Introduction to Programming (CS 101)

Spring 2024

Lecture 19:

Namespaces, Variable scope, Global/Static Variables

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Based on material developed by Prof. Abhiram Ranade and Prof. Manoj Prabhakaran

Recap (I): Works?

```
#ifndef MATHOPS_H
#define MATHOPS_H

#include <cmath>

float roundup(float a) {
    return ceil(a);
}

#endif  // MATHOPS_H
```

mathops.h

```
#include <iostream>
#include "mathops.h"
#include "mathops.h"

int main() {
   float input; std::cin >> input;
   std::cout << "Round up " << input << " to "
             << roundup(input) << std::endl;
}
```

INPUT: **22.3**

OUTPUT: **Round up 22.3 to 23**

main.cpp

Adding `#include "mathops.h"` twice will not cause any issues because of the header guard (within the `ifndef` block)

Recap (II): What does this function return?

```
struct node {
  int val;
  node* next;
};
```

```
node* find(node* head) {
  int l = 0;
  node* tmp = head;
  while(tmp) {
    l++; tmp = tmp->next;
  }
  tmp = head;
  for(int i = 0; i < l/2; i++) {
    tmp = tmp->next;
  }
  return tmp;
}
```

Returns a pointer to the middle node in the linked list. 1->2->3->4, points to 3; 1->2->3, points to 2. Requires two passes.

```
node* find(node* head) {
  node* n1 = head;
  node* n2 = head;
  while(n2 && n2->next) {
    n1 = n1->next;
    n2 = n2->next->next;
  }
  return n1;
}
```

Can you find the middle node by only traversing the list once?

Namespaces

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Namespaces

- Standard library contains useful functions (swap, max, min, distance, begin, end, sort, move, …), data types (string, vector, list, …) and operators (cout, cin, …), many with common names
- But this can be problematic, especially due to function overloading!

Namespaces

- Standard library contains useful functions (swap, max, min, distance, begin, end, sort, move, …), data types (string, vector, list, …) and operators (cout, cin, …), many with common names
- But this can be problematic, especially due to function overloading!
- Suppose you write a function `to_string` as follows:

```
#include <simplecpp>
string to_string(short x) { return x==0 ? "zero" : "non-zero"; }
int main() {
    short a = 1; int b = 1;
    cout << to_string(a) << " vs. " << to_string(b) << endl;
}
```

invokes our to_string

invokes to_string from the standard library!

```
non-zero vs. 1
```

Namespaces

```
#include <simplecpp>
string to_string(short x) { return x==0 ? "zero" : "non-zero"; }
int main() {
     short a = 1; int b = 1;
     cout << to_string(a) << " vs. " << to_string(b) << endl;
}
```

```
non-zero vs. 1
```

- Why did this happen?
  - Standard library already has a function (included via `<simplecpp>`)
    `string to_string (int)`
    (but no function that takes a short — so it was not an error to define ours)
  - For the call `to_string(b)`, the compiler used this library function (which is a better fit than using our function which takes a `short`)

Namespaces

- <simplecpp> has a statement `using namespace std;` which made all the entities in std namespace available without the qualifier `std::`
  - We shall instead use the standard header <iostream>
- To keep entities (functions, types, variables) in a library separate from ours
  - `to_string` vs. `std::to_string`

Risky!

```
#include <iostream>
std::string to_string(short x) { return x==0 ? "zero" : "non-zero"; }
int main() {
    short a = 1; int b = 1;
    std::cout << to_string(a) << " vs. " << to_string(b) << std::endl;
}
```

Invokes our `to_string`, with b cast into a short.
Only `std::to_string` invokes the one from the library.

Namespace definition

```
namespace <name-of-namespace> {
  // declarations or definitions of names
}
```

- Example:

```
namespace num {
  int GCD(int, int);
  int LCM(int m, int n) { return (m*n)/GCD(m,n); }
}
```

- Inside the namespace, you can refer to names in it directly. Example: Use of `GCD` above in the `LCM` function
- Outside the namespace block, use the full `num::GCD` name
- The namespace directive `using namespace num;` allows all names within the namespace `num` to be used directly (without the `num::`)

Example

numbers.h

```
namespace num {
int GCD(int, int);
int LCM(int, int);
}
```

numbers.cpp

```
#include "numbers.h"
#include <cmath>
int num::LCM(int a, int b) {
      return std::abs(a*b)/GCD(a,b); // GCD is num::GCD
}
...
```

main.cpp

```
#include <iostream>
#include "numbers.h"
using std::cout; using std::cin; using std::endl;
int main() {
  cout << "Enter 2 positive numbers: ";
  int a, b; cin >> a >> b;
  if (a<=0 || b<=0) return -1;
  cout << "GCD(a,b) = " << num::GCD(a,b) << endl;
}
```

```
$ g++ -c main.cpp       # this produces main.o
$ g++ -c numbers.cpp    # this produces numbers.o
$ g++ main.o numbers.o  # this produces a.out
$ g++ main.cpp numbers.cpp # produces a.out directly
```

