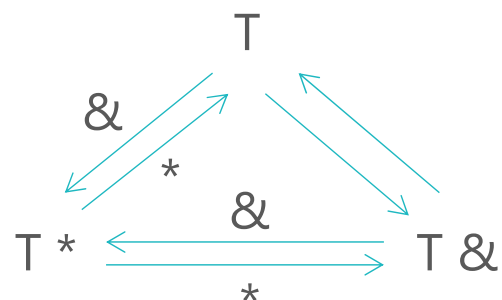


Function

Meng-Hsun Tsai
CSIE, NCKU



Solving Sudoku Recursively

```
1 #include <vector>
2 #include <iostream>
3 #include <fstream>
4 #include "Sudoku.h"
5 using namespace std;
6
7 bool solve(Sudoku question,
            Sudoku & answer)
8 {
9     int firstZero;
10    firstZero = question.getFirstZeroIndex();
11    if(firstZero == -1)
12    { // end condition
13        if(question.isCorrect())
14        {
15            answer = question;
16            return true;
17        }
18    } else
19    { return false;
20    }
21    else
22    {
23        for(int num=1; num <=9; ++num)
24        {
25            question.setElement(
26                firstZero, num);
27            if(solve(question, answer))
28                return true;
29        }
30    } return false;
31 }
32 int main()
33 {
34     Sudoku question;
35     Sudoku answer;
36     int num;
37
38     ifstream infile("infile",ios::in);
```

Solving Sudoku Recursively (cont.)

```

39  for(int i=0;i<81;++i) // read in question
40  {
41      infile >> num;
42      question.setElement(i, num);
43  }
44
45  if(solve(question, answer) == true)
46  {
47      cout << "Solvable!\n";
48      for(int i=0; i<81; i++)
49      {
50          cout << answer.getElement(i) << " ";
51          if(i%9==8)
52              cout << endl;
53      }
54  }
55  else
56      cout << " Unsolvable!!\n";
57
58  }

```

infile (10 blanks)

8	0	5	3	2	0	4	1	7
2	0	3	1	7	5	8	6	9
1	9	7	6	8	4	5	0	3
3	1	9	0	5	8	6	7	4
4	2	6	0	9	1	3	5	8
5	7	8	4	3	0	1	9	2
7	5	4	9	1	3	2	0	6
6	8	2	5	4	0	9	3	1
9	3	1	8	6	2	7	0	5

1	2	3	0	5	6	7	8	9
1	2	3	4	5	6	7	8	0
1	0	3	4	5	6	7	8	9
1	2	3	4	5	0	7	8	9
1	2	3	4	5	6	7	0	9
1	2	0	4	5	6	7	8	9
1	2	3	4	5	6	7	8	9
1	2	3	4	5	0	7	8	9
0	2	3	4	0	6	7	0	9

> time ./sudoku_solve

Solvable!

8	6	5	3	2	9	4	1	7
2	4	3	1	7	5	8	6	9
1	9	7	6	8	4	5	2	3
3	1	9	2	5	8	6	7	4
4	2	6	7	9	1	3	5	8
5	7	8	4	3	6	1	9	2
7	5	4	9	1	3	2	8	6
6	8	2	5	4	7	9	3	1
9	3	1	8	6	2	7	4	5

632.517u 0.000s

10:32.53 99.9%

10+2758k 0+0io 0pf+0w

10 min! → 16 min!

> time ./sudoku_solve

Unsolvable!!

995.174u 0.007s

16:35.20 99.9%

10+2758k 0+0io 0pf+0w

Sudoku.h and Sudoku.cpp

Sudoku.h

```
1 #include <iostream>
2 #include <vector>
3 class Sudoku {
4 public:
5     Sudoku();
6     Sudoku(const int init_map[]);
7     void setMap(const int set_map[]);
8     int getElement(int index);
9     void setElement(int index,
10                    int value);
11     int getFirstZeroIndex();
12     bool isCorrect();
13     static const int sudokuSize = 81;
14 private:
15     bool checkUnity(int arr[]);
16     int map[sudokuSize];
17 };
```

Sudoku.cpp

```
...
24 void Sudoku::setElement(int index, int value)
25 {
26     map[index] = value;
27 }
28 int Sudoku::getFirstZeroIndex()
29 {
30     for(int i=0;i<sudokuSize;++i)
31         if(map[i] == 0)
32             return i;
33     return -1;
34 }
...
```

References and Reference Parameters

- Two ways to pass arguments to functions in many programming languages are **pass-by-value** and **pass-by-reference**.
- When an argument is passed by value, *a copy of the argument's value is made and passed (on the function call stack) to the called function.*
 - Changes to the copy do not affect the original variable's value in the caller.
 - One disadvantage is that, if a large data item is being passed, copying that data can take a considerable amount of execution time and memory space.

```
7 bool solve(Sudoku question, Sudoku & answer)
```

Pass-by-value

References and Reference Parameters (cont.)

