

Programming Language Concepts/Binding and Scope

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Bilgisayar Mühendisliği

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Binding

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Formally: binding occurrence \leftrightarrow applied occurrence.
- Identifiers are declared once, used n times.
- Language should map which corresponds to which.
- **Binding**: Finding the corresponding binding occurrence (definition/declaration) for an applied occurrence (usage) of an identifier.

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int f() { × error!  
    ...  
}  
double y; × error!
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    double f;  ✓ OK
    int y ;    ✓ OK.
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- **Example:**

```
struct Person { ... } x;  
int f(int a) {  
    double y;  
    int x;  
    ... ①  
}  
int main() {  
    double a;  
    ... ②  
}
```


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$O(①) = \{\text{struct Person} \mapsto \text{type},$
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- Block structure of the language is defined by the organization of the blocks.

Monolithic block structure

- Whole program is a block. All identifiers have global scope starting from the definition.
- **Cobol** is a monolithic block structure language.

```
int x;  
int y;  
...  
...
```

- In a long program with many identifiers, they share the same scope and they need to be distinct.

Flat block structure

- Program contains the global scope and only a single level local scope of function definitions. No further nesting is possible.
- **Fortran** and partially **C** has flat block structure.

```
int x;  
int y;  
int f()  
{  
  int a;  
  double b;  
  ...  
}  
int g()  
{  
  int a;  
  double b;  
  ...  
}  
....
```

Nested block structure

- Multiple blocks with nested local scopes can be defined.
- **Pascal** and **Java** have nested block structure.



- C block commands can be nested.
- GCC extensions (**Not C99 standard!**) to C allow nested function definitions.

Hiding

- Identifiers defined in the inner local block hides the outer block identifiers with the same name during their scope. They cannot be accessed within the inner block.

```
int x,y;
int f(double x) {
    ...           // parameter x hides global x in f()
}
int g(double a) {
    int y;        // local y hides global y in g()
    double f;     // local f hides global f() in g()
    ...
}
int main() {
    int y;        // local y hides global y in main()
}
```

Static vs Dynamic Scope/Binding

The binding and scope resolution is done at compile time or run time? Two options:

- 1 Static binding, static scope
- 2 Dynamic binding, dynamic scope
 - First defines scope and binding based on the lexical structure of the program and binding is done at compile time.
 - Second activates the definitions in a block during the execution of the block. The environment changes dynamically at run time as functions are called and returned.

Static binding

- Programs shape is significant. Environment is based on the position in the source (lexical scope)
- Most languages apply static binding (C, Haskell, Pascal, Java, ...)

```
int x=1,y=2;
int f(int y) {
    y=x+y;
    return x+y;
}
int g(int a) {
    int x=3;
    y=x+x+a;    x=x+y;    y=f(x);
    return x;
}
int main() {
    int y=0;    int a=10;
    x=a+y;    y=x+a;    a=f(a);    a=g(a);
    return 0;
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int x=1,y=2;
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    return x+y;
}
int g(int a) {
    int x=3;          /* x local, y global */
    y=x+x+a;          x=x+y;      y=f(x);
    return x;
}
int main() {
    int y=0;          int a=10;    /* x global y local */
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Dynamic binding

- Functions called update their declarations on the environment at **run-time**. Delete them on return. Current stack of activated blocks is significant in binding.
- Lisp and some script languages apply dynamic binding.

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int x=1,y=2;
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    y=x+y;
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    x=a+y;      y=x+a;
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}

```

	Trace	Environment (without functions)
	initial	{x:GL, y:GL }
12	call main	{x:GL, y:main, a:main }
15	call f(10)	{x:GL, y:f , a:main }
4	return f : 30	back to environment before f
15	in main	{x:GL, y:main, a:main }
15	call g(30)	{x:g, y:main, a:g }
9	call f(39)	{x:g, y:f, a:g }
4	return f : 117	back to environment before f
9	in g	{x:g, y:main, a:g }
10	return g : 39	back to environment before g
15	in main	{x:GL, y:main, a:main }
16	return main	x:GL=10, y:GL=2, y:main=117, a:main=39

