

# An Introduction to Procedural and Object-oriented Programming (Object Rexx) 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

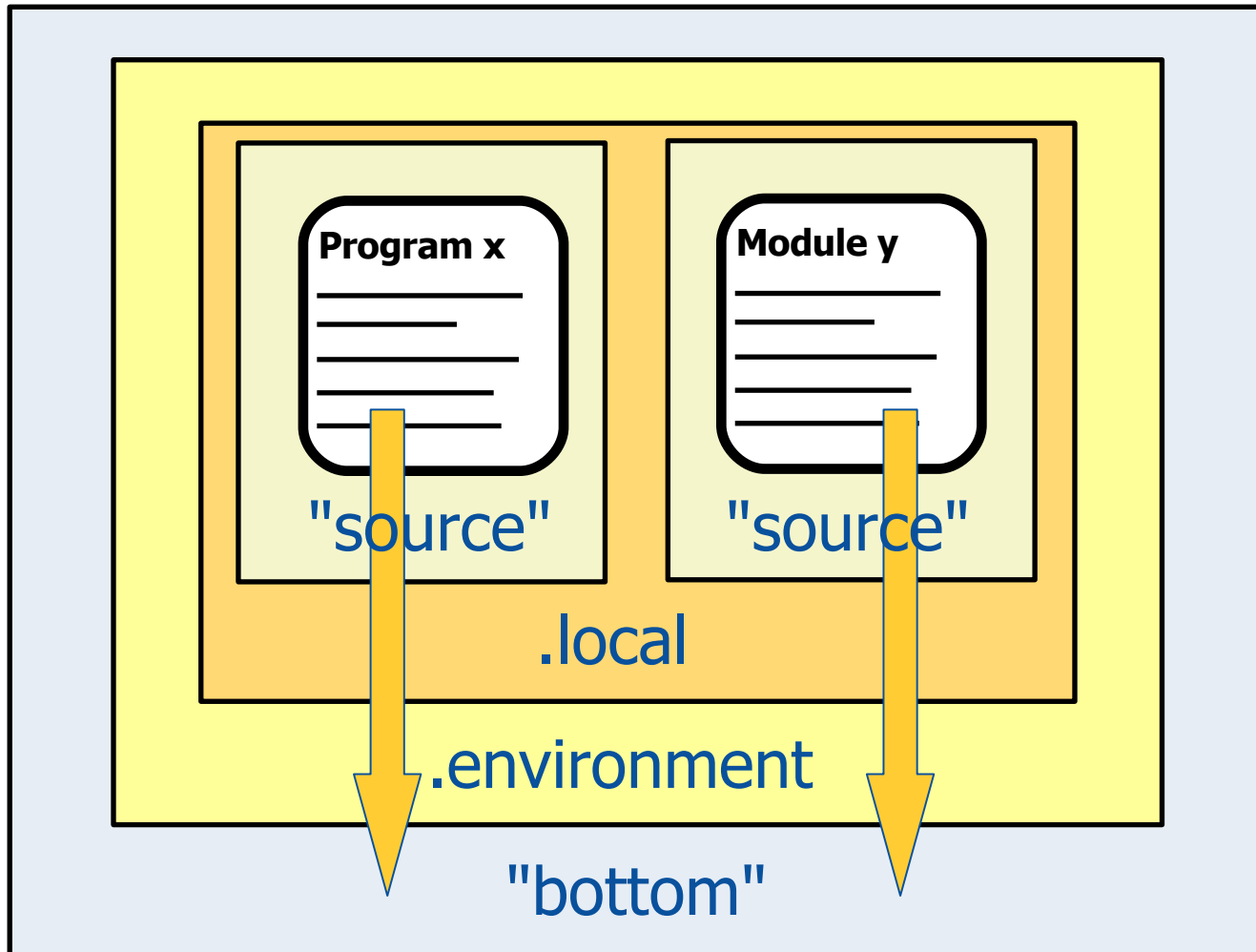
- The directory object "environment"
  - Accessible via the "environment symbol" **.ENVIRONMENT**
    - Created for each process in the operating system (system-wide under OS/2)
  - Contains important objects, e.g.
    - **All** public Object Rexx classes
    - Founding objects, e.g.
      - .nil** indicates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

```
.TEST
[defined as: .class~new("TEST")]
```

BASECLASS  
DEFAULTNAME  
DEFINE  
DELETE  
ENHANCED  
ID  
INHERIT  
INIT  
METACLASS  
METHOD  
METHODS  
MIXINCLASS  
NEW  
QUERYMIXINCLASS  
SUBCLASS  
SUBCLASSES  
SUPERCLASSES  
UNINHERIT



```
o1=.test~new
```



```
o2=.test~new
```



```
o3=.test~new
```



```
INIT
HALLO_1
```

