - *Within* a class by default only one method can be executed for one and the same object, as that method gets **exclusive** access to the attributes, **blocking** all other methods of that class
    - Methods of one and the same object defined in different classes, are able to run concurrently (intra-multithreading) as each of these methods accesses attributes at their class level
  - The keyword **UNGUARD** of a method directives allows that method to run concurrently with any other method in that class for one and the same object
    - *There is **no** exclusive access protection to the objects!*
    - May make sense, if attributes are not accessed at all or are not changed

Multithreading, 3

- Object Rexx default behaviour (continued)
  - It is possible to determine at runtime whether methods are executed concurrently with other methods of the same class for one and the same object
    - REPLY statement of a method
      - Same effect as the RETURN statement
        - Calling program receives execution control (continues to run), **but**
        - **In addition** the method continues to run (concurrently)!
      - Optionally the REPLY statement may return a value for the calling program
        - If a REPLY statement has a return value, then in that method a RETURN statement must not supply a return value later on

Multithreading, 4

- It is possible to determine at runtime whether methods are allowed to be executed concurrently with other methods of the same class for one and the same object
  - GUARD
    - GUARD ON statement
      - **Exclusive access to the attributes is desired**; if another method has already exclusive access, then execution is halted until the other method releases it
    - The GUARD OFF statement releases the exclusive access to the attributes
  - Efficient safeguarding of "critical segments"
    - Waiting for exclusive access can be made dependent on a given value appearing in the attributes of the object
    - Waiting for releasing the exclusive access can be made dependent on a given value appearing in the attributes of the object

Multithreading, 5
Example (REPLY)

```
/* */
a=.x~new
b=.x~new
c=.x~new
fifo=.fifo~new      /* FIFO-instance */
.local~repetitions = 500
a~testwrite(fifo, "from_a")
b~testwrite(fifo, "FROM_B")
c~testread(fifo)
say "after testread"
```

```
::class X

::method testwrite
  use arg fifo, msg1
  REPLY
  do i=1 to .repetitions
    fifo~write(msg1 i)
  end

::method testread
  use arg fifo
  REPLY
  do while fifo~items > 0
    i=fifo~read
    say i
  end
```

```
::class FIFO

::method init
  expose buffer
  buffer=.queue~new

::method write
  expose buffer
  use arg tmp
  buffer~queue(tmp)

::method read
  expose buffer
  return buffer~pull

::method items
  expose buffer
  return buffer~items
```

Output e.g.:

```
after testread
from_a 1
from_a 2
from_a 3
FROM_B 1
from_a 4
FROM_B 2
...
```

Multithreading, 6
Example (REPLY, GUARD ON | OFF)

```
/* */
a=.x~new
b=.x~new
c=.x~new
fifo=.fifo~new      /* FIFO-instance */
.local~repetitions = 500
a~testwrite(fifo, "from_a")
b~testwrite(fifo, "FROM_B")
c~testread(fifo)
say "after testread"
```

```
::class X

::method testwrite
  use arg fifo, msg1
  REPLY
  do i=1 to .repetitions
    fifo~write(msg1 i)
  end

::method testread
  use arg fifo
  REPLY
  do while fifo~items > 0
    i=fifo~read
    say i
  end
```

```
::class FIFO
::method init
  expose buffer lock
  buffer=.queue~new
  lock=.false

::method write UNGUARDED
  expose buffer lock
  GUARD ON WHEN lock=.false
  lock=.true
  GUARD OFF
  use arg tmp
  buffer~queue(tmp)      /* queue item */
  GUARD ON
  lock=.false

::method read  UNGUARDED
  expose buffer lock
  GUARD ON WHEN lock=.false
  lock=.true; GUARD OFF
  data=buffer~pull       /* get item   */
  GUARD ON; lock=.false
  return data

::method items
  expose buffer
  return buffer~items
```

```
Output e.g.:

after testread
from_a 1
from_a 2
from_a 3
from_a 4
FROM_B 1
...
```

