Chapter 3. The C in C++

C++ Object Oriented Programming
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Introduction

- C++ is based on C
  - The part of grammars for C is almost the same as ANSI C except only a few enhancements
  - This part of grammars can be used to do procedural programming (including very low level system programming; C was dubbed a high-level assembly language)
  - About 75% of C++ grammars
  - The other 25% of grammars in C++ is for supporting object oriented programming
  - An OOP program written in C++ uses all grammars both C part and non-C part but is very easy to tell apart from a procedural program written in C.

    It has intrinsically different program structure.

Creating Functions

- Function is the atomic unit of instructions in C/C++.
- Prototypes (forward declarations, declarations)

```
int translate(float x, float y, int z);
int translate(float, float, int);
```

- Definitions

```
int translate(float x, float y, int z)
{
   float r = y * z + 2.0 * x;
   if (r > 0)
      return 1;
   return 0;
}
```

Return type

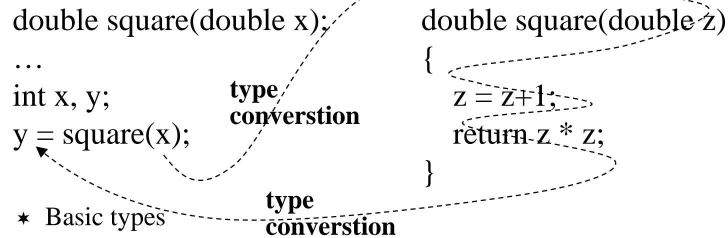
Function name

Parameter names and types

Return value could be void.
Parameter could be void.

Function Argument Passing

- Pass-by-value (call-by-value): the value of an actual argument is copied into the function's formal parameter variable as the control is passed to the calling function



  - Basic types
  - Array
  - Pointers

Controlling Execution

- C: 0 is false, non-zero is true
- Conditional expressions: a == b, c > 1.5…
- if-else

  if (expression) statement   if (expression) statement else statement
- while

  while (expression) statement   do statement while (expression);
- for

  for (initialization; conditional; step) statement
- break and continue
- switch

  switch (selector) {case integral-value: statement; break; … default: statement;}
- goto
- function call and recursion

Data Types

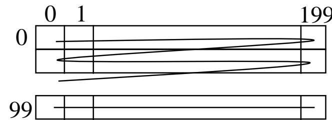
- Built-in data types
  - char, int, float, double
  - Ranges: limits.h and float.h
  - int may have different size of storage on different platforms
- Specifiers
  - long, short, signed, unsigned
- Pointers: storing memory locations or address or a variable or a function
  - & operator to extract the address of a variable
  - * dereference operator
  - Indirect access of variables or functions through pointers
    - **Indirection means flexibility; let the same code have effects on different objects**
    - **Change "outside objects" from within a function**
- User-defined data types (abstract data types, with behaviors)
  - array and struct

Arrays

- int a[100];
  - defines 100 variables to store integers, their names are a[0], a[1], .. a[99]
  - or even have changeable names a[expression]
  - they occupies contiguous memory spaces
  - the value of **a** is the address of the first elements, the type of a is 'int[100]'
  - &a is not suitably defined since a is not a variable, does not have an address; but many compiler take this value as the same as a
  - a[i], denotes one of these variable, is equivalent to *(a+i), *(i+a) (or even i[a])
  - &a[i] denotes the address of the i-th variable a[i]

Arrays

- int b[100][200];
  - defines 100*200 variables for storing integers, their names are b[0][0], … b[99][199]
  - They occupies contiguous memory spaces in the form of 100 repeated blocks of 200-element of int. (so called row major storage allocation)

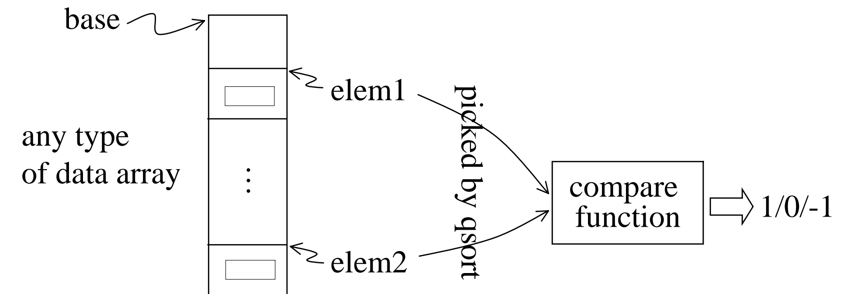


  - each value of b[0], b[1], … b[99] is the starting address of an 'int [200]' array, the type of b[i] is 'int[200]'
  - b[i][j] is equivalent to *(b[i]+j) or *(*(b+i)+j)
  - &b[i][j] denotes the address of the i,j-th variable ((i*200+j)'s variable)

void *

- In C, dynamic polymorphism can be implemented using untyped pointers 'void *'
- Ex. The qsort() stdlib function

```
void qsort(void *base, size_t num, size_t width,
        int (*compare)(const void *elem1, const void *elem2));
```

