Internal and External Field Access

Within a class, members may be accessed without qualification. Thus in

```
class C {
  static int i;
  void subr() {
     int j = i;
  }
}
```

field **i** is accessed like an ordinary non-local variable.

To implement this, we can treat member declarations like an ordinary scope in a block-structured symbol table.

When the class definition ends, its symbol table is popped and members are referenced through the symbol table entry for the class name.

This means a simple reference to **i** will no longer work, but **C.i** will be valid.

In languages like C++ that allow incomplete declarations, symbol table references need extra care. In

```
class C {
  int i;
 public:
  int f();
};
int C::f(){return i+1;}
```

when the definition of **f()** is completed, we must restore **C**'s field definitions as a containing scope so that the reference to **i** in **i+1** is properly compiled.

Public and Private Access

C++ and Java (and most other object-oriented languages) allow members of a class to be marked **public** or **private**.

Within a class the distinction is ignored; all members may be accessed.

Outside of the class, when a qualified access like **C.i** is required, only **public** members can be accessed.

This means lookup of class members is a two-step process. First the member name is looked up in the symbol table of the class. Then, the **public/private** qualifier is checked. Access to **private** members from outside the class generates an error message.

C++ and Java also provide a **`protected`** qualifier that allows access from subclasses of the class containing the member definition.

When a subclass is defined, it "inherits" the member definitions of its ancestor classes. Local definitions may hide inherited definitions. Moreover, inherited member definitions must be **`public`** or **`protected`**; **`private`** definitions may not be directly accessed (though they are still inherited and may be indirectly accessed through other inherited definitions).

Java also allows "blank" access qualifiers which allow **`public`** access by all classes within a package (a collection of classes).

Packages and Imports

Java allows packages which group class and interface definitions into named units.

A package requires a symbol table to access members. Thus a reference

```
java.util.Vector
```

locates the package **`java.util`** (typically using a **`CLASSPATH`**) and looks up **`Vector`** within it.

Java supports **`import`** statements that modify symbol table lookup rules.

A single class import, like

```
import java.util.Vector;
```

brings the name **`Vector`** into the current symbol table (unless a

definition of **`Vector`** is already present).

An "import on demand" like

```
import java.util.*;
```

will lookup identifiers in the named packages after explicit user declarations have been checked.

Classfiles and Object Files

Class files (".class" files, produced by Java compilers) and object files (".o" files, produced by C and C++ compilers) contain internal symbol tables.

When a field or method of a Java class is accessed, the JVM uses the classfile's internal symbol table to access the symbol's value and verify that type rules are respected.

When a C or C++ object file is linked, the object file's internal symbol table is used to determine what external names are referenced, and what internally defined names will be exported.

C, C++ and Java all allow users to request that a more complete symbol table be generated for debugging purposes. This makes internal names (like local variable) visible so that a debugger can display source level information while debugging.

Overloading

A number of programming languages, including Java and C++, allow method and subprogram names to be *overloaded*.

This means several methods or subprograms may share the same name, as long as they differ in the number or types of parameters they accept. For example,

```
class C {
  int x;
  public static int sum(int v1,
                        int v2) {
     return v1 + v2;
  }
  public int sum(int v3) {
     return x + v3;
  }
}
```


For overloaded identifiers the symbol table must return a *list* of valid definitions of the identifier. Semantic analysis (type checking) then decides which definition to use.

In the above example, while checking

```
(new C()).sum(10);
```

both definitions of **sum** are returned when it is looked up. Since one argument is provided, the definition that uses one parameter is selected and checked.

A few languages (like Ada) allow overloading to be disambiguated on the basis of a method's result type. Algorithms that do this analysis are known, but are fairly complex.

Overloaded Operators

A few languages, like C++, allow operators to be overloaded.

This means users may add new definitions for existing operators, though they may not create new operators or alter existing precedence and associativity rules.

(Such changes would force changes to the scanner or parser.)

For example,

```
class complex{
  float re, im;
  complex operator+(complex d){
    complex ans;
    ans.re = d.re+re;
    ans.im = d.im+im;
    return ans;
} }
complex c,d; c=c+d;
```

During type checking of an operator, all visible definitions of the operator (including predefined definitions) are gathered and examined.

Only one definition should successfully pass type checks.

Thus in the above example, there may be many definitions of **+**, but only one is defined to take **complex** operands.

Contextual Resolution

Overloading allows multiple definitions of the same kind of object (method, procedure or operator) to co-exist.

Programming languages also sometimes allow reuse of the same name in defining different kinds of objects. Resolution is by context of use.

For example, in Java, a class name may be used for both the class and its constructor. Hence we see

```
C cvar = new C(10);
```

In Pascal, the name of a function is also used for its return value.

Java allows rather extensive reuse of an identifier, with the same identifier

potentially denoting a class (type), a class constructor, a package name, a method and a field.

