C/C++ Programming Language

CS205 Spring

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Content

- Brief Review
- Reference Variable
- Function Overloading
- Function Template
- Summary

Brief Review

Content of Last Class

- Various function applications
  - Arrays
  - C-style strings
  - Structure
  - String class and array objects
  - Recursion
  - Pointer to functions

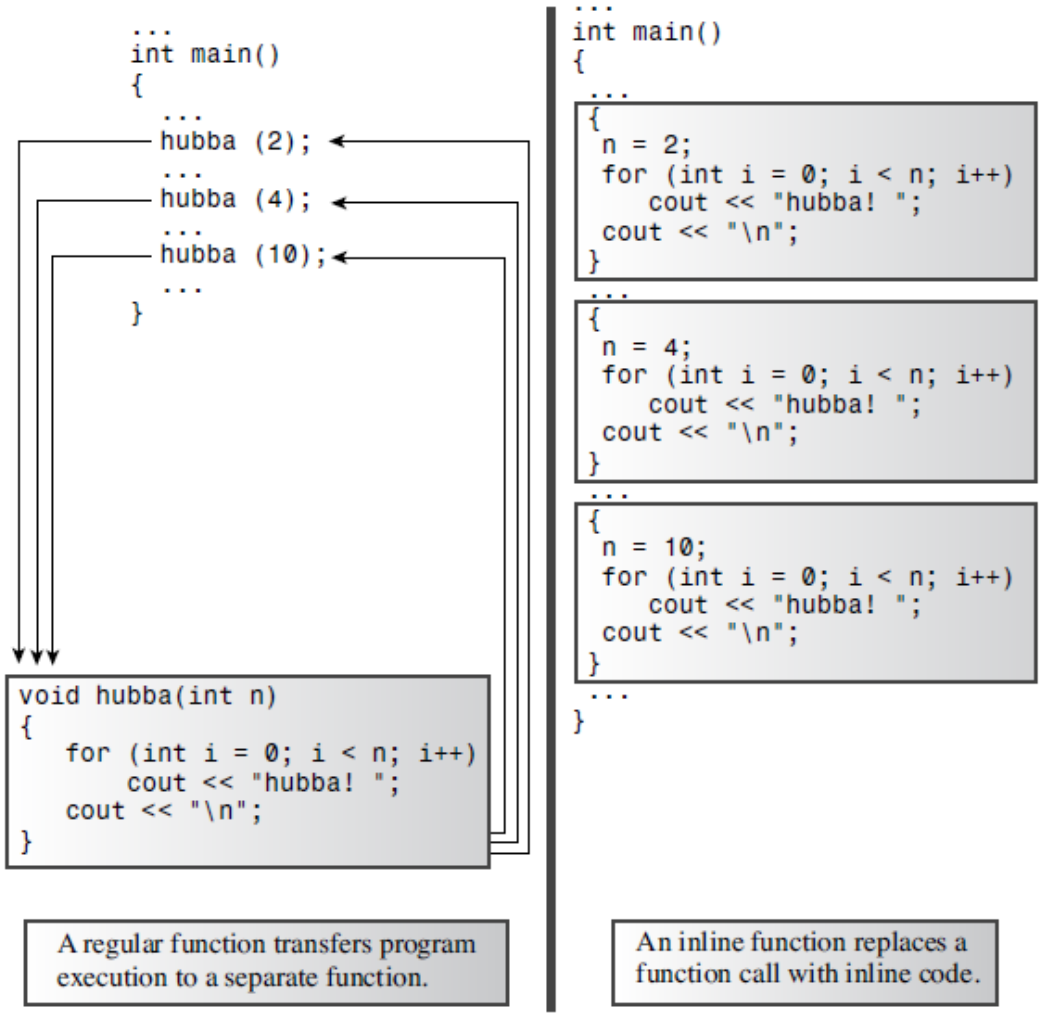
Adventures in Functions

Mechanism of Function Call

- Codes are the data as well
  - The product of the compilation process is an executable program
    - ✓ Consist of a set of machine language instructions
  - The operating system loads these instructions into the memory
    - ✓ Each instruction has a particular memory address
    - ✓ Jump backward or forward to a particular address (loop or branching)
- Normal function: Jump forth and back
  - Store the memory address of the instruction immediately following the function call
  - Copy function arguments to the stack
  - Jump to the memory location that marks the beginning of the function
  - Execute the function code
  - Jump back to the instruction whose address it saved

