



Types and Structs

Types make things better...and sometimes harder...but still better >:(

Today



- **Quick Recap**
- Types
- Intro to structs

Announcements

Logistics Recap

- All course materials on class website cs106l.stanford.edu
- If you missed the first lecture, definitely look over the slides for the [Welcome lecture](#) because we covered the important logistics
- Really excited to be here!

Recap

C++: Basic Syntax + the STL

Basic syntax

- Semicolons at EOL
- Primitive types (ints, doubles etc)
- Basic grammar rules

The STL

- Tons of general functionality
- Built in classes like maps, sets, vectors
- Accessed through the namespace std::

Standard C++: Basic Syntax + std library

Basic The STL

- Series of templates
- Primitive data types
- Containers
- Algorithms
- Iterators
- Functors
- Lambda expressions
- Range-comprehensions
- Tons of general functionality
- Built in classes like maps, sets, vectors
- Accessed through the namespace std::
- Extremely powerful and well-maintained

Namespaces

- MANY things are in the `std::` namespace
 - e.g. `std::cout`, `std::cin`, `std::lower_bound`
- CS 106B always uses the `using namespace std;` declaration, which automatically adds `std::` for you
- We won't (most of the time)
 - it's not good style!

A note about STL naming conventions

- **STL** = Standard Template Library
 - Contains TONS of functionality (algorithms, containers, functions, iterators) some of which we will explore in this class
- The **namespace** for the STL is **std**
 - std is the abbreviation for standard
 - IDK why they didn't name the namespace stl
- So to **access elements** from the STL use **std::**

Today



~~Quick Recap~~

- **Types**
- Intro to structs

C++ Fundamental Types

```
int val = 5; //32 bits
```

```
char ch = 'F'; //8 bits (usually)
```

```
float decimalVal1 = 5.0; //32 bits (usually)
```

```
double decimalVal2 = 5.0; //64 bits (usually)
```

```
bool bVal = true; //1 bit
```

C++ Fundamental Types++

```
#include <string>
int val = 5; //32 bits
char ch = 'F'; //8 bits (usually)
float decimalVal1 = 5.0; //32 bits (usually)
double decimalVal2 = 5.0; //64 bits (usually)
bool bVal = true; //1 bit
std::string str = "Sarah";
```



Fill in the types!

```
_____ a = "test";
```

```
_____ b = 3.2 * 5 - 1;
```

```
_____ c = 5 / 2;
```

```
_____ d(int foo) { return foo / 2; }
```

```
_____ e(double foo) { return foo / 2; }
```

```
_____ f(double foo) { return int(foo / 2); }
```

```
_____ g(double c) {
```

```
    std::cout << c << std::endl;
```

```
}
```



Fill in the types!

```
           std::string a = "test";
```

```
           b = 3.2 * 5 - 1;
```

```
           c = 5 / 2;
```

```
           d(int foo) { return foo / 2; }
```

```
           e(double foo) { return foo / 2; }
```

```
           f(double foo) { return int(foo / 2); }
```

```
           g(double c) {  
std::cout << c << std::endl;  
}
```



Fill in the types!

```
std::string a = "test";
```

```
double b = 3.2 * 5 - 1;
```

```
_____ c = 5 / 2;
```

```
_____ d(int foo) { return foo / 2; }
```

```
_____ e(double foo) { return foo / 2; }
```

```
_____ f(double foo) { return int(foo / 2); }
```

```
_____ g(double c) {  
    std::cout << c << std::endl;  
}
```



Fill in the types!

```
std::string a = "test";
```

```
double b = 3.2 * 5 - 1;
```

```
int c = 5 / 2; // int/int → int, what's the value?
```

```
_____ d(int foo) { return foo / 2; }
```

```
_____ e(double foo) { return foo / 2; }
```

```
_____ f(double foo) { return int(foo / 2); }
```

```
_____ g(double c) {  
    std::cout << c << std::endl;  
}
```




Fill in the types!

```
std::string a = "test";  
double b = 3.2 * 5 - 1;  
int c = 5 / 2; // int/int → int, what's the value?  
  
int d(int foo) { return foo / 2; }  
_____ e(double foo) { return foo / 2; }  
_____ f(double foo) { return int(foo / 2); }  
  
_____ g(double c) {  
    std::cout << c << std::endl;  
}
```



Fill in the types!

```
std::string a = "test";  
double b = 3.2 * 5 - 1;  
int c = 5 / 2; // int/int → int, what's the value?  
  
int d(int foo) { return foo / 2; }  
double e(double foo) { return foo / 2; }  
_____ f(double foo) { return int(foo / 2); }  
  
_____ g(double c) {  
    std::cout << c << std::endl;  
}
```