- With **pass-by-reference**, the caller gives the called function the ability to **access the caller's data directly**, and to modify that data.
- A reference parameter is an **alias** for its corresponding argument in a function call.
- To indicate that a function parameter is passed by reference, simply follow the parameter's type in the function prototype by an ampersand (&).
- **Pass-by-reference is good for performance** reasons, because it can eliminate the pass-by-value overhead of copying large amounts of data.

```
7 bool solve(Sudoku question, Sudoku & answer)
```

Pass-by-reference

References and Reference Parameters (cont.)

- **Pass-by-reference** can **weaken security**; the called function can corrupt the caller's data.
- Because reference parameters are mentioned only by name in the body of the called function, **you might inadvertently treat reference parameters as pass-by-value parameters**. This can cause **unexpected side effects if the original variables are changed by the function**.
- To specify a reference to a constant, place the **const** qualifier before the type specifier in the parameter declaration.
- For passing large objects, use a constant reference parameter to **simulate the appearance and security of pass-by-value** and **avoid the overhead of passing a copy of the large object**.

```
int func(const Sudoku & su)
```


Error: Reference Without Initialization

```
1 #include <iostream>
2 using namespace std;
3
4 int main()
5 {
6     int x = 3;
7     int &y;
8     cout << "x = " << x << "\t" << " y = " << y << endl;
9     y = 7;
10    cout << "x = " << x << "\t" << " y = " << y << endl;
11 }
```

```
> g++ -o reference reference.cpp
reference.cpp: In function 'int main()':
reference.cpp:7: error: 'y' declared as reference but not initialized
```



Error: Reference Initialized as a Literal

```
1 #include <iostream>
2 using namespace std;
3
4 int main()
5 {
6     int x = 3;
7     int &y = 3;
8     cout << "x = " << x << "\t" << " y = " << y << endl;
9     y = 7;
10    cout << "x = " << x << "\t" << " y = " << y << endl;
11 }
```

```
> g++ -o reference2 reference2.cpp
reference2.cpp: In function 'int main()':
reference2.cpp:7: error: invalid initialization of non-const reference of
type 'int&' from a temporary of type 'int'
```



Reference Initialized as Another Variable

```
1 #include <iostream>
2 using namespace std;
3
4 int main()
5 {
6     int x = 3;
7     int &y = x;
8     cout << "x = " << x << "\t" << " y = " << y << endl;
9     y = 7;
10    cout << "x = " << x << "\t" << " y = " << y << endl;
11 }
```



```
> ./reference3
```

```
x = 3    y = 3
```

```
x = 7    y = 7
```

Initializing a Reference

- References can also be used as **aliases for other variables** within a function.

```
7 int &y = x;
```

- Reference variables **must be initialized in their declarations** and **cannot be reassigned** as aliases to other variables.

```
int &y = x;  
y = z;
```



- Once a reference is declared as an alias for another variable, **all operations** supposedly performed on the alias are actually **performed on the original variable**.

Returning a Reference

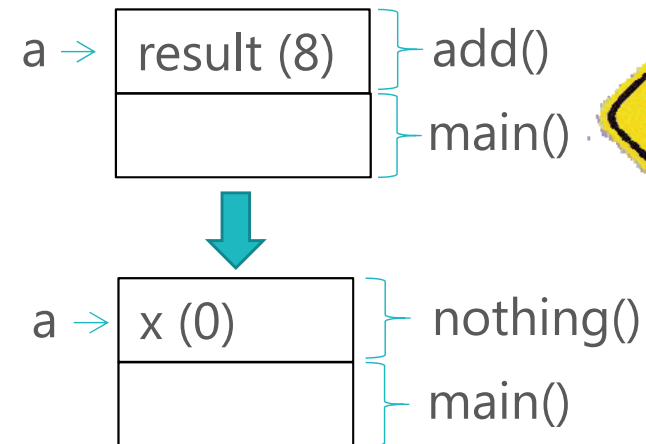
- Functions can return references, but this can be dangerous.
- Returning a reference to an automatic variable in a called function is a logic error. Some compilers issue a warning when this occurs.
- When returning a reference to a variable declared in the called function, the variable should be declared `static` in that function.