C++ Inline Functions

- Compiler replaces the function call with the corresponding function code
  - Run a little faster than regular functions
  - Come with a memory penalty
  - Be selective about using inline functions
- Two steps
  - Preface the declaration with the keyword inline.
  - Preface the function definition with the keyword inline
- Inline versus macros
  - Macros don't pass by value



Reference Variables

- A new compound type to the language—the reference variable
  - A reference is a name that acts as an alias
  - An alternative name, for a previously defined variable
- Use a reference as an argument
  - The function works with the original data instead of with a copy
  - A alternative to pointers for processing large structures

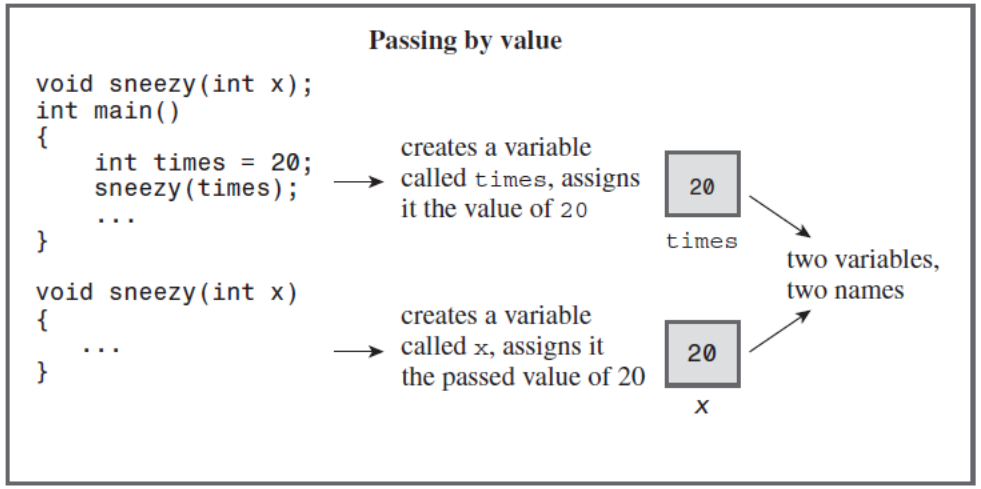
Creating a Reference Variable

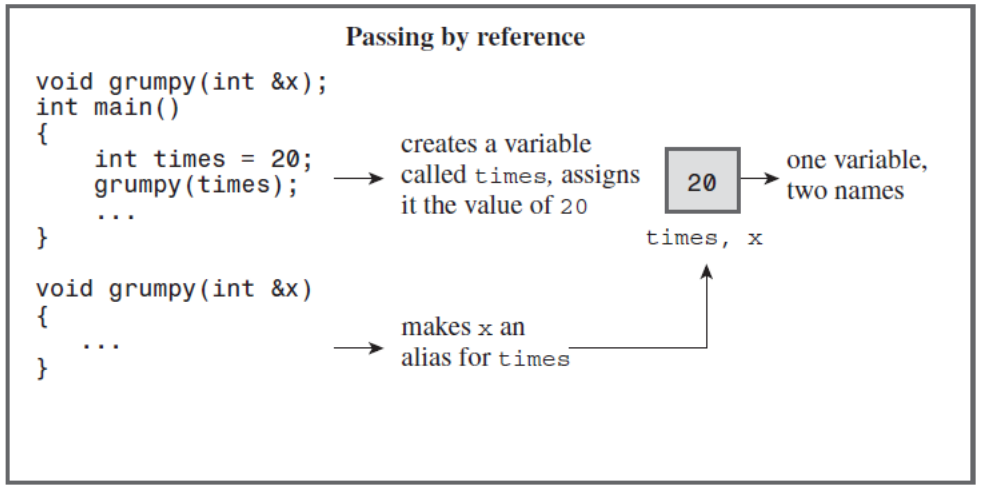
- The & symbol
  - Indicate the address of a variable
  - Declare references
    - ✓ int & means reference-to int
    - ✓ The reference declaration allows you to use two variables interchangeably
    - ✓ Both refer to the same value and the same memory location
  - It is necessary to initialize the reference when you declare it
- Run program example 1