Fill in the types!

```
std::string a = "test";  
double b = 3.2 * 5 - 1;  
int c = 5 / 2; // int/int → int, what's the value?  
  
int d(int foo) { return foo / 2; }  
double e(double foo) { return foo / 2; }  
int f(double foo) { return int(foo / 2); }  
  
_____ g(double c) {  
    std::cout << c << std::endl;  
}
```



Fill in the types!

```
std::string a = "test";  
double b = 3.2 * 5 - 1;  
int c = 5 / 2; // int/int → int, what's the value?  
  
int d(int foo) { return foo / 2; }  
double e(double foo) { return foo / 2; }  
int f(double foo) { return int(foo / 2); }  
  
void g(double c) {  
    std::cout << c << std::endl;  
}
```

C++ is a statically typed
language

Definition


statically typed: everything with a name (variables, functions, etc) is given a type **before runtime**

Definition

Ex. Python is
dynamically typed

dynamically typed:
everything with a name
(variables, functions, etc) is
given a type **at runtime**
based on the thing's current
value


Translated: Converting source code into something a computer can understand (i.e. machine code)



Compiled vs Interpreted

Main Difference: When is source code translated?

Source Code: Original code, usually typed by a human into a computer (like C++ or Python)



Compiled vs Interpreted: When is source code translated?

Dynamically typed, interpreted

- Types checked on the fly, during execution, line by line
- Example: Python

Statically typed, compiled

- Types before program runs during compilation
- Example: C++

Runtime: Period when program is executing commands (after compilation, if compiled)

C++ Types in Action

```
int a = 3;
```

```
string b = "test";
```

```
char func(string c) {
```

```
    // do something
```

```
}
```

```
b = "test two";
```

```
func(b);
```

```
// don't need to declare type after initialization
```

Dynamic vs Static typing: Python vs C++

Python

```
a = 3
b = "test"

def func(c):
    # do something
```

C++

```
int a = 3;
string b = "test";

char func(string c) {
    // do something
}
```

Dynamic vs Static typing: Python vs C++

Python

```
val = 5  
bVal = true  
str = "hi"
```

val



bVal



str



C++

```
int val = 5;  
bool bVal = true;  
string str = "hi";
```

val



bVal



str



Dynamic vs Static typing: Python vs C++

Python

```
val = 5  
bVal = true  
str = "hi"  
val = "hi"  
str = 100
```

val

bVal

str



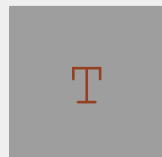
C++

```
int val = 5;  
bool bVal = true;  
string str = "hi";
```

val

bVal

str



Dynamic vs Static typing: Python vs C++

Python

```
val = 5  
bVal = true  
str = "hi"  
val = "hi"  
str = 100
```

val

bVal

str

"hi"

T

100

C++

```
int val = 5;  
bool bVal = true;  
string str = "hi";  
val = "hi";  
str = 100;
```

ERROR!

val

bVal

str

"hi"

T

100

Dynamic typing can
cause some
unexpected results

Dynamic vs Static typing: Python vs C++

Python

```
def div_3(x):  
    return x / 3  
  
div_3("hello")
```

C++

```
int div_3(int x) {  
    return x / 3;  
}  
  
div_3("hello")
```

Dynamic vs Static typing: Python vs C++

Python

```
def div_3(x):  
    return x / 3  
  
div_3("hello")
```

//CRASH during runtime,
can't divide a string

C++

```
int div_3(int x) {  
    return x / 3;  
}  
  
div_3("hello")
```


Dynamic vs Static typing: Python vs C++

Python

```
def div_3(x):  
    return x / 3  
  
div_3("hello")
```

//CRASH during runtime,
can't divide a string

C++

```
int div_3(int x) {  
    return x / 3;  
}
```

```
div_3("hello")  
//Compile error: this code  
will never run
```

Dynamic vs Static typing: Python vs C++

Python

```
def mul_3(x):  
    return x * 3  
  
mul_3("10")
```

C++

```
int mul_3(int x) {  
    return x * 3;  
}  
  
mul_3("10");
```

Dynamic vs Static typing: Python vs C++

Python

```
def mul_3(x):  
    return x * 3  
  
mul_3("10")
```

//returns "101010"

C++

```
int mul_3(int x) {  
    return x * 3;  
}  
  
mul_3("10");
```

//Compile error: "10" is a string! This code won't run

Dynamic vs Static typing: Python vs C++

Python

```
def add_3(x):  
    return x + 3  
  
add_3("10")
```

//returns "103"