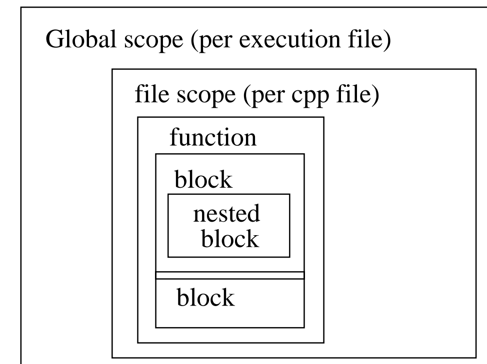


Storage Allocation

- Global variables:
  - defined outside all function bodies
  - allocated on .data segment
  - use **extern** to declare a global variable in another file
  - the scope of a **static** global variable is constrained in a file (file scope)
- Local variables: (automatic variables: automatically come into being when the scope is entered and going away when the scope closes)
  - Defined inside a block or a function
  - allocated on the stack
  - register keyword makes the variable on the a register (a register variable can not be global or static)
  - **static** keyword makes the variable be allocated on .data segment and the lifetime of the variable extends over multiple entrances of this block
  - **const** qualifier tells the compiler "This never changes"
  - **volatile** qualifier tells the compiler "You never know when this will change". Used with a multithreaded program.
- Dynamically allocated variables:

Scoping Rules

- The scoping rules tell you where a variable is valid (visible). Sometimes the rules also tell you where a variable is create and where it gets destroyed.
- The lifetime of a variable starts from the creation of a variable till the destruction of a variable. (A variable can be static or dynamic.)



Operators

- In C, operators +, -, *, /, ++, --, ==, >, &, ^, ~, >>, ?:, (type)… have default semantic effects. All operators produce a value from their operands without modifying the operands. Some of these operators represent different actions depending on the types of their operands.
- In C++, operator is a special type of function. You can use operator overloading to define an operator.
- Precedence: determining the order in which an expression evaluates
  - http://msdn.microsoft.com/library/default.asp?url=/library/en-us/vccelng/htm/expre_13.asp
  - Programmer can always change the default rules with parentheses.
- Auto increment operator ++, auto decrement operator –
  - Pre-increment and post-increment
  - Side effects
- Assignment: =
  - lvalue = rvalue (lvalue must be a distinct, named variable; must have physical space to store data)

Explicit Type Casts

- "Downcasting" is detrimental to OOP as the "goto" statement to the procedural programming
  - Type casting: Simply tell the compiler "Forget type checking – treat it as this other type instead"
  - Type casting introduce holes in the C/C++ type system, should be used as rarely as possible
- Old C-style casts (type coercion)

```
int x, *xp;
double y;
void *yp;
…
x = (int) y;
…
xp = (int *) yp;
```


Explicit Type Casts (cont'd)

- static_cast: for "well-behaved" and "reasonably well-behaved" casts, including things you might now do without a cast

```
int i;                          i = static_cast<int>(f);
long l;                         void *vp = &i;
float f;                        float* fp = static_cast<float *> (vp);
l = static_cast<long>(i);       void fun(int);
f = static_cast<float>(i);      func(static_cast<int>(f));
```

- const_cast: to cast const to non-const or volatile to non-volatile

```
const int i = 0;
int * j = const_cast<int *>(&i);
volatile int k = 0;
int *u = const_cast<int *>(&k);
```

Note:

```
*j = 10; // this is OK
cout <<"i="<< i <<" *j="<< *j << endl;  // output: i=0 *j=10
cout <<"&i="<< &i <<" j="<< j << endl; //          &i=0012FF7Cj=0012FF7C
```

j and &i are the same, but *j and i differ

Explicit Type Casts (cont'd)

- reinterpret_cast: to cast to a completely different meaning. This is the most dangerous of all the casts.

Ex.

```
istream& istream::read(char* pch, int nCount);
int data[100]; ifstream infile("input.dat");
infile.read((char *)data, sizeof(data));

infile.read(reinterpret_cast<char *>(data), sizeof(data));
```

bit twiddling

Ex.

```
int x=123456;
unsigned char *cp;
cp = (unsigned char *) &x;
cout << hex;
for (int i=0; i<4; i++)
   cout << setw(3) << (int)*cp++;
cout << endl;
```

```
cp = reinterpret_cast<unsigned char *>(&x);
```

Output: 40 e2 1 0

- dynamic_cast: For type-safe downcasting, will be explained after inheritance

Debugging

- C Assert macro

```
#include <cassert>              // or #include <assert.h>
using namespace std;
int main() {
   int i = 100;
   someFunction();
   assert(i == 100); // fails
}
```

- You can verify whatever design assumptions and code them into the program.
- You can remove the code from the executable by

```
#define NDEBUG
```

  - If you use Visual Studio and set active configuration as Release, NDEBUG is defined automatically

