Unicon—History

One predecessor of Unicon is Idol, Icon-derived Object Language.

Idol was developed at the University of Arizona by Clint Jeffery in 1988 for a graduate course on object-oriented programming.

"Unicon" initially stood for "UNIX Icon"—a version of Icon with a set of POSIX extensions by Shamim Mohamed developed in 1997. Mohamed learned Icon at the U of A but, because of Icon's lack of access to many OS facilities, used Perl for a variety of systems programming tasks. He wrote:

> "*While it is true that Perl substitutes for a conglomeration of* `sed`*,* `awk` *and shell scripts, it does so with some of the worst language features from them.*"

Unicon was his solution.

In 1999 Jeffery and Mohammed merged their work and other elements, such as an ODBC interface, into a single system, which was tentatively called Icon-2.

The name Unicon was later recycled, now standing for "Unified Extended Icon".

Class and method basics

Here is a simple Unicon class that models a coordinate-less rectangle:

```
class Rectangle(width, height)
    method area()
        return width * height
    end

    method perimeter()
        return width*2 + height*2
    end

    method str()
        return "Rectangle(" || width || "x" ||
                                height || ")"
    end
end
```

The class name is `Rectangle`.

It has two *attributes* (or *fields*), `width` and `height`.

It has three methods: `area`, `perimeter`, and `str`.

The `str` method produces a value such as

    "Rectangle(3x4)"

Class and method basics, continued

For reference:

```
class Rectangle(width, height)
    method area()
        return width * height
    end
    ...
end
```

We can create instances of `Rectangle` like this:

```
r := Rectangle(3,4)

Rs := [Rectangle(3,4), Rectangle(5.0,7)]

r2 := Rectangle("3.4", 7)
```

For this class the constructor is essentially a record constructor—the supplied values are assigned directly to the fields `width` and `height`.

Methods are invoked with a familiar syntax:

```
a := r.area()

write("Perim: ", r.perimeter())

every write((!Rs).str())

write(Rectangle(2.9, 9.02).perimeter())
```

Class and method basics, continued

Just like any other Icon procedure call or record construction, no error checking is done. A null value is used for missing arguments and extra arguments are ignored.

All of the following execute without error:

```
r1 := Rectangle(3);

r2 := Rectangle("abc", "xyz");

r3 := Rectangle(7, 9, "abc");
```

Question: Which methods work for which of the above instances?

Unicon has no provision for access specifications like "public" and "private"—all attributes and methods are accessible in any context. This works:

```
procedure main()
    rr := Rectangle(3,4)
    rr.width := 20
    rr.height := 30
    write(rr.area())
end
```

Question: How can encapsulation be enforced?

Class and method basics, continued

The constructor is a procedure and can be treated like any other procedure:

```
R := Rectangle

r1 := R(5,7)

r2 := [R][1](3,4)

r3 := ("Rect"||"angle")(3,4);
```

Class and method basics, continued

Here is a program that produces a memory fault on SunOS 5.9:

```
class X()
    method f()
        write("in f()...")
    end
end

procedure main()
    x := X()
    x.f()
    x.g()
end
```

Execution:

```
% bogus
in f()...

Run-time error 302
File bogus.icn; Line 10
memory violation
Traceback:
   main()
   {record X__state_1(record X__state_1(2),
    record X__methods_1(1)) . g} from line 10
   in bogus.icn
```

The `initially` section

The simplistic behavior of assigning values in a constructor call to the attribute in the corresponding position is often inadequate.

An `initially` section can be added to trigger processing when the constructor is called.

```
class Rectangle(width, height, _area)
    method area()
        return _area
    end
    ...other methods...
    initially(w, h)
        write("initially: ",
             Image([width, height, _area],3))
        width := w
        height := h
        _area := w * h
end
```

If present, `initially` must follow all methods.

The `end` that ends the class definition also ends the `initially` section.

```
][ rr := Rectangle(3,4);
initially: L1:[&null,&null,&null]
   r := ...lots...

][ rr.area();
   r := 12  (integer)
```

If `initially(...)` is present, no attributes are automatically initialized.

`initially`, continued

The `initially` section can be used to enforce constraints on the constructor's arguments.

```
class Rectangle(width, height, _area)
    ...
    initially(w, h)
        if /w | /h then fail
        if not numeric(w) |
           not numeric(h) then fail
        width := w
        height := h
        _area := width * height
end
```

Execution:

```
][ rr := Rectangle(3);
Failure

][ rr := Rectangle(3, "x");
Failure

][ rr := Rectangle(3, "3.4");
   r := ...lots...
```

Note that by default an `initially` section succeeds.