The global namespace

- Functions defined without using a namespace implicitly become part of a *global namespace*
- Using a name without a namespace qualifier means it is either in the global namespace or a named one. Functions in the global namespace can be accessed as `::<function-name>`

numbers.h

```
namespace num {
  int GCD(int, int);
  int LCM(int m, int n) { return (m*n)/GCD(m,n); }
}
```

main.cpp

```
using namespace num;

int LCM(int m, int n) { return m+n; }

int main() {
  cout << LCM(24,36);
}
```

Compiler error! Ambiguous use of `LCM`
Use either `num::LCM` or `::LCM` that refers to the global namespace

Namespaces

- Conventions to avoid unexpected conflicts
  - Every library should (and typically does) keep the entities they define within a separate (hopefully unique) namespace
    - E.g., std, boost, …
  - Programmers access entities in a library by explicitly specifying the namespace (e.g. `std::to_string(…)`, `std::string`, etc.)
  - But if desired, a programmer can shorten `nspace::entity` to just `entity` (say, because it is used in a lot of places in the program), by adding the statement `using nspace::entity;`
  - Alternately, one can write `using namespace nspace;` and the prefix `nspace::` can be dropped for *all* the entities in `nspace` (Might be risky, as we saw earlier with `to_string`!)

Example (I)

```
namespace One {
  int aggregate(int x, int y) {
    return x + y;
  }
}

namespace Two {
  int aggregate(int x, int y) {
    return x * y;
  }
}

int aggregate(int x, int y) {
  return x - y;
}

int main() {
  // What is the output?
  int x = 10, y = 5;
  cout << aggregate(x,y);
}
```

OUTPUT: **5**

Example (II)

```
namespace One {
  int aggregate(int x, int y) {
    return x + y;
  }
}

namespace Two {
  int aggregate(int x, int y) {
    return x * y;
  }
}

int aggregate(int x, int y) {
  return x - y;
}

int main() {
  // What is the output?
  int x = 10, y = 5;
  cout << Two::aggregate(x,y);
}
```

OUTPUT: **50**

Global and static variables

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Global variables

- Global variables are variables defined outside all functions
- These variables are accessible by any function. Example:

```
int i = 3; //global variable definition

void f() { i *= 3; } //accessing global variable

int main() {
  cout << i; //accessing global variable
  f();
  cout << " " << i << endl; //accessing global variable
}
```

- Use of global variables are generally not encouraged since any function could potentially alter it
- If a local variable has the same name as a global variable, then the local variable will *shadow* the global variable (example coming up)

Recall: Scope of Variables

- In C++, a variable can be used only where its declaration is "visible"
  - Visible only <u>within the "block"</u> it is declared in
  - And only <u>after</u> it is declared
  - Scope of a variable: region in the code where it is visible

```
{
  {
    // not visible here (before declaration)
    int x;
    // visible here
    {
      // visible here
    }

    // visible here
  }
  // not visible here (outside the block)
}
```

- A variable cannot be declared twice within the same block
  - However can declare a new variable with the same name (but possibly a different type) in a "sub-block"
  - In its scope, the new variable "shadows" the old one

Recall: Scope of Variables

```
void f(int x) {
  ...
}
```

```
{
  ...
}
```

```
for(int x=0;;) {
  ...
}
```

```
while(condition) {
  ...
}
```

```
{
  {
    // not visible here (before declaration)
    int x;
    // visible here
    {
       // visible here
    }

    // visible here
  }
  // not visible here (outside the block)
}
```

scope of x

- Examples of different kinds of blocks:
  - A function's body (including parameter declarations)
  - A block of statements enclosed in braces
  - A for loop (including declarations in the initialisation)
  - A while or do-while statement (condition can have declarations)
  - ...

Scope of Variables

```
int g; // a global variable. remains visible till the end of the file
...
void f(int x) { // x is visible inside the body of the function
  int y; // visible from here till the end of the function
  for(int g=x; g<3; g--) { // a new local g! visible till
    ...                     // the end of the for statement.
  } // now this g goes out of scope. global g visible again.
  {  // start of a new scope
    g = x + 1;  // this refers to the global g
    float g; // this is a different g! global g not visible.
  }  // now this g goes out of scope. global g visible again.
  g++;   // global g
}        // here x, y go out of scope.
```

Lifetime of Variables

- A variable is *created* (a "box" allocated for it) when control reaches its declaration
- It gets destroyed when the variable "goes out of scope"
  - i.e., control goes outside the block in which it was defined

```
{
  int c=0; // c "created" here
  while(c<12){
     int x = 2;  // x "created" in each iteration
     x++; c += x;
  } // at the end of each iteration x "destroyed"
} // here c is "destroyed"
```

