520 — Principles of Programming Languages

20: Modula-2

Christian Collberg

collberg@cs.arizona.edu

Department of Computer Science

University of Arizona

History

- Modula-2 is a descendant of Pascal, also designed by Niklaus Wirth. There was an intermediate language called “Modula” but it never caught on. Modula-3 was not designed by Wirth but by a committee from Olivetti and DEC.
- Modula-2 also traces its ancestry from Mesa, a language designed at Xerox. The joke is that Modula-2 is what Wirth remembered of Mesa after he returned from a sabbatical at Xerox, slightly drunk and jet-lagged from the trans-atlantic flight.

Modula-2 vs. Pascal

- Unlike Pascal, Modula-2 is case sensitive. All keywords are in **CAPITALS**.
- Unlike Pascal, all control structures have matching **END**s.
- Comments can be nested, like this:

```
(* (* Hi! *) Bye! *)
```

- There are no gotos.
- There’s no automatic conversion between integers and reals.
- Boolean expressions are short-circuit.

Control Structures

```
IF boolean expression THEN
    statement-sequence
ELSIF boolean expression THEN
    statement-sequence
ELSIF boolean expression THEN
    statement-sequence
ELSE
    statement-sequence
END

WHILE boolean expression DO
    statement-sequence
END
```

Control Structures...

```
LOOP
   statement-sequence (* EXIT can occur here.  *
END

designator := expression;

REPEAT
   statement-sequence
UNTIL boolean expression

(* The BY-part is optional.
   step must be a constant.*)
FOR i := from TO to [BY step] DO
   statement-sequence
END
```


Control Structures...

```
designator(actual parameters);

(* The ELSE-part is optional.
CASE expression OF
   case list:  statement-sequence |
   case list:  statement-sequence |
   case list:  statement-sequence |
   ELSE        statement-sequence END

(* To return a value from a function:  *)
RETURN expression;
```


Declarations

- Modula-2 has a less strict declaration order than Pascal. Declarations can be given in any order as long as names are declared before use. The exception is procedures which can be declared in any order.
- There is a new *equivalence* type introduced which gives a new name to a type.
- Records can have arbitrarily many variant parts (**CASE**).
- There is no special **FUNCTION** keyword.
- There is a special function type.

Declarations...

```
TYPE equivalence = type;
TYPE subrange = [from..to];
TYPE enumeration = (id,id,...);
TYPE array = ARRAY range OF type;
TYPE record = RECORD
                 field :  type;
                 field :  type;
                 CASE tag:type OF
                 ...;
                 END;
                 CASE tag:type OF
                 ...;
                 END;
              END;
```

Declarations...

```
TYPE func = PROCEDURE (INTEGER):REAL;
TYPE set = SET OF type;
TYPE ptr = POINTER TO type;

VAR name : type;
CONST name = value;

PROCEDURE name (formal-list) [: type];
BEGIN
      ...
END name
```


Open Array Parameters

- Unlike Pascal, Modula-2 has open array parameters which allows you to pass arrays of any size to a procedure:

```
PROCEDURE P (w : ARRAY OF INTEGER);
```

- An open array of `SYSTEM.WORD` matches any argument:

```
PROCEDURE P (w : ARRAY OF WORD); ...

VAR x : RECORD a:INTEGER; b:CHAR; END;
BEGIN
   P(x);
END
```


Open Array Parameters...

```
PROCEDURE P (w : ARRAY OF INTEGER);
BEGIN
FOR i := 0 HIGH(w)-1 DO
   ...w[i]...
END P;

VAR x : ARRAY [1..10] OF INTEGER;
VAR y : ARRAY [1..100] OF INTEGER;
BEGIN
   P(x);
   P(y);
END
```


Types

- `CARDINAL` is an unsigned integer type, which Pascal doesn't have.
- `BITSET` is a special set the exact size of a machine word.
- `SYSTEM.WORD` is a type the exact size of a machine word which is compatible with all other types of this size.

Types...

- You can do arbitrary type conversions, as long as the types are the same size. Conversions convert static types only, no bits actually change.

```
VAR x :  ARRAY [1..1] OF INTEGER;
VAR y :  INTEGER;
VAR z :  CARDINAL;
BEGIN
   z := (CARDINAL)x;
   y := (INTEGER)z + 6;
END
```


Separate Compilation

- From the very beginning of language design history, it was realized that monolithic languages (the entire program is stored in one file and compiled all at once) were no good.
- Monlithic languages made compilation slow and made it difficult for several programmers to work on the same problem.
- As early as 1958, FORTRAN II had separately compiled procedures!

Separate Compilation...

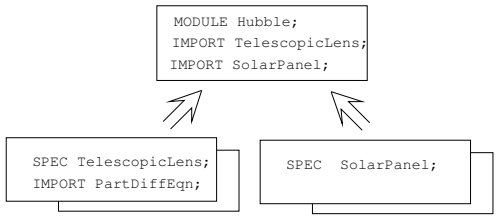
- Eventually it was realized that a more formal approach had to be taken to the definition of separately compiled modules. A number of languages (Mesa, Modula-2, Ada, ...) constructed module systems built on the ideas of David Parnas:

The specification must provide

1. to the intended user *all* the information that he will need to use the program, *and nothing more*.
2. to the implementer *all* the information about the intended use that he needs to complete the program, and *no additional information*.

Separate Compilation...

- Each module has two parts, the specification and the implementation. Much like `.h` and `.c` files in C, only each part is separately compiled.