Aliasing a type name with typedef

- Simple rule: *typedef* original_type_name new_type_name;

```
typedef unsigned long ulong;
ulong x; // equivalent to long x;
```

- More general rule: *typedef* type definition of new_type_name;

```
typedef int IntAry[20];
IntAry y[30]; // equivalent to int y[30][20];
```

```
typedef double (*(*FP)( ))[10];
FP fp; // equivalent to double (*(*fp)())[10];
meaning: "a function pointer fp to a function that takes no argument and
              returns a pointer to a 10-element array of double"
Equivalent and more self explaining definitions:
     typedef double DoubleArray[10];
     typedef PtrDoubleArray *DoubleArray;
     typedef PtrDoubleArray (*FP)();
```


Aliasing a type name with typedef

- You can also define multiple new type names in one typedef statement

```
typedef struct
{
   int x;
   int y;
} Point, *PtrPoint;
Point point;          // equivalent to struct { int x; int y; } point;
PtrPoint ptrPoint; // equivalent to struct { int x; int y; } *ptrPoint;
```


Complex Data Type Definitions

- Examples:

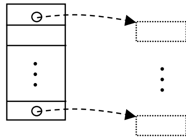
```
int *x;
int *x[10];
int (*x)[10];
int (**x)[10];
int *(**x)[10];
void (*funcPtr)();
void *funcPtr();  // definition of a function
void (*signal(int, void(*)(int)))(int);  // definition of a function
void *(*(*fp1)(int))[10];
float (*(*fp2)(int, int, float))(int);
double (*(*(*fp3)())[10])();
int (*(*f4())[10])();
```

Using typedef can simplify these definitions

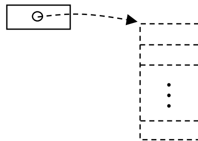
Complex Data Type Definitions

- Two simplest examples first:

int *x[10]; // 10-element ARRAY of (PTR to integer)



int (*x)[10]; // PTR to (10-element ARRAY of integers)



TYPE [n] means "n-element ARRAY of TYPE"

TYPE * means "PTR to TYPE"

[ ] has higher precedence than *, ( ) can change the priority

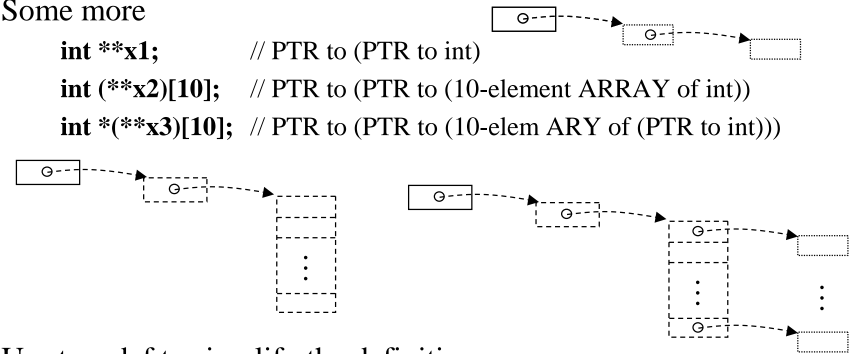
Complex Data Type Definitions

- Some more

int **x1; // PTR to (PTR to int)

int (x2)[10];** // PTR to (PTR to (10-element ARRAY of int))

int *(x3)[10];** // PTR to (PTR to (10-elem ARY of (PTR to int)))



- Use typedef to simplify the definition

typedef int *IPTR;

IPTR *x1;

typedef int IARY[10];

typedef IARY *PTRIARY;

PTRIARY *x2;

typedef IPTR IPTRARY[10];

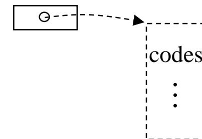
typedef IPTRARY *PTR_IPTRARY;

PTR_IPTRARY *x3;

Complex Data Type Definitions

- Function pointers

void (*funcPtr)(); // PTR to a function that takes no argument and return void



- Real example:

void (*(*fp)(int, void(*)(int)))(int);

// fp is a PTR to a function that takes two arguments, an int, (a function pointer that takes one int argument and returns void), and returns (a function pointer that takes one int argument and returns void)

Equivalently,

typedef void (*sig_t)(int);

sig_t (*fp)(int, sig_t);

Complex Data Type Definitions

- Ex: PTR to a function that takes an int and returns a PTR to (10-element array of (PTR to void))

void *(*(*fp1)(int))[10];

- Ex: PTR to a function that takes three arguments: int, int, float and returns (PTR to a function that takes an int and returns float)

float (*(*fp2)(int, int, float))(int);

- Ex: PTR to a function that takes no argument, returns (PTR to (10-element ARRAY of (PTR to a function that takes no argument and returns double)))

double (*(*(*fp3)())[10])();

- Ex: function that takes no argument, returns (PTR to (10-element ARRAY of (PTR to function that takes no argument and returns int)))

int (*(*f4())[10])();