Problem: There is no overloading of method names or the `initially` section. How could, for example, an omitted height default to the same value as the width?

```
r := Rectangle(3)
```

`initially`, continued

If there is a parameterless `initially` section then the arguments of the constructor call are used to initialize the attributes.

Example:

```
class Counter(count)
    method inc()
        count +:= 1
        return count
    end

    method value()
        return count
    end

    initially
        /count := 0
end
```

Usage:

```
][ A := Counter(10);
   r := ...lots...

][ B := Counter();
   r := ...lots...

][ A.value();
   r := 10  (integer)

][ B.value();
   r := 0  (integer)
```

The implicit variable `self`

Unicon's counterpart for Java's `this` is `self`.

One use is to distinguish between attributes and parameters:

```
class Rectangle(_area, width, height)
    initially(width,height)
        self.width := width
        self.height := height
        ...
end
```

Class specification—general form

Here is the general form of a class specification:

class *classname*(*attribute1*, *attribute2*, ..., *attributeN*)

method *method1*(*param1*, *param2*, ..., *paramN*)
...code for method...
end

...additional methods...

initially(*param1*, *param2*, ..., *paramN*)
...code to execute upon construction...
end

Note that all attributes are specified in the list following the class name.

Here is a minimal class definition:

```
class X()
end
```

Method result sequences

Methods may fail, or produce a single result, or be generative, just like regular Icon procedures. Imagine a `side()` method that generates the width and height of a rectangle:

```
class Rectangle(width, height, _area)
    ...
    method side()
        suspend width | height
    end
    ...
end
```

Usage:

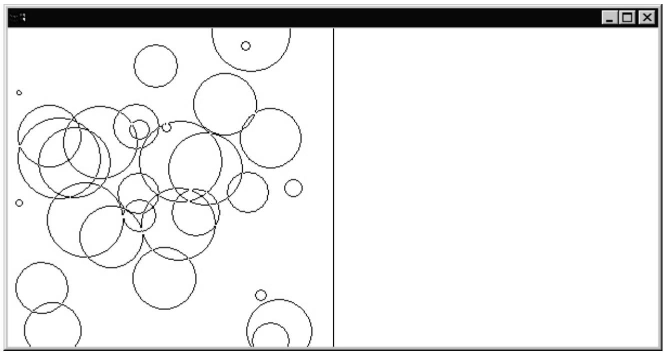
```
procedure main()
    rects := []
    every 1 to 20 do
        put(rects, Rectangle(?20, ?20))

    every r := !rects do
        if r.side() > 10 then
            write(r.str())
end
```

Output:

```
Rectangle(7x11)
Rectangle(2x15)
Rectangle(2x15)
Rectangle(11x13)
Rectangle(12x15)
Rectangle(15x5)
...
```

Circle drag/drop in Unicon

Recall this program from Graphics slide 31: (`drag1`)



```
record circle(x,y,r)
procedure main()
    WOpen("size=600,300","drawop=reverse")
    DrawLine(300,0,300,300)
    circles := make_circles()
    repeat case Event() of {
      &lpress:
        if c := point_in(circles, &x, &y) then {
          lastx := c.x; lasty := c.y
          r := c.r
          repeat case Event() of {
            &ldrag: {
              DrawCircle(lastx, lasty, r)
              DrawCircle(lastx := &x,lasty :=&y, r)
              }
            &lrelease: {
              DrawCircle(lastx, lasty, r)
              if &x <= 300 then {
                    DrawCircle(&x, &y, r)
                    c.x := &x; c.y := &y
                    }
              else
                    delete(circles, c)
                break
              }
            }
          }
        }
end
```

Circle drag/drop in Unicon, continued

Here is a version in Unicon. First, a `Circle` class:

```
class Circle(x, y, r)
    method has_pt(pt_x, pt_y)
        if sqrt((x-pt_x)^2+(y-pt_y)^2) < r then
            return self
    end

    method move_to(new_x, new_y)
        erase()
        x := new_x; y := new_y
        draw()
    end

    method erase()
        draw()
    end

    method draw()
        DrawCircle(x, y, r)
    end

    initially
        draw()
end
```

Note that the `initially` section counts on direct assignment of attributes from the constructor call.

The code above does not track the on-screen state (drawn or not) and thus places an additional responsibility on the caller.

Circle drag/drop in Unicon, continued

Main program:

```
procedure main()
    WOpen("size=600,300","drawop=reverse")
    DrawLine(300,0,300,300)

    circles := make_circles()

    repeat case Event() of {
      &lpress:
        if c := (!circles).has_pt(&x, &y) then {
          repeat case Event() of {

            &ldrag: c.move_to(&x, &y)

            &lrelease: {
              if &x <= 300 then
                    c.move_to(&x, &y)
              else {
                    c.erase()
                    delete(circles, c)
                    }
              break
              }
            }
          }
        }
end
```

Which version is better?