References as Function Parameters

- Passing by reference allows a called function to access variables in the calling function

- Run program example 2





Temporary Variables, Reference Arguments, and const

- The compiler generates a temporary variable
  - 1: When the actual argument is the correct type but isn't an lvalue
    - ✓ An lvalue is a data object that can be referenced by address including variable, array element, structure member, reference, dereferenced pointer
    - ✓ Non-lvalues include literal constants and expressions with multiple terms
  - 2: When the actual argument is of the wrong type, but it's of a type that can be converted to the correct type
  - The reason to use: temporary variables cause no harm
- A function with reference arguments is to modify variables
- Use const when you can
  - Protect you against programming errors that inadvertently alter data
  - Process both const and non-const actual arguments when omits const in the prototype
  - Generate and use a temporary variable appropriately

Using References with a Structure

- References were introduced primarily for use with C++'s user-defined types, not for use with the basic built-in types
- Run program example 3
- Why return a reference?
  - Normal return value: involve copying the entire structure to a temporary location and then copying that copy
  - But with a reference return value, the returned value is copied directly to the variable in calling function, a more efficient approach
- Being careful about what a return reference refers to
  - Remember when returning a reference is to avoid returning a reference to a memory location that ceases to exist when the function terminates

Using References with a Class Object

- Run program example 4
  - string class defines a char *-to-string conversion
  - A property of const reference formal parameters is that the original data cannot be modified from inside the function
  - A const string & parameter can handle a string object or a quoted string literal, a null-terminated array of char, or a pointer variable that points to a char (a char * or const char *)

When to Use Reference Arguments

- Two main reasons for using reference arguments
  - To allow you to alter a data object in the calling function
  - To speed up a program by passing a reference instead of an entire data object (const)
- A function modifies data in the calling function
  - If the data object is a built-in data type, use a pointer (more clear)
  - An array, use your only choice: a pointer
  - A structure, use a reference or a pointer
  - A class object, use a reference

A function uses passed data without modifying it

- If the data object is small, such as a built-in data type or a small structure, pass it by value
- If the data object is an array, use a pointer because that's your only choice. Make the pointer a pointer to **const**
- If the data object is a good-sized structure, use a **const** pointer or a **const** reference to increase program efficiency
- If the data object is a class object, use a **const** reference.

Default Arguments

- How do you establish a default value?
  - You must use the function prototype
- When you use a function with an argument list, you must add defaults from right to left

```
int harpo(int n, int m = 4, int j = 5);          // VALID
int chico(int n, int m = 6, int j);              // INVALID
int groucho(int k = 1, int m = 2, int n = 3);    // VALID
```

- The actual arguments are assigned to the corresponding formal arguments from left to right; you can't skip over arguments
- Run program example 5

Function Overloading

- Function overloading:
  - Let you use **multiple** functions sharing the **same** name
  - Compared to default argument: call the same function by using varying numbers of arguments
- C++ enables you to define two functions by the same name, provided that the functions have different signatures
  - Function signature: function's argument list
  - Signature can differ in the number of arguments or in the type of arguments, or both
- Run program example 6