Error: Returning a Reference of a Local Variable

```
int & add ( int x, int y)    int main()
{
    int result;
    result = x + y;
    return result;
}

int nothing()
{
    int x = 0;
    return x;
}
```

```
int & a = add(3, 5);
cout << a << endl;
nothing();
cout << a << endl;
return 0;
```



```
$ g++ -o reference reference.cpp
reference.cpp: In function `int& add(int, int)':
reference.cpp:6: warning: reference to local variable `result' returned
$ ./reference.exe
8
0
```

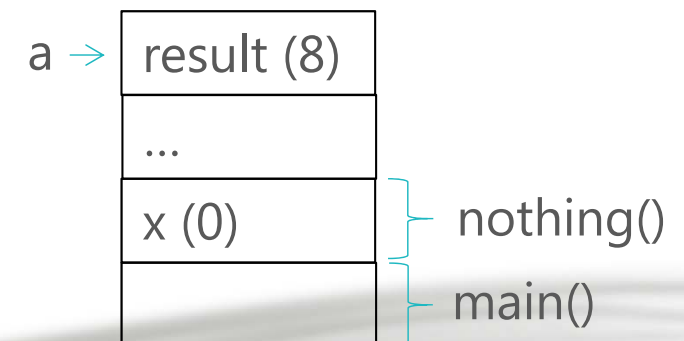
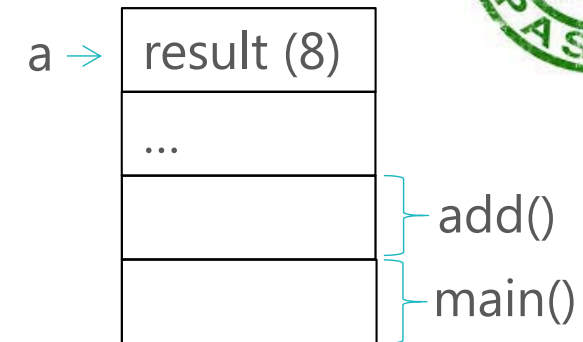
Returning a Reference of a *Static* Local Variable

```
int & add ( int x, int y)
{
    static int result;
    result = x + y;
    return result;
}

int nothing()
{
    int x = 0;
    return x;
}
```

```
int main()
{
    int & a = add(3, 5);
    cout << a << endl;
    nothing();
    cout << a << endl;
    return 0;
}
```

```
$ g++ -o reference2 reference2.cpp
$ ./reference2.exe
8
8
```



Passing a Variable vs. Passing a Reference

```
void func(int & y, int z)
{
    int x;
    printf("In func():\n &x = %u\n", &x );
    printf("&y = %u\n", &y );
    printf("&z = %u\n", &z );
}
int main()
{
    int autovar;
    int & autoref = autovar;
    printf("In main():\n&autovar = %u\n", &autovar );
    printf("&autoref = %u\n", &autoref );
    func(autovar, autovar);
    func(autoref, autoref);
    return 0;
}
```

In main():
&autovar = 3217024508
&autoref = 3217024508
In func():
&x = 3217024468
&y = 3217024508
&z = 3217024484
In func():
&x = 3217024468
&y = 3217024508
&z = 3217024484

3217024468

3217024484

3217024508

x	}	func()
z		
autovar (autoref, y)	}	main()

Default Arguments

- It is common for a program to invoke a function repeatedly with the same argument value for a particular parameter.
- In this case, the programmer can specify that such a parameter has a **default argument**, i.e., a default value to be passed to that parameter.
- When a program omits an argument for a parameter with a default argument in a function call, the **compiler** rewrites the function call and inserts the default value of that argument.
- Default arguments must be the **rightmost (trailing)** arguments in a function's parameter list.

Using Default Arguments in *boxVolume()*

```
1 #include <iostream>
2 using namespace std;
3
4 int boxVolume(int length=1, int width=1, int height=1);
5
6 int main()
7 {
8     cout << boxVolume() << endl;
9     cout << boxVolume(20) << endl;
10    cout << boxVolume(20, 10) << endl;
11    cout << boxVolume(20, 10, 3) << endl;
12    return 0;
13 }
14
15 int boxVolume(int length, int width, int height)
16 {
17     return length * width * height;
18 }
```

1
20
200
600

Notice on Using Default Arguments

- Using default arguments can simplify writing function calls. However, some programmers feel that explicitly specifying all arguments is clearer.
- If the default values for a function change, all client code using the function must be recompiled.
- Specifying and attempting to use a default argument that is not a rightmost argument (while not simultaneously defaulting all the rightmost arguments) is a syntax error.



```
int boxVolume(int length=1, int width, int height=1);
```

With default argument

without default argument

Function Overloading

- C++ enables **several functions of the same name** to be defined, **as long as they have different signatures**.
- This is called **function overloading**.
- The C++ compiler selects the proper function to call by examining **the number, types and order of the arguments** in the call.
- Function overloading is used to create several functions of the same name that **perform similar tasks, but on different data types**.
- Overloading functions that perform closely related tasks can make programs more readable and understandable.

Function Overloading (cont.)

- Overloaded functions are distinguished by their **signatures**.
- A signature is a combination of **a function's name and number, types and order of its parameters**.
- The compiler **encodes each function identifier** with the number and types of its parameters to enable **type-safe linkage**.
 - Ensures that the proper overloaded function is called and that the types of the arguments conform to the types of the parameters.