Inheritance

Here is a simple general form for specifying inheritance:

> class *class-name* : *superclass-name* (*class-attributes*)
> ...
> end

Here is a skeletal three class hierarchy to model geometric shapes:

```
class Shape(name)
end

class Rectangle: Shape (width, height)
end

class Circle: Shape (radius)
end
```

`Rectangle` is a subclass of `Shape` and has three attributes: `name`, `width`, and `height`.

`Circle` is a subclass of `Shape` and has two attributes: `name` and `radius`.

In Unicon there is no common superclass such as Java's `Object` class.

Superclass initialization

If a subclass has no `initially` section then the superclass's `initially` section is called.

The superclass's `initially` section is NOT CALLED if the subclass has an `initially` section.

Example:

```
class Shape(name)
    initially
        write("Shape's initially")
end

class Circle: Shape (radius)
end

class Rectangle: Shape (width, height)
    initially
        write("Rectangle's initially")
end

procedure main()
    c := Circle(5)
    r := Rectangle(3,4)
end
```

Output:

```
Shape's initially
Rectangle's initially
```

If a subclass requires an `initially` section then it should explicitly invoke the superclass `initially` section.

Superclass initialization, continued

Here is an example of invoking a superclass initially section:

```
class Shape(name)
    initially(nm)
        name := \nm | "<none>"
        write("Shape initially(), name = ", name)
end

class Rectangle: Shape (width, height)
    initially(w, h, nm)
        write("Rectangle initially()")
        width := w
        height := h
        self$Shape.initially(nm)
end

procedure main()
    r := Rectangle(3, 4)
    write(Image([r.name, r.width, r.height],3))

    r2 := Rectangle(5, 7, "B")
    write(Image([r2.name, r2.width, r2.height],3))
end
```

Output:

```
Rectangle initially()
Shape initially(), name = <none>
L1:["<none>",3,4]

Rectangle initially()
Shape initially(), name = B
L2:["B",5,7]
```

Note that there is no rule that specifies when superclass initialization must be done.

Method inheritance and overriding

Unicon's rule for method inheritance is a common one: Subclasses inherit superclass methods unless they supply their own version of a method.

```
class Shape()
    method area()
    end
end

class Rectangle: Shape (_width, _height)
    method area()
        return _width * _height
    end
end

class Circle: Shape (_radius)
end

procedure main()
    r := Rectangle(3, 4)
    c := Circle(5)

    write("r's area = ", r.area())
    write("c's area = ", c.area())
end
```

Output:

```
r's area = 12
```

Abstract classes

Unicon provides no means to declare a class or method as abstract.

One way to ensure that a subclass overrides a method is to add code that produces an error if an overriding method is forgotten:

```
class Shape()
    method area()
        stop("Shape.area() called!?")
    end
end
```

Question: Icon's association of type with values rather than variables implies that some errors are not detectable until the code is executed. Would it be possible to enforce an abstract declaration at compile time?

Inheritance and dynamic typing

Languages like Java use inheritance to allow code to be written in terms of a superclass and then be run with subclass instances.

```
public static Shape biggestArea(Shape shapes[ ]) {
    if (shapes.length == 0) return null;
    Shape it = shapes[0];
    for (int i = 1; i < shapes.length; i = i + 1) {
        if (shapes[i].getArea( ) > it.getArea( ))
            it = shapes[i];
        }
    return it;
    }
```

Because of Icon's value-based typing, inheritance is not needed to write such code.

In the following code there is no common superclass for `A` and `B`, but the routine `show_what()` can a handle a list of `A`s, `B`s, and any other objects that have a `what()` method.

```
class A()
    method what()
        return "I'm an A!"
    end
end

class B()
    method what()
        return "I'm a B..."
    end
end

procedure show_what(L)
    every o := !L do
        write(o.what())
end
```

Multiple inheritance

Unicon supports *multiple inheritance*—a class can have any number of superclasses. Here's an abstract example:

class A(_a)
   method f()
      write("A.f()")
   end
end
 	
class B(_b1, _b2)
   method g()
      write("B.g()")
   end
end
 	
class C(_c)
end
	class D(_d1, _d2, _d3)
	   method h()
	      write("D.h()")
	   end
	end
	
	class ABC: A : B : C (_abc1)
	   method g()
	      write("ABC.g()")
	   end
	end
	
	class M : D : ABC (_m1, _m2)
	end

A subclass inherits all attributes and methods of all its superclasses.

```
procedure main()
   abc := ABC()
   abc.f()  # calls A.f()
   abc.g()  # calls ABC.g()

   m := M()
   m.f()    # calls A.f()
   m.g()    # calls ABC.g()
   m.h()    # calls D.h()
end
```

