Programming Paradigms

Names, Scopes, and Bindings (Part 3)

Prof. Dr. Michael Pradel

Software Lab, University of Stuttgart

Summer 2020

Overview

- Object lifetime and storage management
- Scopes
- Aliasing and overloading
- Binding of referencing environments

Scoping Rules

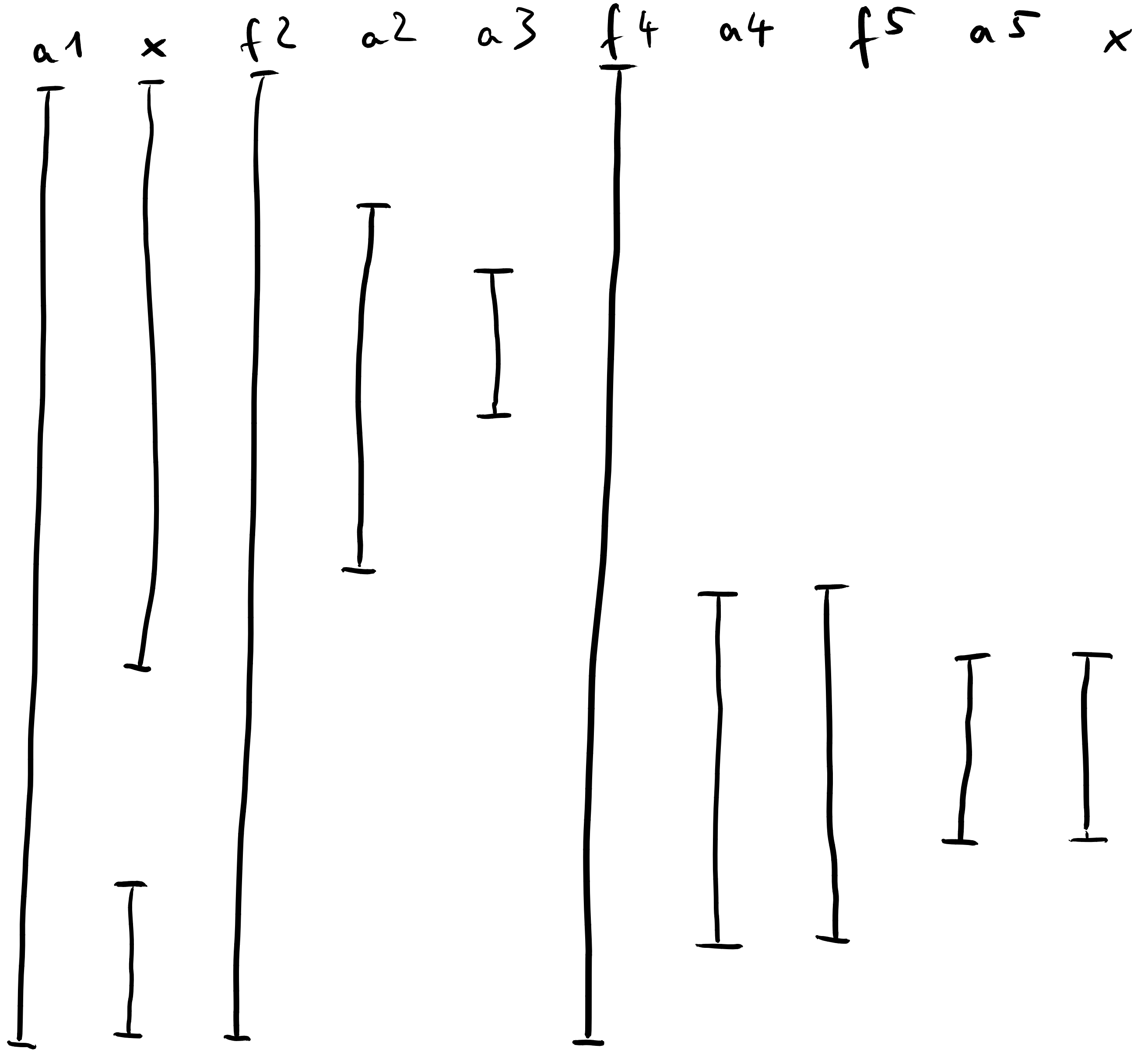
- **Scoping rules: Define which bindings are active**
  - I.e., what's the meaning of a name at a given program point?
- **Each PL defines its scoping rules**
  - E.g., Basic has only one scope
  - Most PLs have nested scopes for subroutines

Nested Scopes

- **Common for nested subroutines**
- **Each subroutine has its own scope**
- **Closest nested scope rule**
  - Name is known in scope where it is declared and all internally nested scopes
  - Inner scopes can hide names from outer scopes

Example

```
fun f1 (a1) {
    var x
    fun f2 (a2) {
        fun f3 (a3) {
            ⋮
        }
        ⋮
    }
    fun f4 (a4) {
        fun f5 (a5) {
            var x
            ⋮
        }
        ⋮
    }
}
```