- It gets more complicated if nested functions are allowed:

```
let x = 5
  y = 10
  func x = x * x + other y
  other x = x + x
in func x + let other x = x - 1
  y = 2
  in func x
```

Binding Process

- Language processor keeps track of current environment in a data structure called **Symbol Table** or **Identifier Table**
- Symbol table maps identifier strings to their type and binding.
- Each new block introduces its declarations/bindings to the symbol table and on exit, they are cleared.
- Usually implemented as a Hash Table.
- For static binding, Symbol Table is a compile time data structure and maintained during different stages of compilation.
- For dynamic binding, symbol table is maintained at run time.

Declarations

- Definitions vs Declarations
- Sequential declarations
- Collateral declarations
- Recursive declarations
- Collateral recursive declarations
- Block commands
- Block expressions

Definitions and Declarations

- **Definition:** Creating a new name for an existing binding.
- **Declaration:** Creating a completely new binding.
- in C: `struct Person` is a declaration. `typedef struct Person persontype` is a definition.
- in C++: `double x` is a declaration. `double &y=x;` is a definition.
- creating a new entity or not. Usually the distinction is not clear and used interchangeably.

Sequential Declarations

- $D_1 ; D_2 ; \dots ; D_n$
- Each declaration is available starting with the next line. D_1 can be used in D_2 and afterwards, D_2 can be used in D_3 and afterwards,...
- Declared identifier is not available in preceding declarations.
- Most programming languages provide only such declarations.

Collateral Declarations

- `Start; D1 and D2 and ... and Tn ; End`
- Each declaration is evaluated in the environment preceding the declaration group. Declared identifiers are available only after all finish. D_1, \dots, D_n uses in the environment of `Start`. They are available in the environment of `End`.
- ML allows collateral declarations additionally.

Recursive declarations

- Declaration:Name = Body
- The body of the declaration can access the declared identifier. Declaration is available in the body of itself.
- C functions and type declarations are recursive. Variable definitions are usually not recursive. ML allows programmer to choose among recursive and non-recursive function definitions.

Recursive Collateral Declarations

- All declarations can access the others regardless of their order.
- All Haskell declarations are recursive collateral (including variables)
- All declarations are mutually recursive.
- ML allows programmer to do such definitions.
- C++ class members are like this.
- in C a similar functionality can be achieved by prototype definitions.

Block Expressions

- Allows an expression to be evaluated in a special local environment. Declarations done in the block is not available outside.
- in Haskell: `let D1; D2; ... ; Dn in Expression or Expression where D1; D2; ... ; Dn`

```
x=5
t=let  xsquare=x*x
      factorial n = if n<2 then 1 else n*factorial (n-1)
      xfact = factorial x
in    (xsquare+1)*xfact/(xfact*xsquare+2)
```

- Hiding works in block expressions as expected:

```
x=5 ; y=6 ; z = 3
t=let x=1
  in let y=2
    in x+y+z
{-- t is 1+2+3 here. local x and y hides the ones above --}
```

- GCC (only GCC) block expressions has the last expression in block as the value:

```
double min ;
...
min = ({ double tmp;
        if (b < a) then {
            tmp = a;  a = b ; b = tmp;
        }
        a; // this is the value of the block
    });
```

Block Commands

- Similar to block expressions, declarations done inside a block command is available only during the block. Statements inside work in this environment. The declarations lost outside of the block.

```
int x=3, i=2;
x += i;
while (x>i) {
    int i=0;
    ...
    i++;
}
/* i is 2 again */
```

Block Declarations

- A declaration is made in a local environment of declarations. Local declarations are not made available to the outer environment.
- in Haskell: D_{exp} where $D_1; D_2; \dots ; D_n$
Only D_{exp} is added to environment. Body of D_{exp} has all local declarations available in its environment.

```
fifthpower x = (forthpowerx) * x where
    squarex = x*x
    forthpowerx = squarex*squarex
```

Summary

- Binding, scope, environment
- Block structure
- Hiding
- Static vs Dynamic binding
- Declarations
- Sequential, recursive, collateral
- Expression, command and declaration blocks