Multiple inheritance, continued

A less abstract example—a `DrawableRectangle`:

```
class Drawable(_x, _y)
    method draw()
        stop("Drawable.draw() not overridden")
    end
    initially(x,y)
        _x := x; _y := y
end

class DrawableRectangle : Rectangle : Drawable ()
    method draw()
        DrawRectangle(_x, _y, _width, _height)
    end
    initially(w, h, x, y, nm)
        self$Rectangle.initially(w,h,nm)
        self$Drawable.initially(x,y)
end

procedure main()
    WOpen("size=300,300")
    rects := [ ]
    every i := 1 to 20 do
        put(rects, DrawableRectangle(?40, ?40, ?300, ?300))

    every r := !rects do
        if r.area() < 1000 then
            r.draw()

    WDone()
end
```

Class variables and methods

Unicon does not have support for class variables and methods.

Problem: What is the essence of class variables and methods and how can they be approximated/simulated?

Class variables and methods, continued

Here is a version of the Rectangle class that uses a global variable to loosely simulate a class method that returns the number of rectangles that have been created.

```
class Rectangle(width, height)
    method area()
        return width*height
    end
    initially
        initial{
            Rectangle_num_created := 0
            }
        Rectangle_num_created +:= 1
end

global Rectangle_num_created

procedure Rectangle_created()
    return Rectangle_num_created
end

procedure main()
    every 1 to 20 do
        Rectangle(?100, ?100)

    write(Rectangle_created(),
         " rectangles created")
end
```

What are the pros and cons of this approach?

Class variables and methods, continued

Another approach is to use a method with a static variable and have a parameter serve as a flag indicating whether the value should be fetched or modified.

```
class Rectangle(width, height)
    ...
    method created(increment)
        static created
        initial created := 0
        if \increment then
            created +:= 1
        else
            return created
    end

    initially
        created(1)   # any non-null value would do
end

procedure main()
    every 1 to 20 do
        Rectangle(?100, ?100)

    write(Rectangle().created(),
         " rectangles created")
end
```

What are the pros and cons of this approach?

Class variables and methods, continued

Here is another approach:

```
class Rectangle(width, height)
    initially
      initial {
       if type(Rectangle_class) == "procedure" then
          Rectangle_class()
          }
      Rectangle_class.new_instance()
end

class Rectangle_class(num_rects)
    method created()
        return num_rects
    end
    method new_instance()
        num_rects +:= 1
    end
    initially
        Rectangle_class := self
        num_rects := 0
end

procedure main()

    every 1 to 20 do
        Rectangle(?100, ?100)

    write(Rectangle_class.created(),
         " rectangles created")
end
```

What are the pros and cons of this approach?

Behind the scenes in Unicon

Unicon programs are preprocessed, yielding a syntactically valid Icon program that is then compiled with `icont`. The resulting bytecode executable can then be run on the Unicon virtual machine.

A Unicon method is translated into an Icon procedure that has the class name prepended and an initial argument of `self`.

The methods in this Unicon class:

```
class Rectangle(width, height)
    method area()
        return width * height
    end
    method set_width(w)
        width := w
    end
end
```

are translated into this Icon code:

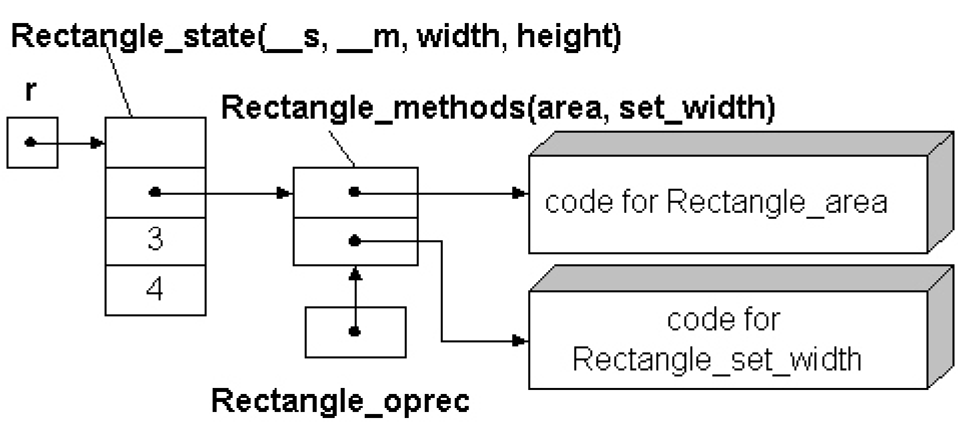
```
procedure Rectangle_area(self)
    return self.width * self.height
end

procedure Rectangle_set_width(self, w)
     self.width := w
end
```