C++

```
int add_3(int x) {  
    return x + 3;  
}
```

```
add_3("10");  
//Compile error: "10" is a  
string! This code won't  
run
```

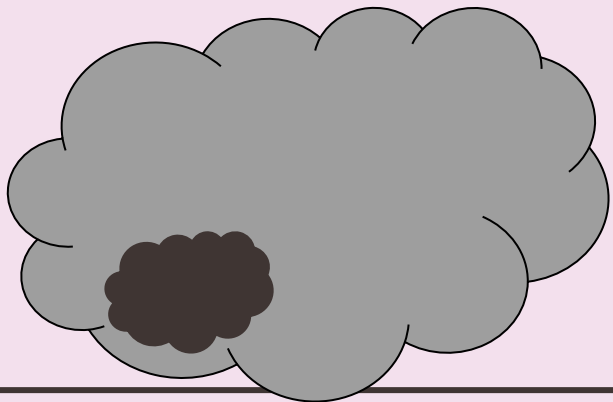
static typing helps us to
**prevent errors before our
code runs**

Static Types + Functions

Python

```
def div_3(x)
```

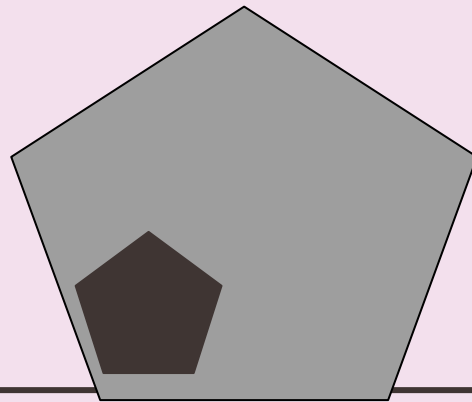
```
div_3: __ -> ??
```



C++

```
int div_3(int x)
```

```
div_3: int -> int
```



C++ to Python, probably



Static Types + Functions

What are the “types” of the following functions?

```
int add(int a, int b);
```

int, int -> int

```
string echo(string phrase);
```

```
string helloworld();
```

```
double divide(int a, int b);
```

Static Types + Functions

What are the “types” of the following functions?

```
int add(int a, int b);
```

int, int -> int

```
string echo(string phrase);
```

string -> string

```
string helloworld();
```

```
double divide(int a, int b);
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Static Types + Functions

What are the “types” of the following functions?

```
int add(int a, int b);
```

```
int, int -> int
```

```
string echo(string phrase);
```

```
string -> string
```

```
string helloworld();
```

```
void -> string
```

```
double divide(int a, int b);
```

Static Types + Functions

What are the “types” of the following functions?

```
int add(int a, int b);
```

```
int, int -> int
```

```
string echo(string phrase);
```

```
string -> string
```

```
string helloworld();
```

```
void -> string
```

```
double divide(int a, int b);
```

```
int, int -> double
```

Questions?

Function Overloading

- What if we want two versions of a function for two different types?
- Example: int division vs double division

Function Overloading

Define two functions with the same name but different types

```
int half(int x) {  
    std::cout << "1" << endl;    // (1)  
    return x / 2;  
}
```

```
double half(double x) {  
    cout << "2" << endl;    // (2)  
    return x / 2;  
}
```

```
half(3)    // uses version (1), returns ?
```

```
half(3.0)  // uses version (2), returns ?
```

Function Overloading

Define two functions with the same name but different types

```
int half(int x) {  
    std::cout << "1" << endl;    // (1)  
    return x / 2;  
}
```

```
double half(double x) {  
    cout << "2" << endl;    // (2)  
    return x / 2;  
}
```

```
half(3)    // uses version (1), returns 1
```

```
half(3.0)  // uses version (2), returns 1.5
```

Function Overloading

Define two functions with the same name but different types

```
int half(int x, int divisor = 2) {           // (1)
    return x / divisor;
}
```

```
double half(double x) {                     // (2)
    return x / 2;
}
```

half(4) // uses version ??, returns ??

half(3, 3) // uses version ??, returns ??

half(3.0) // uses version ??, returns ??

Function Overloading

Define two functions with the same name but different types

```
int half(int x, int divisor = 2) {           // (1)
    return x / divisor;
}
```

```
double half(double x) {                     // (2)
    return x / 2;
}
```

half(4) // uses version (1), returns 2

half(3, 3) // uses version (1), returns 1

half(3.0) // uses version (2), returns 1.5

Questions?

Today



~~— Quick Recap~~

~~— Types~~

- **Intro to structs**

Definition

struct: a group of named variables *each with their own type*. A way to bundle different types together

Structs in Code

