Streamlining symbol files in the Oberon operating system

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Overview

This technical note presents a simplification of the handling of import and export for the Oberon programming language and system, as realized in *Extended Oberon*[1], a revision of the *Project Oberon 2013* system, which is itself a reimplementation of the original *Oberon* system on an FPGA development board around 2013, as published at *www.projectoberon.com.*

Brief historical context

The topic of *symbol files* (=module interface files) has accompanied compiler development ever since the original *module* concept with *separate compilation* and type-checking *across* module boundaries (as opposed to *independent* compilation where no such checks are performed) has been introduced in the 70s and adopted in languages such as Mesa, Ada, Modula-2 and Oberon.

A correct implementation of the *module* concept was by no means obvious initially. However, the concept has evolved and today, simple implementations exist covering all key requirements, e.g.,

1. *Hidden record fields:* Offsets of non-exported pointer fields are needed for garbage collection.
2. *Re-export conditions*: Imported types may be *re-exported* and their *imports* may be hidden.
3. *Recursive data structures*: Pointer declarations may *forward reference* a record type.
4. *Module aliases*: A module can be imported under a different (alias) name.

A careful and detailed study of the evolution that led to today's status quo – which contains many useful lessons and is therefore well worth the effort – is far beyond the scope of this technical note. The reader is referred to the literature [1-13]. Here, a very rough sketch must suffice:

- Module concept introduced in 1972, early languages include Mesa, Modula and Ada [1].
- Modula-2 implementation on PDP-11 already used the concept of *separate* compilation [2].
- Modula-2 implementation on Lilith already used the concept of *separate* compilation [3].
- First single-pass compiler for Modula-2 compiler in 1984 used a *post-order* traversal [4, 5, 7].
- Some Oberon compilers in the 1990s used a *pre-order* traversal of the symbol table [8-11].
- The Oberon on ARM compiler (2008) used a *fixup* technique for types in symbol files [12].
- The FPGA Oberon RISC compiler (2013) uses *pre-order* traversal and a *fixup* technique [13].

As with the underlying languages, all these re-implementations and refinements of the handling of import and export (and the symbol files) are characterized by a *continuous reduction of complexity*.

In this technical note, we present yet another simplification by eliminating the so-called "fixup" technique for *types* during export and subsequent import.

[1] *http://www.github.com/andreaspirklbauer/Oberon-extended*

Symbol files in ARM Oberon (2008) and in FPGA Oberon (2013)

The Oberon system and compiler were re-implemented in 2013 using FPGA. The compiler was derived from an earlier version of the Oberon compiler for the ARM processor. In the FPGA Oberon compiler, the same "fixup" technique to implement forward references *in* symbol files as in the ARM Oberon compiler is used. Quoting from the *Oberon on ARM* report [12]:

If a type is imported again and then discarded, it is mandatory that this occurs before a reference to it is established elsewhere. This implies that types must always be defined before they are referenced. Fortunately, this requirement is fulfilled by the language and in particular by the one-pass strategy of the compiler. However, there is one exception, namely the possibility of forward referencing a record type in a pointer declaration, allowing for recursive data structures:

TYPE P = POINTER TO R;
R = RECORD x, y: P END

Hence, this case must be treated in an exceptional way, i.e. the definition of P must not cause the inclusion of the definition of R, but rather cause a forward reference in the symbol file. Such references must by fixed up when the pertinent record declaration had been read. This is the reason for the term {fix} in the syntax of (record) types. Furthermore, the recursive definition

TYPE P = POINTER TO RECORD x, y: P END

suggests that the test for re-import must occur before the type is established, i.e. that the type's name must precede the type's description in the symbol file, where the arrow marks the fixup.:

TYP [#14 P form = PTR [^1]]
TYP [#15 R form = REC [^9] lev = 0 size = 8 {y [^14] off = 4 x [^14] off = 0}] → 14

Observations

The above excerpt correctly states that "*types must always be defined before they are referenced*". However, if ***pre-order traversal*** is used when generating the symbol file – as is the case in FPGA Oberon on RISC – this is *already* the case.