Behind the scenes in Unicon, continued

Here is the balance of the generated Icon code for the class:

```
record Rectangle__state(__s, __m, width, height)

record Rectangle__methods(area, set_width)

global Rectangle__oprec

procedure Rectangle(width,height)
    local self,clone
    initial {
        if /Rectangle__oprec then
            Rectangleinitialize()
        }
  self := Rectangle__state(&null, Rectangle__oprec,
                           width, height)
  self.__s := self
  return self
end

procedure Rectangleinitialize()
    initial Rectangle__oprec :=
       Rectangle__methods(Rectangle_area,
                          Rectangle_set_width)
end
```

For `r := Rectangle(3,4)` here is the picture:



Behind the scenes in Unicon, continued

For reference:

```
record Rectangle__state(__s,__m, width, height)

record Rectangle__methods(area, set_width)
```

Here is a main program. The Unicon preprocessor makes no changes in it:

```
procedure main()
    r := Rectangle(3,4)
    r.set_width(7)
    write("Area: ", r.area())
end
```

Recall that the type of `r` is `Rectangle__state` and note that there is no `area` field in that record.

What happens is this: When the field operator (binary period) detects that `r` has no field named `area`, it looks to see if the first field of `r` is named `__s`. If so, it then looks in the record referenced by the second field (`__m`) for a field named `area` and if found, the value of the field is the result of evaluating `r.area`.

To see the result of Unicon preprocessing, use the `-E` flag:

```
unicon -E myclass.icn
```

Access to system services

The object-oriented programming facilities are one aspect of Unicon. Another is Unicon's access to operating system services.

One of the services available is the `stat()` system call, which produces a variety of information about a file. Unicon's `stat(fname)` call returns a record with the following information (and more) about the file `fname`:

Field name	*Description*
`dev`	ID of device containing the file
`ino`	Inode number
`mode`	File mode (e.g. protections)
`nlink`	Number of links
`uid`, `gid`	User-id and group-id
`size`	Size of the file in bytes
`atime`	Time of last access
`mtime`	Time of last modification
`ctime`	Time of last inode change
`symlink`	If a symbolic link, the name linked to.

Example: List files by size

`bysize` is a program that uses `stat(fname)` to produce a list of files in a named directory sorted by file size in descending order:

```
% bysize /home/cs451/a5
    10663 mtimes
     3730 day
     3461 mtimes.1
     3450 mcycle
      701 mcycle.2
      632 mtimes.2
      562 mtimes.ex
      229 tmtimes.sh
      148 mcycle.1
      104 mtimes.3
```

An `ls`, for comparison:

```
% ls -la /home/cs451/a5
total 60
drwxr-sr-x   3 whm      cs451        4096 Apr 21 03:15 .
drwxr-sr-x  19 whm      cs451        4096 Apr 16 03:40 ..
drwx------   2 whm      cs451        4096 Feb 12 04:45 v1
-r-xr-xr-x   1 whm      cs451        3730 Feb 12 22:33 day
-r-xr-xr-x   1 whm      cs451        3450 Feb 12 21:54 mcycle
-r--r--r--   1 whm      cs451         148 Feb 12 21:54 mcycle.1
-r--r--r--   1 whm      cs451         701 Feb 12 21:54 mcycle.2
-r-xr-xr-x   1 whm      dept        10663 Feb 12 04:42 mtimes
-r-xr-xr-x   1 whm      cs451        3461 Feb 12 04:41 mtimes.1
-r-xr-xr-x   1 whm      cs451         632 Feb 12 04:41 mtimes.2
-r-xr-xr-x   1 whm      cs451         104 Feb 12 04:41 mtimes.3
-r-xr-xr-x   1 whm      cs451         562 Feb 12 04:41 mtimes.ex
-r-xr-xr-x   1 whm      cs451         229 Feb 12 04:41 tmtimes.sh
```

Note that `bysize` does not show the three directories (`.`, `..`, and `v1`)

bysize.icn

```
record file_info(name, size)  # name and size of a file

procedure main(args)
   #
   # Change to the directory named on the command line
   chdir(args[1]) |
      stop(args[1], ": Bad directory")

   #
   # A directory can be opened like a file.   Reading from a directory
   # produces the entries in the directory.
   dir := open(".")

   files := [ ]
   #
   # Read each directory entry and stat it.  If an entry is not a directory,
   # add it to the list.
   #
   while fname := read(dir) do {
      stat_rec := stat(fname)

      #
      # If not a directory, include it.
      #
      if stat_rec.mode[1] ~== "d" then
         put(files, file_info(fname, stat_rec.size))
      }

   #
   # Sort by file size and print.
   #
   files := sortf(files, 2)
   every r := files[*files to 1 by -1] do
      write(right(r.size,9)," ", r.name)
end
```

Example: A simple shell

An interesting application of Unicon's system service facilities is a simple command processor, commonly called a shell, that is used to invoke programs.