For example,

```
class C {
  double v;
  C(double f) {v=f;}
}
class D {
  int C;
  double C() {return 1.0;}
  C cval = new C(C+C());
}
```

At type-checking time we examine all potential definitions and use that definition that is consistent with the context of use. Hence new **C()** must be a constructor, **+C()** must be a function call, etc.

Allowing multiple definitions to co-exist certainly makes type checking more complicated than in other languages.

Whether such reuse benefits programmers is unclear; it certainly violates Java's "keep it simple" philosophy.

Type and Kind Information in CSX

In CSX symbol table entries and in AST nodes for expressions, it is useful to store *type* and *kind* information.

This information is created and tested during type checking. In fact, most of type checking involves deciding whether the type and kind values for the current construct and its components are valid.

Possible values for **`type`** include:

- **`Integer`** (**`int`**)
- **`Boolean`** (**`bool`**)
- **`Character`** (**`char`**)
- **`String`**

- **`Void`**
  `Void` is used to represent objects that have no declared type (e.g., a label or procedure).
- **`Error`**
  `Error` is used to represent objects that should have a type, but don't (because of type errors). **`Error`** types suppress further type checking, preventing cascaded error messages.
- **`Unknown`**
  `Unknown` is used as an initial value, before the type of an object is determined.

Possible values for **`kind`** include:

- **`Var`** (a local variable or field that may be assigned to)
- **`Value`** (a value that may be read but not changed)
- **`Array`**
- **`ScalarParm`** (a by-value scalar parameter)
- **`ArrayParm`** (a by-reference array parameter)
- **`Method`** (a procedure or function)
- **`Label`** (on a **`while`** loop)

Most combinations of **`type`** and **`kind`** represent something in CSX.

Hence **`type==Boolean`** and **`kind==Value`** is a **`bool`** constant or expression.

`type==Void` and **`kind==Method`** is a procedure (a method that returns no value).

Type checking procedure and function declarations and calls requires some care.

When a method is declared, you should build a linked list of **`(type,kind)`** pairs, one for each declared parameter.

When a call is type checked you should build a second linked list of **`(type,kind)`** pairs for the actual parameters of the call.

You compare the lengths of the list of formal and actual parameters to check that the correct number of parameters has been passed.

You then compare corresponding formal and actual parameter pairs to check if each individual actual parameter correctly matches its corresponding formal parameter.

For example, given

```
p(int a, bool b[]){ …
```

and the call

```
p(1,false);
```

you create the parameter list **(Integer, ScalarParm), (Boolean, ArrayParm)**

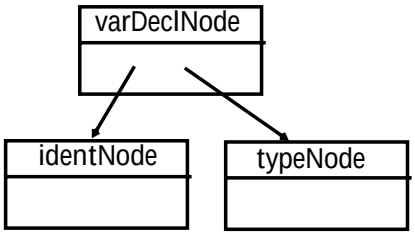
for **p**'s declaration and the parameter list

(Integer,Value),(Boolean, Value)

for **p**'s call.

Since a **Value** can't match an **ArrayParm**, you know that the second parameter in **p**'s call is incorrect.

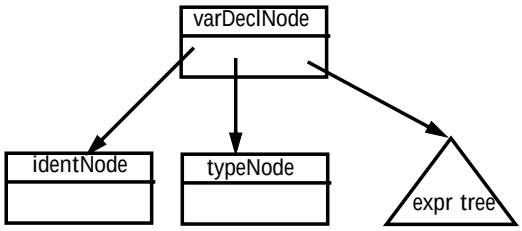
Type Checking Simple Variable Declarations



Type checking steps:

1. Check that identNode.idname is not already in the symbol table.
2. Enter identNode.idname into symbol table with type=typeNode.type and kind = Variable.

Type Checking Initialized Variable Declarations

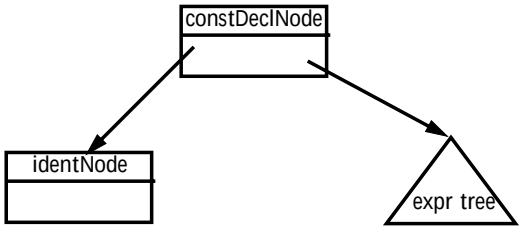


Type checking steps:

1. Check that identNode.idname is not already in the symbol table.
2. Type check initial value expression.
3. Check that the initial value's type is typeNode.type
4. Check that the initial value's kind is scalar (Variable, Value or ScalarParm).

5. Enter identNode.idname into symbol table with type=typeNode.type and kind = Variable.

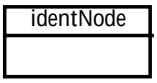
Type Checking Constant Declarations



Type checking steps:

1. Check that identNode.idname is not already in the symbol table.
2. Type check the const value expression.
3. Check that the const value's kind is scalar (Variable, Value or ScalarParm).
4. Enter identNode.idname into symbol table with type = constValue.type and kind = Value.

Type Checking IdentNodes



Type checking steps:

1. Lookup identNode.idname in the symbol table; error if absent.
2. Copy symbol table entry's type and kind information into the identNode.
3. Store a link to the symbol table entry in the identNode (in case we later need to access symbol table information).