```
struct Student {  
    string name; // these are called fields  
    string state; // separate these by semicolons  
    int age;  
};
```

```
Student s;  
s.name = "Sarah";  
s.state = "CA";  
s.age = 21; // use . to access fields
```

Use structs to pass around grouped information

```
Student s;  
s.name = "Sarah";  
s.state = "CA";  
s.age = 21; // use . to access fields
```

```
void printStudentInfo (Student s) {  
    cout << s.name << " from " << s.state;  
    cout << " (" << s.age ")" << endl;  
}
```

Use structs to return grouped information

```
Student randomStudentFrom(std::string state) {  
    Student s;  
    s.name = "Sarah"; //random = always Sarah  
    s.state = state;  
    s.age = std::randint(0, 100);  
    return s;  
}
```

```
Student foundStudent = randomStudentFrom("CA");  
cout << foundStudent.name << endl; // Sarah
```

Abbreviated Syntax to Initialize a struct

```
Student s;
```

```
s.name = "Sarah";
```

```
s.state = "CA";
```

```
s.age = 21;
```

```
//is the same as ...
```


Abbreviated Syntax to Initialize a struct

```
Student s;  
s.name = "Sarah";  
s.state = "CA";  
s.age = 21;
```

//is the same as ...

```
Student s = {"Sarah", "CA", 21};
```

Questions?

Definition

`std::pair`: An STL
built-in struct with
two fields *of any type*

std::pair

- **std::pair** is a **template**: You specify the types of the fields inside <> for each pair object you make
- The fields in **std::pairs** are named **first** and **second**

```
std::pair<int, string> numSuffix = {1, "st"};
```

```
cout << numSuffix.first << numSuffix.second;  
//prints 1st
```

`std::pair`

- `std::pair` is a **template**: You specify the types of the fields inside `<>` for each pair object you make
- The fields in `std::pairs` are named **first** and **second**

```
struct Pair {  
    fill_in_type first;  
    fill_in_type second;  
};
```

Use `std::pair` to return success + result

```
std::pair<bool, Student> lookupStudent(string name) {  
    Student blank;  
  
    if (notFound(name)) return std::make_pair(false, blank);  
  
    Student result = getStudentWithName(name);  
  
    return std::make_pair(true, result);  
}  
  
std::pair<bool, Student> output = lookupStudent("Julie");
```

To avoid specifying the types of a pair, use

std::make_pair(field1, field2)

```
std::pair<bool, Student> lookupStudent(string name) {  
    Student blank;  
  
    if (notFound(name)) return std::make_pair(false, blank);  
  
    Student result = getStudentWithName(name);  
  
    return std::make_pair(true, result);  
}  
  
std::pair<bool, Student> output = lookupStudent("Julie");
```

Questions?

Aside: Type Deduction with `auto`

Definition

auto: Keyword used in lieu of type when declaring a variable, tells the compiler to deduce the type.

Type Deduction using auto

// What types are these?

```
auto a = 3;
```

```
auto b = 4.3;
```

```
auto c = 'X';
```

```
auto d = "Hello";
```

```
auto e = std::make_pair(3, "Hello");
```



auto does not mean that the variable doesn't have a type.

It means that the type is **deduced** by the compiler.

Type Deduction using auto

```
// What types are these?
```

```
auto a = 3; // int
```

```
auto b = 4.3; // double
```

```
auto c = 'x'; // char
```

```
auto d = "Hello"; // char* (a C string)
```

```
auto e = std::make_pair(3, "Hello");
```

```
// std::pair<int, char*>
```

 **auto** does not mean that the variable doesn't have a type.

It means that the type is **deduced** by the compiler.

!! `auto` **does not mean that the variable doesn't have a type.**

It means that the type is **deduced** by the compiler.

Code Demo!

quadratic.cpp

a general quadratic equation can always be written:

$$ax^2 + bx + c = 0$$

Radical

the solutions to a general quadratic equation are:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

If Radical < 0, no real roots

Recap

- Everything with a name in your program has a **type**
- **Static type system** prevent errors before your code runs!
- **Structs** are a way to bundle a bunch of variables of many types
- **std::pair** is a type of struct that had been defined for you and is in the STL
- So you access it through the **std:: namespace** (std::pair)
- **auto** is a keyword that tells the compiler to deduce the type of a variable, it should be used when the type is obvious or very cumbersome to write out

Next Time:

- **Uniform Initialization**
 - A “uniform” way to initialize variables of different types!
- **References**
 - Allow us to alias variables
- **Const**
 - Allow us to specify that a variable can't be modified

Thank you for coming!
Hope you have a wonderful weekend
