Scope

Programming Languages

CS 214

Scope

The portion of a program in which an identifier is bound to a particular meaning is called the *scope of that binding*.

Example:

```
procedure p1 is
   i: integer := 1;
   procedure p2 is
   begin
     put_line(i);
   end p2;
   procedure p3 is
     i: float := 3.0;
   begin
     p2;
   end p3;
    begin
      p2;
   p3;
 end p1;
```

If scope is ________:

i refers to the integer declared in *p1*.

If scope is ________:

When called by *p1*, *i* refers to the integer declared in *p1*.

When called by *p3*, *i* refers to the float declared in *p3*.

Ada and most languages use *static* scope.

Dynamic Scope

- Lisp uses *dynamic scope*, in which an identifier's binding is determined at run-time.
- The meaning of a symbol depends on the *run-time context* in which it is accessed.
- Example: If we write:

```
(setq i 0)

(defun p2 ()
  (princ i)
  (terpri))

(defun p3 ()
  (let ((i 3.0))
        (p2)))

(defun p1 ()
 (setq i 1)
 (p2)
 (p3))
```

- and then call *p2* by itself:

```
(p2)     ;; call p2
____     ;;  by itself
```

- but if we call *p2* in different contexts (*p1* vs. *p3*):

```
(p1)     ;; call p2
____     ;;  within p1
____     ;;  within p3
```

Dynamic Scope: What is happening?

Each activation record contains a *control link*, pointing to the activation record of its caller:

… Caller's AR …
return-value
parameters
locals
control-link
other caller state …
temporaries

When an identifier *id* is accessed, the system follows this algorithm:

a. *temp* = *stack pointer*;

b. do (in the AR pointed to by *temp*):

1) *found* = search *temp*'s parameters/locals for *id*;

2) if not *found*: *temp* = *temp->control_link*;

while *temp* != NULL && not *found*.

On a non-local access, dynamic scope *follows control-links* "down" through the run-time stack until a definition of *id* is found.

Dynamic Scope: Trace

The initial *setq* defines *i* globally...

We call *p2*, which searches down, finds *i* == 0

p2 terminates...

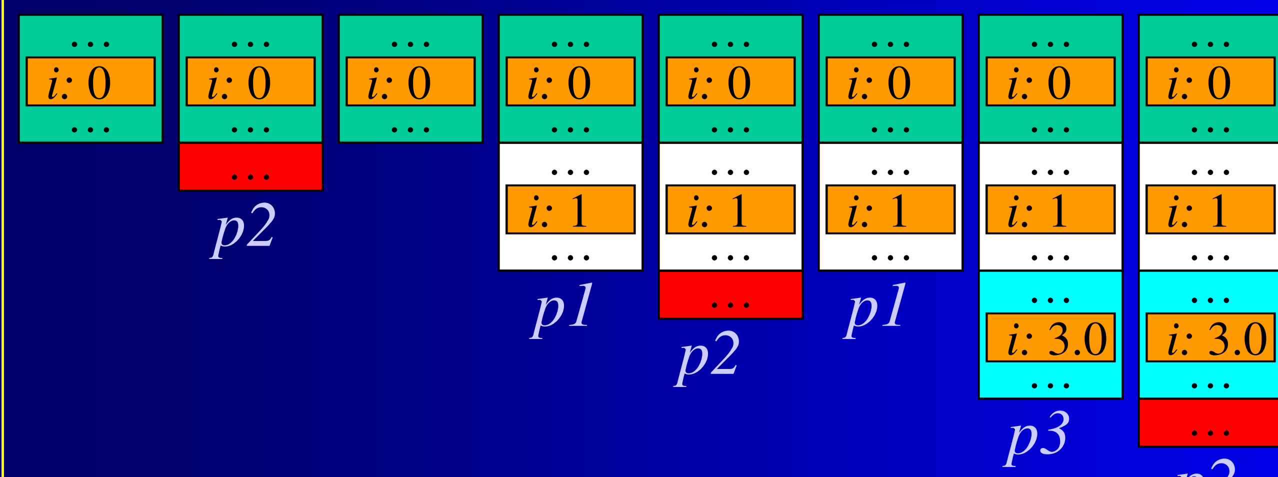
We call *p1* that defines *i* as the integer 1...

p1 calls *p2*, which searches down, finds *i* == 1

p2 terminates...

p1 calls *p3*, which defines *i* as the real 3.0

p3 calls *p2*, which searches down, finds *i* == 3.0




```
(setq i 0)

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   (princ i)
   (terpri))

(defun p3 ()
   (let ((i 3.0))
         (p2)))

(defun p1 ()
  (setq i 1)
  (p2)
  (p3))
```

```
(p2)
```

```
(p1)
```

Static Scope

Static-scoped languages bind identifiers at *compile-time*.

The basic static scope rule:

The scope of a binding begins at an identifier's *declaration*; and ends at the end of the structure containing that declaration.

So *p2 always* accesses integer *i*, because *p2* lies within its scope, and not within the scope of float *i*.

A *scope context* is the construct used by a particular language to delimit a binding's scope.

```
procedure p1 is
   i: integer := 1;
   procedure p2 is
   begin
      put_line(i);
   end p2;
   procedure p3 is
      i: float := 3.0;
   begin
      p2;
   end p3;
begin
   p2;
   p3;
end p1;
```

Static Scope: Holes

A nested declaration of the same identifier creates a *hole* in the scope of the outer binding:

- Within *p3*, references to *i* access float *i*, not integer *i*.
- Ada provides a workaround:

  within *p3* , *p1.i* will access integer *i*.