Definition Module

```
DEFINITION MODULE IntStack;
   TYPE Stack;

   PROCEDURE Create () :  Stack;
   PROCEDURE Destroy (VAR S : Stack);

   PROCEDURE Push (S : Stack; E : INTEGER);
   PROCEDURE Pop (S : Stack; VAR E : INTEGER);
END IntStack.
```


Modula-2 Modules

- The information that the stack uses an array implementation is hidden within the module's implementation unit, which is available only to the module's implementer.
- Note that the Stack type is implemented as a *pointer*. This is in contrast to an Ada implementation which used a static representation.
- Note that – since Modula-2 does not support garbage collection – we need explicit procedures for memory allocation and deallocation.

Implementation Module

```
IMPLEMENTATION MODULE IntStack;
   TYPE Stack = POINTER TO RECORD
                   space :  ARRAY [1..100] OF INTEGER;
                   index :  CARDINAL;
                END;
   PROCEDURE Create () :  Stack;
   BEGIN ... END Create;
   PROCEDURE Destroy (VAR S : Stack);
   BEGIN ... END Destroy;
   PROCEDURE Push (S : Stack; E : INTEGER);
   BEGIN ... END Push;
   PROCEDURE Pop (S : Stack; VAR E : INTEGER);
   BEGIN ... END Pop;
END IntStack.
```


Using a Module

```
MODULE Main;
   IMPORT IntStack, Storage;
   VAR S : IntStack.Stack;
BEGIN
   S := IntStack.Create ();
   IntStack.Push (S, 314);
   IntStack.Destroy (S);
END Main.
```

Generic Modules

- Modula-2 does not support Generic modules, but much like in C, this can be simulated using untyped pointers.
- `SYSTEM.ADDRESS` is equivalent to C's `void*`.

Generic Definition Module

```
DEFINITION MODULE GenStack;
   IMPORT SYSTEM;

   TYPE Stack;

   PROCEDURE Create () :  Stack;
   PROCEDURE Destroy (VAR S : Stack);

   PROCEDURE Push (S : Stack; E : SYSTEM.ADDRESS);
   PROCEDURE Pop (S:Stack; VAR E:SYSTEM.ADDRESS);
END GenStack.
```


Generic Implementation Module

```
EMENTATION MODULE GenStack;
MPORT SYSTEM, Storage;
YPE Stack = POINTER TO RECORD
         space :  ARRAY [1..100] OF SYSTEM.ADDRESS
         index :  CARDINAL; END;
ROCEDURE Create () :  Stack;
EGIN ... END Create;
ROCEDURE Destroy (VAR S : Stack);
EGIN ... END Destroy;
ROCEDURE Push (S : Stack; E : SYSTEM.ADDRESS);
EGIN ... END Push;
ROCEDURE Pop (S:Stack; VAR E:SYSTEM.ADDRESS);
EGIN ... END Pop;
GenStack.
```


Using a Generic Module

```
MODULE Main;
   IMPORT GenStack, Storage;
   VAR S : GenStack.Stack;
       E : POINTER TO INTEGER;
BEGIN
   S := GenStack.Create ();
   NEW (E); E^ := 314;
   GenStack.Push (S, E);
   GenStack.Destroy (S);
END Main.
```

Local Modules

- Modula-2 also has local modules.
- Local modules can be nested within ech other, within procedures, etc.
- No sane person ever used them.

```
MODULE P;
   IMPORT ...;
   EXPORT ...;
   MODULE Q;
      IMPORT ...;
      EXPORT ...;
      MODULE R;
         IMPORT ...;
         EXPORT ...;
      END R;
      MODULE S;
         IMPORT ...;
         EXPORT ...;
      END S;
   END Q;
END P.
```


IO

- Modula-2 has no defined IO procedures like Pascal's **read** and **write**.
- Instead, each implementation was supposed to define its own set of standard modules to do IO and related systems functions.
- There were some standard modules for IO, but even them were't always compatible.
- This made porting a Modula-2 program much harder than it should have been.

Dynamic Allocation

- There is a special module *Storage* that exports two procedures `ALLOCATE` and `DEALLOCATE`.
- The two built-in procedures `NEW` and `DISPOSE` are translated into calls to `ALLOCATE` and `DEALLOCATE`.
- This allows us, at least in theory, to write our own storage allocators.
- Modula-2 does not support garbage collection.

Module SYSTEM

Modula-2 has a special `SYSTEM` module that contains any system-specific definitions.

```
DEFINITION MODULE SYSTEM;
CONST BITSPERLOC    = 8;
TYPE  LOC;        (* Smallest addressable unit of storage *)
      ADDRESS = POINTER TO LOC;

PROCEDURE ADDADR (addr: ADDRESS; offset: CARDINAL): ADDRESS;
  (* The address given by (offset + addr).  *)

PROCEDURE ADR (VAR v: <anytype>): ADDRESS;
  (* The address of variable v *)

PROCEDURE TSIZE (<type>; ...): CARDINAL;
  (* Number of LOCS used to store a value of type <type>. *)
END SYSTEM.
```

Facilities for Systems Programming

- The `SYSTEM` module also has functions for constructing co-routines (`NEWPROCESS` and `TRANSFER`).
- The `SYSTEM` module also has a function `IOTRANSFER` for handling interrupts. Modules can be given an interrupt priority:

```
MODULE Printer[2];
   ...
BEGIN
   ...
END Printer;
```


Readings and References

- `http://murray.newcastle.edu.au/users/staff/peter/m2/Modula2.html`
- `http://www.modulaware.com/m2wr`
- `http://floppsie.comp.glam.ac.uk/Glamorgan/gaius/web/GNUModula2.html`
- A Modula-2-to-C translator is available on lectura: `/home/cs520/2003/bin/m2c`. It can also be downloaded from here: `http://www.mathematik.uni-ulm.de/modula`.