Multithreading, 7
Class MESSAGE

- **Message** class
  - Two possibilities to dispatch messages
    - SEND - synchronous execution
      - Execution proceeds, after the message was carried out in complete
    - START - **a**synchronous execution (multithreading)
      - Message is dispatched and causes the activation of the method
      - Execution of the calling program proceeds concurrently
  - Additional interesting methods in the **Message** class
    - COMPLETED - indicates, whether an asynchronously excecuting method has completed
    - RESULT - waits and returns the result of an asynchronously executing method
    - NOTIFY - allows sending a message to an object to notify it that a message has finished executing

Multithreading, 8
Example: Using Class MESSAGE, no REPLY!

```
/* */
a=.x~new
b=.x~new
c=.x~new
fifo=.fifo~new            /* FIFO-instance */
.local~repetitions = 500
.message~new(a, "testwrite", "I", fifo, "from_a")~start
.message~new(b, "testwrite", "I", fifo, "FROM_B")~start
.message~new(c, "testread",  "I", fifo)          ~start
say "after testread"


::class X

::method testwrite
  use arg fifo, msg1

  do i=1 to .repetitions
    fifo~write(msg1 i)
  end

::method testread
  use arg fifo

  do while fifo~items > 0
    i=fifo~read
    say i
  end
```

```
::class FIFO

::method init
  expose buffer
  buffer=.queue~new

::method write
  expose buffer
  use arg tmp
  buffer~queue(tmp)

::method read
  expose buffer
  return buffer~pull

::method items
  expose buffer
  return buffer~items
```

Output e.g.:

```
after testread
from_a 1
from_a 2
from_a 3
from_a 4
FROM_B 1
FROM_B 2
...
```

Multithreading, 8
Example: Using OBJECT's START-method, no REPLY!

```
/* */
a=.x~new
b=.x~new
c=.x~new
fifo=.fifo~new            /* FIFO-instance */
.local~repetitions = 500
a~start("testwrite", fifo, "from_a")
b~start("testwrite", fifo, "FROM_B")
c~start("testread",  fifo)
say "after testread"


::class X

::method testwrite
  use arg fifo, msg1

  do i=1 to .repetitions
    fifo~write(msg1 i)
  end

::method testread
  use arg fifo

  do while fifo~items > 0
    i=fifo~read
    say i
  end
```

```
::class FIFO

::method init
  expose buffer
  buffer=.queue~new

::method write
  expose buffer
  use arg tmp
  buffer~queue(tmp)

::method read
  expose buffer
  return buffer~pull

::method items
  expose buffer
  return buffer~items
```

Output e.g.:

```
after testread
from_a 1
from_a 2
from_a 3
from_a 4
FROM_B 1
FROM_B 2
...
```

Multithreading, 9

- Executing threads concurrently
  - How to determine whether all concurrently executing threads have stopped?
- Example class **Waiter**
  - Simple class whose only instance method "wait" is to run in the background for a random length of time
  - Number of running threads is counted with a class attribute
  - Class method "wait" blocks until counter drops to 0 and returns then to the caller/invoker
  - Original idea and code: cf. Ian Collier, news:comp.lang.rexx, 2004-11-09

Multithreading, 10
Example: Class WAITER, Waiting on Threads ...

```
w=.waiter~new -- create an instance
do i=1 to 5
   w~wait(i)  -- invoke instance method
end

say "Waiting for counter to drop to 0..."
.waiter~wait  -- invoke class method
say "All done"

/* Waiter */
::class waiter

   -- class methods
::method init class  -- class method
   expose counter
   counter=0         -- set initial value

::method up   class  -- class method
   expose counter
   counter=counter+1 -- increase counter

::method down class  -- class method
   expose counter
   counter=counter-1 -- decrease counter

::method wait class  -- class method
   expose counter
   -- wait until counter drops to 0
   guard on when counter=0
```

```
   -- instance methods
::method wait unguarded -- instance method
   a=random(1,6)  -- get a number between 1 and 6
   reply          -- now concurrency starts
   parse arg n    -- get invocation number
   .waiter~up     -- increase counter
   if n\='' then say 'Waiter' n 'waiting' a 'seconds'
   call syssleep a   -- sleep a few seconds
   if n\='' then say 'Waiter' n 'finished'
   .waiter~down   -- decrease counter
```

Possible Output:

```
Waiter 1 waiting 2 seconds
Waiter 2 waiting 6 seconds
Waiter 3 waiting 6 seconds
Waiting for counter to drop to 0...
Waiter 4 waiting 4 seconds
Waiter 5 waiting 2 seconds
Waiter 1 finished
Waiter 5 finished
Waiter 4 finished
Waiter 3 finished
Waiter 2 finished
All done
```