Print Start Time of *Timer* and *Clock* Objects

```
1 #include <iostream>
2 #include "Timer.h"
3 #include "Clock.h"
4
5 void printStart(Timer & t)
6 {
7     cout << "Start time is ";
8     cout << t.getStart();
9     cout << " seconds since 1970/1/1
10         00:00:00. \n";
11 }
12 void printStart(Clock & c)
13 {
14     cout << "Start time is ";
15     cout << c.getStart();
16     cout << " virtual clocks since the
17         program executes. \n";
18 }
```

```
18 int main()
19 {
20     Timer tmr;
21     Clock clk;
22
23     tmr.start();
24     clk.start();
25
26     printStart(tmr);
27     printStart(clk);
28     return 0;
29 }
```

```
> nm get_start
0000000000400ba0 T _Z10printStartR5Clock
0000000000400bf0 T _Z10printStartR5Timer
0000000000400c40 T main
```

Start time is 1391758338 seconds since 1970/1/1 00:00:00.
Start time is 3 virtual clocks since the program executes.

Encoding of Function Identifier

```
> cat overloading.cpp
double average(double n1, double n2) { return ((n1 + n2) / 2.0); }
double average(double n1, double n2, double n3)
{
    return ((n1 + n2 + n3) / 3.0);
}
int average(int n1, int n2) { return ((n1 + n2) / 2); }
int main() { return 0; }
> g++ -o overloading overloading.cpp
> nm overloading
```

```
...
00000000000400600 T _Z7averagedd
00000000000400640 T _Z7averageddd
00000000000400680 T _Z7averageii
000000000004006a0 T main
```

From nm's man page:

nm - list symbols from object files

"**T**" The symbol is in the text (code) section.

Error: Take Return Type as Part of Signature

- Creating overloaded functions with **identical parameter lists** and **different return types** is a **compilation error**.
- A **function with default arguments omitted might be called identically to another overloaded function**; this is a **compilation error**.



```
1 double average(int n1, int n2)
2 {
3     return ((n1 + n2) / 2);
4 }
5 int average(int n1, int n2)
6 {
7     return ((n1 + n2) / 2);
8 }
9 int main() { return 0; }
```

```
$ g++ -o overloading2 overloading2.cpp
overloading2.cpp: In function `int average(int,
int)':
overloading2.cpp:5: error: new declaration `int
average(int, int)'
overloading2.cpp:1: error: ambiguates old
declaration `double average(int, int)'
```

Error: Ambiguous Function Call to Overloaded Functions

```
1 #include <iostream>
2 using namespace std;
3 double add(int x, double y) { return x + y; }
4 double add(double x, int y) { return x + y; }
5 int main()
6 {
7     cout << add(1.3,1.5);
8     return 0;
9 }
```



```
$ g++ -o overloading3 overloading3.cpp
overloading3.cpp: In function `int main()':
overloading3.cpp:7: error: call of overloaded `add(double, double)' is ambiguous
overloading3.cpp:3: note: candidates are: double add(int, double)
overloading3.cpp:4: note: double add(double, int)
```

Function Templates

- If the program logic and operations are identical for each data type, overloading may be performed more compactly and conveniently by using **function templates**.
- You write a single function template definition.

Return the Maximum Value

max.h

```
1 template <typename T>
2 T maximum(T v1, T v2, T v3)
3 {
4     T max = v1;
5     if(v2 > max)
6         max = v2;
7     if(v3 > max)
8         max = v3;
9     return max;
10 }
```

maximum integer is 7
maximum double is 5.2
maximum char is C

max.cpp

```
1 #include <iostream>
2 #include "max.h"
3 using namespace std;
4
5 int main()
6 {
7     int i1 = 7, i2 = 2, i3 = 3;
8     double d1 = 2.1, d2 = 5.2, d3 = 3.3;
9     char c1 = 'A', c2 = 'B', c3 = 'C';
10    cout << "maximum integer is " <<
11         maximum(i1, i2, i3) << endl;
12    cout << "maximum double is " <<
13         maximum(d1, d2, d3) << endl;
14    cout << "maximum char is " <<
15         maximum(c1, c2, c3) << endl;
16    return 0;
17 }
```

Syntax of Function Templates

- All function template definitions begin with the `template` keyword followed by a `template parameter list` to the function template enclosed in angle brackets (< and >).
- Every parameter in the template parameter list (often referred to as a `formal type parameter`) is preceded by keyword `typename` or keyword `class`.
- The formal type parameters are `placeholders for fundamental types or user-defined types`.
- These placeholders are used to specify the types of the `function's parameters`, to specify the `function's return type` and to `declare variables` within the body of the function definition.

```
1 template <typename T>
2 T maximum(T v1, T v2, T v3)
3 {
4     T max = v1;
```