Lifetime of Variables

- A variable is *created* (a "box" allocated for it) when control reaches its declaration
- It gets destroyed when the variable "goes out of scope"
  - i.e., control goes outside the block in which it was defined

```
for(int c=0 /* c "created" here */; c<12; ) {
  int x = 2;  // x "created" in each iteration
  x++; c += x;
}  // at the end of each iteration x "destroyed", but c is alive
// on exiting the loop, c is "destroyed"
```

Lifetime of Variables

- A variable is *created* (a "box" allocated for it) when control reaches its declaration
- It gets destroyed when the variable "goes out of scope"
- But a variable stays alive when it is shadowed

```
void f(int x) {// in each call of f, x is created and initialised

  for(int c=0 /* c "created" here */; c<12; ) {
    int x = 2;   // x "created" in each iteration// parameter x visible
    x++; c += x;                                . parameter x shadowed.
  }  // at the end of each iteration x "destroyed", but c is alive

  // on exiting the loop, c is "destroyed"
  return x; // parameter x's value to be returned. x is destroyed.
}
```

Static Variables in Functions

- Global variables (possibly declared in a namespace) are useful as they stay alive throughout the program.
  - But they can be modified from many points in the program, making it hard to debug
- A local variable in a function can be declared to be static, so that it behaves like a global variable in terms of lifetime, but a local variable in terms of scope
  - Like a global variable, the lifetime of a static variable starts when it is first accessed, and lasts till the end of the program
  - However, the scope is limited to the function: can only be accessed from within the function

Static Variables in Functions

- Example:
- Here, p will be initialised on the first call to the function
- Even after the function returns, p remains alive
- In subsequent calls, the value of p at the end of the previous invocation is retained (initialisation skipped)

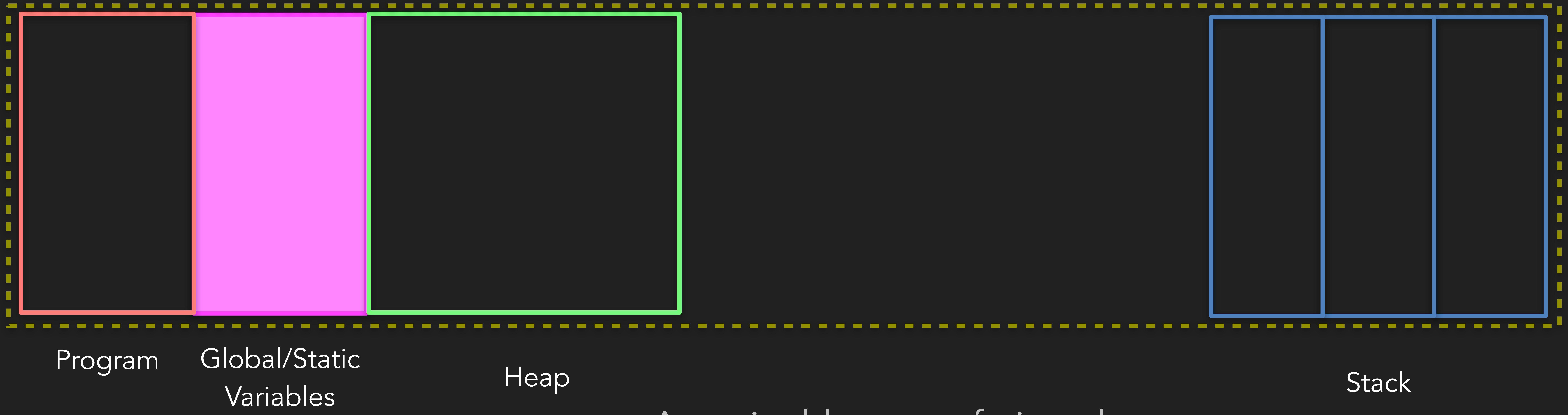
```
struct posn { double x, y, deg; };

posn change(double step, double turn) {
    static posn p = {0, 0, 0};

    p.deg += turn;
    p.x += step*cosine(p.deg);
    p.y += step*sine(p.deg);
    return p;
}
```

Global/Static Variables in Memory

- Global and static variables occupy a region of memory, separate from the stack
- These variables stay alive across function calls, for the duration of the program



A typical layout of virtual memory

Example of a counter using a static variable

```
#include <iostream>
using namespace std;
void tick() {
    static int count = 0;  // Static variable
    count++;
    cout << " count << " ";
}
int main() {
    for (int i = 0; i < 3; i++) {
        tick();
    }
    return 0;
}
```

OUTPUT: 1 2 3

- **Main takeaway**: A static variable inside a function retains its value across function calls. It is only initialized once during the lifetime of the program.

Debugging (Next class)

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"Debugging is like being the detective in a crime movie where you are also the murderer."

- Filipe Fortes