Security Manager, 1

- Allows supervising and intercepting
  - Access to the **environment**
    - ADDRESS statement
    - Messages to .local or .environment
  - Invoking **external** programs (procedures, functions)
    - Invoking **external** programs with the CALL statement or with the help of the ::REQUIRES directive
  - Sending **protected** messages
    - Keyword PROTECTED in the method directive, or
    - Dynamically at runtime: sending the SETPROTECTED message to the method object
  - Interaction with Stream objects, e.g. using the messages
    - CHARIN, CHAROUT, CHARS, LINEIN, LINEOUT, LINES, STREAM

Security Manager, 2

- This allows to monitor (Object) Rexx programs and inhibit - direct or indirect - access of the environment and external resources!
  - Intercepted (function) calls or messages can
    - be **replaced** by **self defined** functions (procedures) or messages
      - "Transparent": the supervised program is not able to note that another function (procedure) got invoked or another message was sent in place of the original one!
    - lead to a **controlled** access violation which **tears down** the supervised program
    - be allowed to execute

Security Manager, 3

- Enables rather interesting applications
  - Creation of execution profiles for (Object) Rexx programs
  - Creation of company related and task centric supervised execution environments (e.g. "sandbox") for (Object) Rexx programs
    - Secured execution of (Object) Rexx programs, which stem from anonymous or unsecure sources, e.g.
      - "Roaming Agents", which are transmitted/distributed via the Internet
  - Logging of functions (procedures) and/or messages, which are regarded to be important
  - ...

Security Manager, 4

- Course of action
  - The program wishing to employ the Security Manager creates a method object by sending the NewFile message to the class **METHOD**, supplying the name of the program to be supervised
  - The method object gets assigned a supervisor object by sending it the SetSecurityManager message, supplying the supervisor object
  - After activating the method object, the runtime system's Security Manager sends the supervisor object the following messages
    - CALL, COMMAND, REQUIRES, LOCAL, ENVIRONMENT, STREAM, METHOD
      - Every Security Manager message receives as an argument a directory object, which contains supplemental information and which may be used to communicate with the Security Manager
      - Each method **must** return either 1 (supervisor program carried out the desired action already) or 0 (carry out the desired action)

Security Manager, 5
Client-Programm ("Agent1.cmd")

```
/*================================================================*/
/* Agent Sample, "agent1.cmd"                                     */
/*================================================================*/

   interpret 'echo Hello There'
   'dir foo.bar'
   call rxfuncadd sysloadfuncs, rexxutil, sysloadfuncs
   say result
   say syssleep(1)
   say linein('c:\config.sys')
   say .array
   .object~objectname
   ::requires agent2.cmd
```

(Example originates from the online reference for Object Rexx, c.f. section "Security Manager)

Security Manager, 6
Supervisor-Programm: "No Way!"

- For the supervised program a method object is created using the NewFile message of the class **METHOD**, which then gets an instance of the supervisor class "**noWay**" assigned to
- In this example the method object containing the supervised program will be activated (run) with the help of an agent object, which gets the supervised method object assigned to under the name "DISPATCH", hence sending that message to this one-off object runs the method

```
/* parameter: filename of agent program */
 parse arg program                    -- parse name of file
 method = .method~newfile(program) -- create a method from the program in given file
 say "Calling program" program "with a closed cell manager:"
 pull
 method~setSecurityManager(.noWay~new) -- define which supervisor object to use
 agent = .agent~new(method) -- give instance the program to be supervised
 agent~dispatch             -- invoke program
/*-------------------------------------------------------------------------*/
 ::CLASS Agent
 ::METHOD init                                /* Agent initialisation       */
  use arg agentmethod
  self~setmethod('DISPATCH', agentmethod) /* method available with 'dispatch'  */
/*-------------------------------------------------------------------------*/
 ::CLASS noWay -- a supervisor class using the security manager
 ::METHOD unknown /* everything trapped by unknown and everything is an error  */
   raise syntax 98.948 array("You didn't say the magic word!")
```

(Example originates from the online reference for Object Rexx, c.f. section "Security Manager)