UNIX shells use a "fork and exec" sequence to start programs.

The call `fork()` creates a child process that is a copy of the current process. In the parent process, `fork()` returns the process id of the child. In the child process, `fork()` returns zero.

Example:

```
procedure main()
    if fork() = 0 then
        write("child process id is ", getpid())
    else
        write("parent process id is ", getpid())

    write("Hello, world!")
end
```

Output:

```
parent process id is 7713
Hello, world!
child process id is 7716
Hello, world!
```

Note that fork creates a process, not a thread—there's no sharing of memory between the two processes.

A simple shell, continued

Here is a larger example with `fork()`. Both the parent and child process identify themselves and then do three random sleeps (`delay()`s), printing the time when they awake.

```
link random
procedure main()
    if fork() = 0 then who := "child "
                  else who := "parent"

    randomize()
    write(who, " process id is ", getpid())
    every 1 to 3 do {
        delay(?10000)
        write(who, " @ ", &clock)
        }

    write(who, " done")
end
```

Output:

```
% fork
parent process id is 8730
child  process id is 8733
child  @ 03:43:46
parent @ 03:43:49
parent @ 03:43:49
child  @ 03:43:53
parent @ 03:43:57
parent done
% child  @ 03:43:59
child  done
```

Questions:

(1) Why is there a "%" in the middle of the output?

(2) What happens if the `randomize()` call is omitted?

A simple shell, continued

The second element for a shell is the `exec()` call:

```
exec(fname, arg0, arg1, ..., argN)
```

This call replaces the current process with an execution of the program named by `fname`, supplying the remaining parameters as arguments to the program.

A simple example: (`exec0.icn`)

```
procedure main()
    write("Ready to exec ls...")
    exec("/bin/ls", "ls", "-ld", "/")
    write("Done with exec...")
end
```

Execution:

```
% exec0
Ready to exec ls...
drwxr-xr-x  27 root  wheel   1024 Apr 13 16:56 /
%
```

Note that `exec()`'s `arg0` through `argN` corresponds to, e.g., `argv[0]` through `argv[N]` in a C program:

```
void main(int argc, char *argv[])
{
...
}
```

A simple shell, continued

As mentioned earlier, UNIX shells use a "fork and exec" sequence: When the user types a command to run, the shell forks and then uses an `exec()` call in the child to overlay the child process with the command of interest.

A very simple shell:

```
procedure main()
    while writes("Cmd? ") & cmdline := read() do {
        if (child := fork()) = 0 then {
            #
            # We're the child process.  Split up
            # command line and exec it.
            w := split(cmdline)
            cmd := get(w)
            exec!(["/bin/"||cmd, cmd] ||| w)
            }
        else
            #
            # We're the parent.  Wait for the child
            # to terminate before prompting again.
            wait(child)
        }
end
```

Execution:

```
Cmd? ls -ld /
drwxr-xr-x  27 root  wheel     1024 Apr 13 16:56 /
Cmd? date
Mon Apr 21 04:13:29 MST 2003
Cmd? wc /etc/passwd
    1462    3840   98991 /etc/passwd
Cmd? wc </etc/passwd
wc: cannot open </etc/passwd
Cmd? who >out
who: Cannot stat file '>out'
```

A simple shell—I/O redirection

UNIX shells allow standard input and standard output to be *redirected* with the < and > symbols.

Here is a shell command that runs `wc` on the class mailing list mailbox and redirects the output to the file `wc.output`

```
% wc < /home/cs451/mail > wc.output
```

The result:

```
% cat wc.output
   6257   31501  268989
```

IO redirection, continued

For reference:

```
% wc < /home/cs451/mail > wc.output
```

A cornerstone of redirection is that the `exec()` call replaces the current process with the execution of another program, but file descriptors are unaffected. For example, standard input (`&input`) in the original process is standard input in the replacement process.

Here is a program (`redir1`) that takes advantage of this carryover of file descriptors to mimic the shell command above:

```
procedure main()

   infile := open("/home/cs451/mail")
   fdup(infile, &input)  # like &input := infile

   outfile := open("wc.output", "w")
   fdup(outfile, &output)

   exec("wc", "wc")
end
```

Execution:

```
% redir1
% cat wc.output
   6257   31501  268989
```

The `fdup(`*`from`*`, `*`to`*`)` function replaces the file descriptor associated with the file value `to` with the file descriptor associated with the file value `from`.