Static vs. Dynamic Scoping

Static scoping

- Binding of a name can be derived from program text
- Most common in today's PLs

Dynamic scoping

- Binding of a name depends on control flow
  - I.e., not known statically (in general)

Example

Pseudo code:

```
global x = 1
fun a() {
    local x = 3
    b()
}
fun b() {
    y = x
}
a()
```

Example

Pseudo code:

```
global x = 1
fun a() {
    local x = 3
    b()
}
fun b() {
    y = x
}
a()
```

Static scoping:

`y` gets value 1 because `b` doesn't have a local variable called `x` and the surrounding static scope provides the global variable `x`

Example

Pseudo code:

```
global x = 1
fun a() {
    local x = 3
    b()
}
fun b() {
    y = x
}
a()
```

Dynamic scoping:

`y` gets value 3 because `b` doesn't have a local variable called `x` and the dynamically closest scope provides the local variable `x` of `a`

Quiz: Dynamic Scoping

What does the following Perl code print?

```
$b = 0;
sub foo {
  return $b;
}
sub bar {
  local $b = 1;
  return foo();
}
print bar();
```

Please vote via Ilias.

Quiz: Dynamic Scoping

What does the following Perl code print?

```
$b = 0;
sub foo {
  return $b;
}
sub bar {
  local $b = 1;
  return foo();
}
print bar();
```

Result: 1

Please vote via Ilias.

Quiz: Dynamic Scoping

What does the following Perl code print?

```
$b = 0;
sub foo {
  return $b;
}
sub bar {
  local $b = 1;
  return foo();
}
print bar();
```

Global variable that would be used with static scoping

Result: 1

Please vote via Ilias.

Quiz: Dynamic Scoping

What does the following Perl code print?

```
$b = 0;
sub foo {
   return $b;
}
sub bar {
   local $b = 1;
   return foo();
}
print bar();
```

- **But: Perl has dynamic scoping**
- **Uses last encountered definition of `$b`**

Result: 1

Please vote via Ilias.

Function Stack vs. Static Scopes

- Push allocation frames on calls
- Pop frames on returns

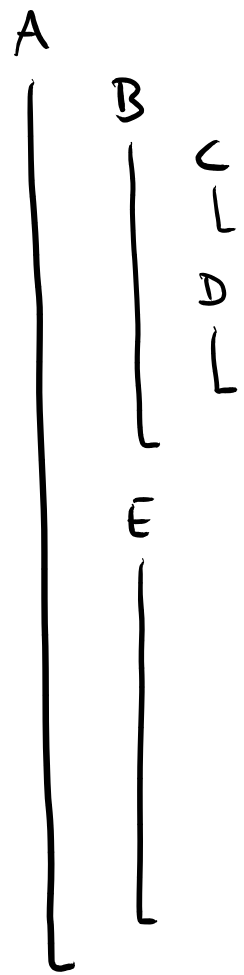
- Not affected by which functions get called

How to resolve bindings outside of current scope?

- Each allocation frame has a static link to its parent scope

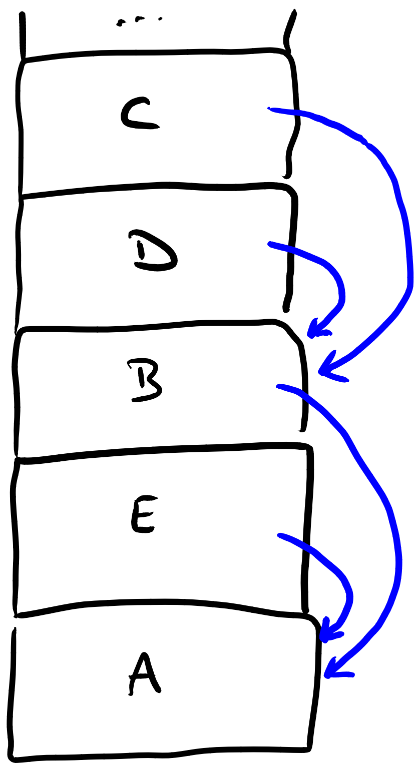
Example:

Nested functions



Function stack

→ ... static



Built-in Objects

Many PLs have built-in (or predefined) objects

- E.g., for built-in types and APIs
- Invisible, outer-most scope
- Accessible from all scopes, except if hidden

Quiz: Scopes

What does this Python code print?

(Hint: Python uses static scoping)

```
x = "a"
def f():
    def g():
        print(x)
    def h():
        g()
        x = "c"
        print(x)
    x = "b"
    h()
    print(x)
f()
print(x)
```

Please vote in Ilias.

Quiz: Scopes

What does this Python code print?

(Hint: Python uses static scoping)

```
x = "a"
def f():
    def g():
        print(x) # (1) x in f    : "b"
    def h():
        g()
        x = "c"
        print(x) # (2) x in h    : "c"
    x = "b"
    h()
    print(x)     # (3) x in f    : "b"
f()
print(x)         # (4) x in main: "a"
```

Please vote in Ilias.