Security Manager, 7
Supervisor-Programm: "Dumper"

```
/* parameter: filename of agent program */
 parse arg program
 method = .method~newfile(program) /* Read the agent program from file */
 say "Calling program" program "with an audit manager:"
 pull
 method~setSecurityManager(.Dumper~new(.output))
 agent = .agent~new(method)
 agent~dispatch
/*----------------------------------------------------------------------------*/
 ::CLASS Agent
 ::METHOD init                              /* Agent initialisation            */
  use arg agentmethod
  self~setmethod('DISPATCH', agentmethod) /* method available with 'dispatch'  */
/*----------------------------------------------------------------------------*/
 ::CLASS dumper

 ::METHOD init
   expose stream                          /* target stream for output         */
   use arg stream                         /* hook up the output stream        */

 ::METHOD unknown                         /* generic unknown method           */
   expose stream                          /* need the global stream           */
   use arg name, args                     /* get the message and arguments    */
                                          /* write out the audit event        */
   stream~lineout(time() date() 'Called for event' name)
   stream~lineout('Argments are:')        /* write out the arguments          */
   info = args[1]                         /* info directory is the first arg  */
   do name over info                      /* dump the info directory          */
     stream~lineout('Item' name':' info[name])
   end
   return 0                               /* allow this to proceed            */
```

Security Manager, 8
Supervisor-Programm: "Replacer"

```
::CLASS replacer SUBCLASS noWay          /* inherit restrictive UNKNOWN method*/

::METHOD command                         /* issuing commands                  */
  use arg info                           /* access the directory              */

  info~rc = 1234                         /* set the command return code       */
  info~failure = .true                   /* raise a FAILURE condition         */
  return 1                               /* return "handled" return value     */
::METHOD call                            /* external function/routine call    */
  use arg info                           /* access the directory              */
                                         /* all results are the same          */
  info~result = "uh, uh, uh...you didn't say the magic word"
  return 1                               /* return "handled" return value     */
::METHOD stream                          /* I/O function stream lookup        */
  use arg info                           /* access the directory              */
                                         /* replace with a different stream   */
  info~stream = .stream~new('C:\OBJREXX\READ.ME')
  return 1                               /* return "handled" return value     */
::METHOD local                           /* .LOCAL variable lookup            */
                                         /* no value returned at all          */
  return 1                               /* return "handled" return value     */
::METHOD environment                     /* .ENVIRONMENT variable lookup      */
                                         /* no value returned at all          */
  return 1                               /* return "handled" return value     */
::METHOD method                          /* protected method invocation       */
  use arg info                           /* access the directory              */
                                         /* all results are the same          */
  info~result = "uh, uh, uh...you didn't say the magic word"
  return 1                               /* return "handled" return value     */
::METHOD requires                        /* REQUIRES directive                */
  use arg info                           /* access the directory              */
                                         /* switch to load a different file   */
  info~name = 'C:\OBJREXX\AGENT3.CMD'
  info~securitymanager = self            /* load under this authority         */
  return 1                               /* return "handled" return value     */
```

Off the Records: Important General Feature # 1 UNKNOWN Method

- If a method cannot be found,
  - then the UNKNOWN method is invoked, if defined in one of the searched classes
    - The runtime system supplies two arguments
      - Name of the message for which no method could be found
      - An array object containing the supplied arguments to the message

```
/* A possible UNKNOWN method */
::METHOD UNKNOWN
    USE ARG meth_name, meth_args
    SAY "unknown method: ["meth_name"]“
    DO i=1 TO meth_args~items
       SAY "  arg #" i": ["i"] value: ["meth_args[i]"]“
    END
```

  - otherwise the runtime system raises the NOMETHOD exception
    - If no exception handling is defined for this, the program will be aborted with the message "object cannot understand message"

Off the Records: Important General Feature # 2 FORWARD Statement

- "Redirection of messages"
  - Changing the target object of the message (TO)
  - Changing the starting class for searching for the method using one of the available superclass objects (CLASS)
  - Changing of the message name (MESSAGE)
  - Forwards the accompanying arguments unchanged, except if
    - ARGUMENT or
    - ARRAY is given
  - Returns afterwards to the original sender of the message, unless
    - CONTINUE is given