`ish`: A shell in Unicon

Here is `ish`, a rudimentary shell that provides I/O redirection and background processes (via `&`):

```
procedure main()
    while line := (writes("ish -- "), read()) do {
        if *line = 0 then next
        w := split(line)
        cmd := get(w)

        background := if w[-1] == "&" then { pull(w); 1} else &null

        if fork() = 0 then {
            pgmargs := [ ]
            stdin := stdout := &null
            while arg := get(w) do {
                case arg[1] of {
                    "<": stdin := arg[2:0]    # assume no space after '<' and '>'
                    ">": stdout:= arg[2:0]
                    default: put(pgmargs, arg)
                    }
                }
            if \stdin then {
                stdin := open(stdin) | stop(stdin, ": Can't open")
                fdup(stdin, &input)
                }
            if \stdout then {
                stdout := open(stdout, "w") | stop(stdin, ": Can't open")
                fdup(stdout, &output)
                }
            exec!([cmd, cmd] ||| pgmargs)
            }
        else {
            if /background then wait()
            }
        }
end
```

`ish` in operation

```
% ish
ish -- date
Wed Apr 23 23:33:48 MST 2003
ish -- date >out
ish -- cat out
Wed Apr 23 23:33:54 MST 2003
ish -- wc <ish.icn
     38     115     832
ish --
ish -- du /usr >du.out &
ish -- wc du.out
    562    1124   21711 du.out
ish -- who
whm      tty1     Apr  6 23:50
whm      pts/0    Apr  6 23:52 (:0)
ish -- date
Wed Apr 23 23:42:56 MST 2003
ish -- wc du.out
   1644    3288   64077 du.out
ish -- ^D
%
```

Some work remains:

```
ish --
ish -- ls *.icn
ls: *.icn: No such file or directory
ish --
ish -- ls | wc
ls: |: No such file or directory
ls: wc: No such file or directory
```

Pipes

A standard feature of UNIX shells is the ability to send the output from one program into the input of another program.

```
ls | wc
ls -t | grep -v ".icn$" | head -1
```

The supporting mechanism for this is called a *pipe*.

A pipe is an operating system mechanism that arranges for output written to a file descriptor to be available as input on another file descriptor.

Reads from a pipe will block until something is written to the other end. Writes to a pipe will block if a sufficient amount of already written data is still unread.

Unicon's `pipe()` function creates a pipe and returns a list of two file values: the first for reading and the second for writing:

```
][ pipe();
   r := [file(pipe), file(pipe)]  (list)
```

A trivial example:

```
procedure main(args)
    pipes := pipe()
    write(pipes[2], "Testing...")
    write(reverse(read(pipes[1])))
end
```

Output:

```
...gnitseT
```

Pipes, continued

In most cases a pipe is used to send data between two processes.

In the following program a child process writes to a parent process at random intervals.

```
procedure main()
    pipe_pair := pipe()
    if fork() = 0 then
        every i := 1 to 5 do {
            delay(?5000)
            write(pipe_pair[2], i)
            }

    while line := read(pipe_pair[1]) do
        write("My child wrote to me! (",
            line, " at ", &clock, ")")
end
```

Output:

```
My child wrote to me! (1 at 21:14:04)
My child wrote to me! (2 at 21:14:06)
My child wrote to me! (3 at 21:14:08)
My child wrote to me! (4 at 21:14:10)
My child wrote to me! (5 at 21:14:13)
```

Pipes, continued

Consider a program that prompts for two commands and uses a pipe to connect the output of the first to the output of the second: (blank lines have been added...)

```
Pipe from? ls
Pipe to? wc
    118     118     917

Pipe from? ls
Pipe to? grep fork
fork
fork.icn
fork0
fork0.icn

Pipe from? who
Pipe to? wc
     71     355    2201

Pipe from? iota 3
Pipe to? cat
1
2
3

Pipe from? iota 3
Pipe to? tac
3
2
1
```

Pipes, continued

Here is the from/to piper:

```
procedure main()
    repeat {
        writes("Pipe from? ")
        from_cmd := split(read())
        writes("Pipe to? ")
        to_cmd := split(read())

        pipe_pair := pipe()
        if fork() = 0 then {
            fdup(pipe_pair[2], &output)
            close(pipe_pair[1])
            exec!([from_cmd[1]]|||from_cmd)
            write("exec failed! (from)")
            }

        if fork() = 0 then {
            fdup(pipe_pair[1], &input)
            close(pipe_pair[2])
            exec!([to_cmd[1]]|||to_cmd)
            write("exec failed! (to)")
            }

        close(pipe_pair[1])
        close(pipe_pair[2])

        wait()  # wait for both children to
        wait()  # terminate
        }
end
```

Note that the `close()`s are needed to make it work.

How could we add piping to `ish`?