Holes are not limited to Ada...

```
char i = 'J';
{
   int i = 1;     // char i now
   if (  …  )     // hidden
   {
     double i = 3.0;
   } // char, int i both hidden
}
```

```
procedure p1 is
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   begin
     p2;
   end p3;
begin
   p2;
   p3;
end p1;
```
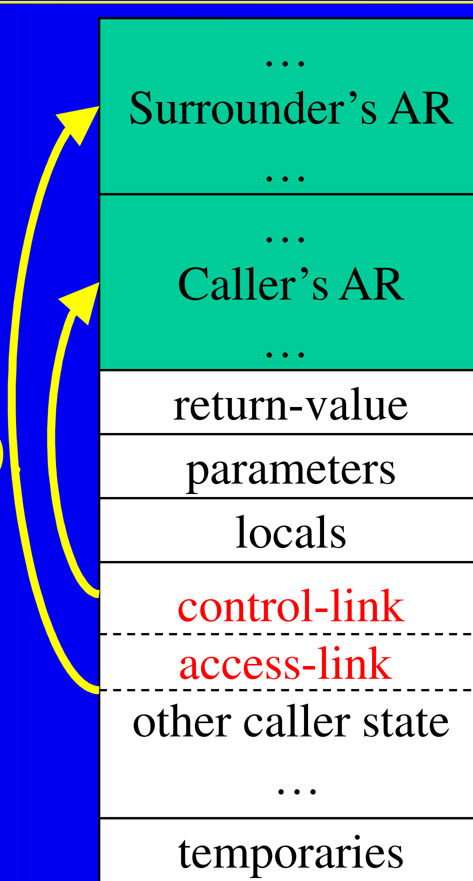

Static Scope: How it works

In addition to the control-link, static-scoped languages add an *access-link* that points to the AR (Activation Record) of the *textually-surrounding scope context* (which may or may not be the caller).

– The textually-surrounding scope context is guaranteed to be already on the stack; otherwise this subprogram could not be called.

– *Non-local accesses* traverse the access-links to find the definition, instead of control-links.



Access-link traversal occurs at run-time, so accesses to *non-locals* take 2+ times longer than accesses to locals.

Static Scope: Trace

We run our program (*p1*)...

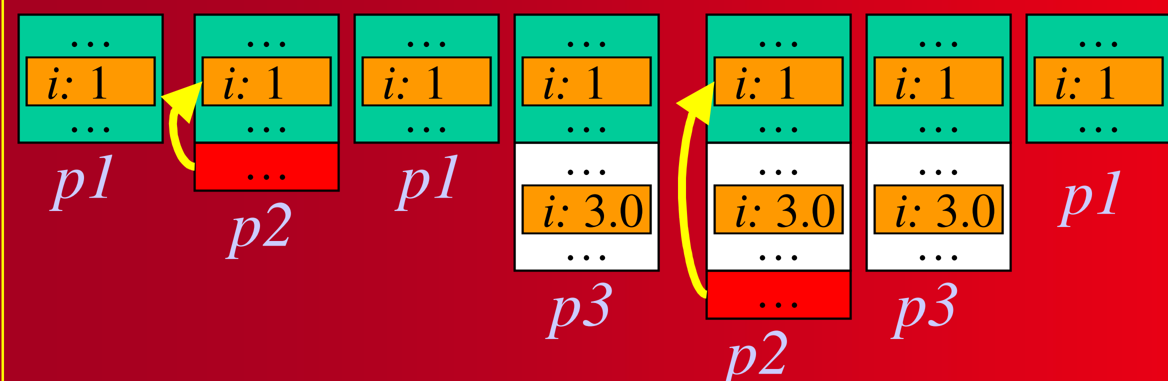
p1 calls *p2*, which traverses its access-links to find integer *i* == 1

p2 terminates...

p1 calls *p3*, which defines *i* as the real 3.0

p3 calls *p2*, which traverses its access-links to find integer *i* == 1

p2 terminates... *p1* terminates...

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begin
   p2;
   p3;
end p1;
```

Note: *i*'s *physical address* is *unknown until run-time*...

Non-local Accesses

Non-locals should be avoided where possible because:

- Non-local accesses take 2+ times as long as local accesses
  - Traversal of access-links at run-time increases access time.
- Non-local accesses separate the *use* of an identifier from its *declaration*, reducing readability *and maintainability*.
- Subprograms that access non-locals are *not self-contained*, *reducing their modularity*, as they *depend on the non-local*.
- If a subprogram accesses no non-locals, then *it doesn't matter whether the language uses static or dynamic scope*
  - Static- and dynamic-scoped languages *behave exactly the same* if a subprogram only accesses its locals and parameters.

Non-local Accesses (ii)

Non-local accesses cannot be completely avoided though…

```
#include <iostream> using namespace std;

class Point {
 public:
  Point(int x, int y) { myX = x; myY = y; }
  int getX() const { return myX; }
  int getY() const { return myY; }
  void print(ostream & out)
     { out << '(' << myX << ',' << myY << ')';
 }private:
  int myX, myY;
};
int main() {
  Point aPoint(0, 0);
  aPoint.print(cout);
}
```

How many non-local accesses can you find in this example ?

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 private:
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int main() {
  Point aPoint(0, 0);
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```

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Summary

Dynamic-scoped languages bind identifiers at *run-time*

- Traversing *control-links* down the run-time stack.

Static-scoped languages bind locals at *compile-time*

- But binding for non-locals still occurs at run-time via *access links*

Static- and dynamic-scoping behave exactly the same, except when resolving accesses to non-local varaibles.