When an identifier is to be exported, the export of the type *(Type)* precedes that of the identifier *(Object)*, which therefore always refers to its type by a *backward* reference. Also,a type's name always *precedes* the type's description in the symbol file (see *OutType* and *Export* in *ORB*):

```
PROCEDURE OutType(VAR R: Files.Rider; t: Type);
  ...
BEGIN
  IF t.ref > 0 THEN (*type was already output*) Write(R, -t.ref)
  ELSE ...
    IF t.form = Pointer THEN OutType(R, t.base)
    ELSIF t.form = Array THEN OutType(R, t.base); ...
    ELSIF t.form = Record THEN
      IF t.base # NIL THEN OutType(R, t.base) ELSE OutType(R, noType) END ;
   ELSIF t.form = Proc THEN OutType(R, t.base); ...
   END ; ...
END OutType;
```

```
PROCEDURE Export*(VAR modid: ORS.Ident; VAR newSF: BOOLEAN; VAR key: LONGINT);
BEGIN ...
  WHILE obj # NIL DO
  IF obj.expo THEN
    Write(R, obj.class); Files.WriteString(R, obj.name);   (*type name*)
    OutType(R, obj.type);
    IF obj.class = Typ THEN ...
    ELSIF obj.class = Const THEN ...
    END ;
    obj := obj.next
  END ;
  ...
END Export;
```

And similarly for procedures *InType* and *Import* in *ORB*:

```
PROCEDURE InType(VAR R: Files.Rider; thismod: Object; VAR T: Type);
BEGIN Read(R, ref);
  IF ref < 0 THEN T := typtab[-ref]  (*already read*)
  ELSE NEW(t); T := t; typtab[ref] := t; t.mno := thismod.lev;
      ..
    IF form = Pointer THEN InType(R, thismod, t.base); ...
    ELSIF form = Array THEN InType(R, thismod, t.base); ...
    ELSIF form = Record THEN InType(R, thismod, t.base); ...
    ELSIF form = Proc THEN InType(R, thismod, t.base); ...
    END
  END
END InType;

PROCEDURE Import*(VAR modid, modid1: ORS.Ident);
BEGIN ...
  Read(R, class);
  WHILE class # 0 DO
    NEW(obj); obj.class := class; Files.ReadString(R, obj.name);
    InType(R, thismod, obj.type); ...
    IF class = Typ THEN ...
    ELSE
      IF class = Const THEN ...
      ELSIF class = Var THEN ...
      END
    END ;
    ...
  END
END Import;
```

One can easily verify that types are *always* already “fixed” with the right value, by slightly modifying the current implementation of *ORP.Import* as follows

```
  WHILE k # 0 DO
    IF typtab[k].base # t THEN ORS.Mark("type not yet fixed up") END ;
    typtab[k].base := t; Read(R, k)
  END
```

The message "type not yet fixed up” will *never* be printed while importing a module.

This shows that the fixup of cases of previously declared pointer types is *not necessary* as they are already "fixed" with the right value. A more formal proof can of course easily be constructed. It rests on the observation that the *type* is written to the symbol file <u>before</u> the corresponding *object*.

Code that can be omitted

The following code (shown in red) in procedures *Import* and *Export* in ORB can be omitted. See the appendix for a complete program listing of module ORB showing all changes made.

```
PROCEDURE Import*(VAR modid, modid1: ORS.Ident);
   ...
BEGIN
  IF modid1 = "SYSTEM" THEN
    ...
    IF F # NIL THEN
      ...
      Read(R, class);
      WHILE class # 0 DO
        NEW(obj); obj.class := class; Files.ReadString(R, obj.name);
        InType(R, thismod, obj.type); obj.lev := -thismod.lev;
        IF class = Typ THEN t := obj.type; t.typobj := obj; Read(R, k);  (*<---*)
          (*fixup bases of previously declared pointer types*)
          WHILE k # 0 DO typtab[k].base := t; Read(R, k) END
        ELSE
          IF class = Const THEN ...
          ELSIF class = Var THEN ...
          END
        END
        obj.next := thismod.dsc; thismod.dsc := obj; Read(R, class)
      END ;
    ELSE ORS.Mark("import not available")
    END
  END
END Import;

PROCEDURE Export*(VAR modid: ORS.Ident; VAR newSF: BOOLEAN; VAR key: LONGINT);
BEGIN ...
  obj := topScope.next;
  WHILE obj # NIL DO
    IF obj.expo THEN
      Write(R, obj.class); Files.WriteString(R, obj.name);
      OutType(R, obj.type);
      IF obj.class = Typ THEN
        IF obj.type.form = Record THEN obj0 := topScope.next;
          (*check whether this is base of previously declared pointer types*)
          WHILE obj0 # obj DO
            IF (obj0.type.form = Pointer) & (obj0.type.base = obj.type)
              & (obj0.type.ref > 0) THEN Write(R, obj0.type.ref) END ;
            obj0 := obj0.next
          END
        END ;
        Write(R, 0)                     (*<---*)
      ELSIF obj.class = Const THEN ...
      ELSIF obj.class = Var THEN ...
      END
    END ;
    obj := obj.next
  END ;
  ...
END Export;
```

Module *ORTool* will also need to be adapted to bring it in sync with the modified module *ORB*. See the appendix for a complete program listings of modules ORB and ORTool. If there is a need to keep symbol files backward compatible, the code marked with `(*<---*)` should be kept.

References

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