# 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]...
```

```
.TEST
```

```
[.source~test= .class~new("TEST")]
```

BASECLASS  
DEFAULTNAME  
DEFINE  
DELETE  
ENHANCED  
ID  
INHERIT  
INIT  
METACLASS  
METHOD  
METHODS  
MIXINCLASS  
NEW  
QUERYMIXINCLASS  
SUBCLASS  
SUBCLASSES  
SUPERCLASSES  
UNINHERIT

INIT  
HALLO\_2

o1=.test~new

INIT  
HALLO\_2

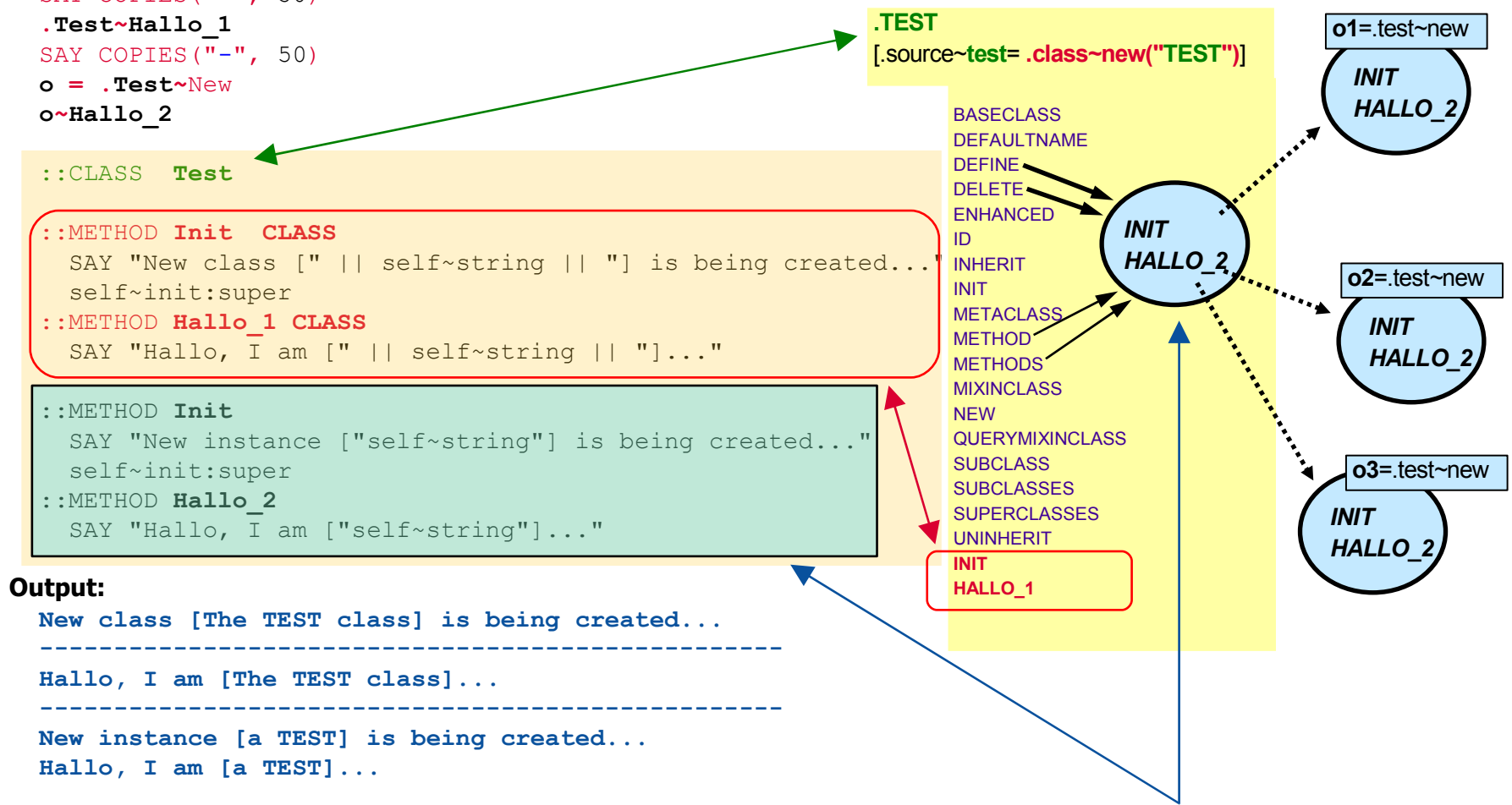
o2=.test~new

INIT  
HALLO\_2

o3=.test~new

INIT  
HALLO\_2

INIT  
HALLO\_1



# 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 heiÙe" self~Name'.'" "
```

```
::METHOD from_where
```

```
RETURN "Ich komme aus Österreich." "
```

## Output:

```
Ich heiÙe 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
      - Multithreading **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 **GUARDED** 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** - asynchronous 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 executing 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: Using Class **MESSAGE**, no **REPLY!**

```
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 sys$sleep 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 sysleep(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('Arguments 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