The `select()` function

The `select()` function allows a program to wait on input from any one of several input sources and, optionally, a delay time. It looks like this:

```
select(file1, file2, ..., wait_time)
```

It returns when input is available on at least one of the files and/or the wait time (in milliseconds) has elapsed. The return value is a list of files on which input is available. If the list is empty, the wait time was exceeded.

In what situations is something like `select()` necessary?

`select()` allegedly works on files, network connections, pipes, and windows. The following example required a patch to the Unicon runtime system.

The `select()` function, continued

In this program a parent process forks three children and then waits to hear from each via a pipe.

```
procedure main()
    cpipes :=[] # input side of pipes from children
    every c := !"ABC" do {
        pipe_pair := pipe()
        put(cpipes, pipe_pair[1])
        if fork() = 0 then {
            randomize()
            repeat {
                delay(?15000) # 15 seconds
                write(pipe_pair[2], c)
                }
            }
        }
    while files := select(cpipes[1], cpipes[2],
      cpipes[3], 3500) do { # should use select!...
        if *files ~= 0 then
            every f := !files do {
                line := read(f)
                write(line, " wrote to me at ",
                      &clock)
                }
        else
             write("My kids never write...")
        }
end
```

Output:

C wrote to me at 02:22:58 My kids never write... B wrote to me at 02:23:04 A wrote to me at 02:23:04 My kids never write... C wrote to me at 02:23:08	A wrote to me at 02:23:11 My kids never write... B wrote to me at 02:23:18 C wrote to me at 02:23:19 C wrote to me at 02:23:22

Defaulting and type conversion

Unicon provides a syntactic structure to specify type conversions and default values. The general, per-parameter form is this:

parameter-name : *conversion-procedure* : *default-value*

Both *conversion-procedure* and *default-value* are optional.

Here's an example that uses only a conversion procedure:

```
class Rectangle(width, height)
    initially(w:integer, h:integer)
        width := w
        height := h
end
```

If the value supplied for `w` or `h` is not convertible to an integer, (i.e., if `integer(...)` fails) error 101 is produced:

```
][ r := Rectangle(3, "four");
Run-time error 101
integer expected or out of range
offending value: "four"

][ r := Rectangle();
Run-time error 101
integer expected or out of range
offending value: &null
```

Note that this specification can be used with both methods and ordinary procedures.

Question: What's the real benefit of this language element?

Defaulting and type conversion, continued

For reference:

parameter-name : *conversion-procedure* : *default-value*

Recall that `split()`'s second argument defaults to the character set containing a blank and a tab.

Instead of this:

```
procedure split(s, c)
    /c := ' \t'
    ...
```

We could do this:

```
procedure split(s, c:' \t')
    ...
```

We could further constrain the argument values by specifying conversion routines:

```
procedure split(s:string, c:cset:' \t')
    ...
```

Note that only a literal is permitted for the default value.

Problem: What's wrong with the following routine?

```
procedure f(x:list)
    ...
```

Defaulting and type conversion, continued

A user defined procedure may be specified as the conversion routine.

If the routine fails, then a run-time error is produced. If it succeeds, the value returned is passed as the argument value. (Just as with a built-in routine like `integer`.)

Example:

```
procedure f(n:odd)
    return n * 2
end

procedure odd(x)
    if x % 2 = 1 then return x
end
```

Usage:

```
][ f(5);
   r := 10  (integer)

][ f(20);
Run-time error 123
invalid type
offending value: 20
```

Problem: There's no way to do something like this:

```
procedure f(x:(integer|string))
    ...
```

How could that effect be achieved?

The `xcodes` facility

The `xcodes` package in the IPL allows a nearly arbitrary data structure to be written to a file and later restored.

Here is a program that generates a random list and saves it to a file using `xencode()`:

```
link xcodes, random
procedure main()
    randomize()

    L := randlist(10, 15)
    write("List: ", ltos(L))

    f := open("randlist.out", "w")

    xencode(L, f)

    close(f)
end
```

Execution:

```
% xcodes1w
List: [29,97,[34,92],[[63,6]],63,35,13]

% cat randlist.out
L
N7
N29
N97
L
N2
N34
N92
L
N1
...a few lines more...
```

The `xcodes` facility, continued

Here is a program that loads <u>any</u> structure written with `xencode()`:

```
link xcodes, image
procedure main(args)
    f := open(args[1]) | stop("Can't open file")
    S := xdecode(f)
    write("Restored structure: ", Image(S))
end
```

Execution:

```
% xcodes1r randlist.out
Restored structure: L1:[
  29,
  97,
  L2:[
    34,
    92],
  L3:[
    L4:[
      63,
      6]],
  63,
  35,
  13]
```

`xencode()` can't accurately save co-expressions, windows, and files, but allows them to be present in the structure.

Problem: How can a facility like `xencode/xdecode` be written?