Function Templates

- Define a function in terms of a generic type
  - A specific type, such as int or double, can be substituted
  - The process is termed generic programming
  - The keywords template and typename (class)

```
template <typename AnyType>
void Swap(AnyType &a, AnyType &b)
{
    AnyType temp;
    temp = a;
    a = b;
    b = temp;
}
```

- Run program example 7
  - Apply the same algorithm to a variety of types

More Templates

- Overloaded Templates
  - Problem: not all types would use the same algorithm
  - Non-template functions take precedence over template functions
  - Need distinct function signatures
  - Run program example 8
- Template Limitations
  - Problem: it's easy to write a template function that cannot handle certain types
- Explicit Specializations
  - Problem: require different codes but the arguments would be the same
  - Run program example 9

Instantiations and Specializations

- Instantiation
  - Template: merely a plan for generating a function definition
  - Instantiation: use the template to generate a function definition
    - ✓ Implicit: the compiler deduces the necessity for making the definition
    - ✓ Explicit: using the <> notation to indicate the type and prefixing the declaration with the keyword template

```
...
template <class T>
void Swap (T &, T &);  // template prototype

template <> void Swap<job>(job &, job &);   // explicit specialization for job
int main(void)
{
  template void Swap<char>(char &, char &); // explicit instantiation for char
  short a, b;
  ...
  Swap(a,b);    // implicit template instantiation for short
  job n, m;
  ...
  Swap(n, m);   // use explicit specialization for job
  char g, h;
  ...
  Swap(g, h);  // use explicit template instantiation for char
  ...
}
```

Which Function Version Does the Compiler Pick?

- Multiple functions of the same name
  - Include: function overloading, function templates, and function template overloading
- Overload resolution
  - **Phase 1**—Assemble a list of candidate functions
  - **Phase 2**—From the candidate functions, assemble a list of feasible functions
    - ✓ Correct number of arguments
    - ✓ An exact match for each type of actual argument to the type of the corresponding formal argument
  - **Phase 3**—Determine whether there is a best viable function

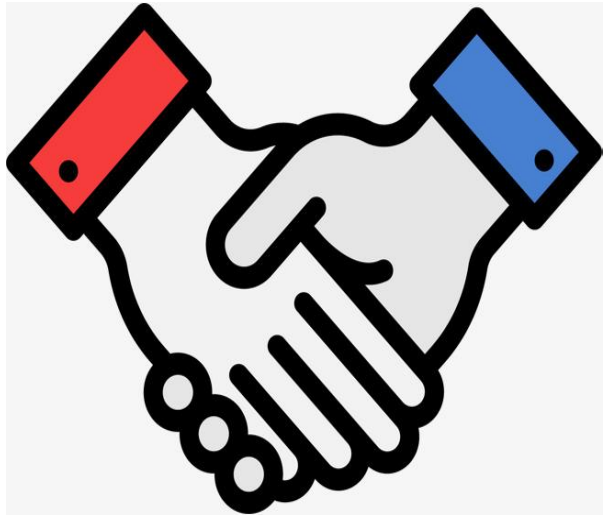
Exact Matches and Best Matches

- C++ allows some "trivial conversions" when making an exact match
  - If there's just one, that function is chosen
  - If more than one are tied, but only one is a non template function, that non template function is chosen
  - If more than one candidate are tied and all are template functions, but one template is more specialized than the rest, that one is chosen
- Error
  - If there are two or more equally good non template functions, or if there are two or more equally good template functions, none of which is more specialized than the rest, the function call is ambiguous and an error
  - If there are no matching calls, that is also an error

From an Actual Argument	To a Formal Argument
`Type`	`Type &`
`Type &`	`Type`
`Type []`	`* Type`
`Type (argument-list)`	`Type (*)(argument-list)`
`Type`	`const Type`
`Type`	`volatile Type`
`Type *`	`const Type *`
`Type *`	`volatile Type *`

Summary

- Inline function
- Reference variables
- Default arguments
- Function overloading
- Function template



Thanks

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