

Lecture 2: Types and Structs

CS 106L, Fall '20

Today's Agenda

- Recap: **Types**
- Structs
- Type Deduction with Auto
- Structured Binding

Namespaces

- Some 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!

Recap: Types

C++ is a static-typed language

Python

```
a = 3
b = "test"

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

C++

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

void func(c) {
    // do something
```

More examples of typing

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

void func(double c) {           // vars take type
    std::cout << b << std::endl; // doesn't return anything,
                                // so it's void
}

if (b == 3) {                   // don't have to repeat types during use
    // do something
}
```

Why static typing?

- Better performance
- Easier to understand
- Better error checking

Catches errors at compile time

```
def add_3(x):  
    return first + 3
```

```
add_3("10")
```

```
// whoops, that's a string! returns "103"...
```



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

```
add_3("10");
```

```
// caught as compiler error!
```


Common Types

int 5

double 77.3

string “test”

bool true

size_t 5 // non-negative



Answer in the chat!

```
_____ 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 blanks in the chat

```
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;
}
```

Overloading

Define two functions with the same name but different call signature

```
double func(int x) {    // (1)
    return (double) x + 3; // typecast: int → double
}

double func(double x) { // (2)
    return x * 3;
}

func(2)           // uses version (1), returns ?
func(2.0)         // uses version (2), returns ?
```



Answer in the chat!

Overloading

Define two functions with the same name but different call signature

```
double func(int x) {    // (1)
    return (double) x + 3; // typecast: int → double
}

double func(double x) { // (2)
    return x * 3;
}

func(2)           // uses version (1), returns 5
func(2.0)         // uses version (2), returns 15.0
```

Example: Student Database

- Every student has:
 - A name (`string`)
 - A home state (`string`)
 - An age (`int`)

A bigger problem

```
___ getStudentWithID(int id) {  
    // how can we return a string, a string, and an int?  
}  
  
// python:  
// return ("a", "b", 3)
```

How can we return multiple things?

Student Database

```
void printStudentInfo(string name, string state, int age) {  
    cout << name << " from " << state;  
    cout << " (" << age ")" << endl;  
}  
  
void enrollStudent(string name, int state, int age) {  
    // do something...  
}
```

Can we group these three variables together?

Structs

A struct is a group of named variables
each with their own type

Struct Example

```
struct Student {  
    string name;           // these are called fields  
    string state;          // separate these by semicolons  
    int age;  
}  
  
Student s;  
s.name = "Ethan";          // use the . operator to access fields  
s.state = "CA";  
s.age = 20;
```

Structs let you group information together.

Pass around information together

```
Student s;  
s.name = "Ethan";           // use the . operator to access fields  
s.state = "CA";  
s.age = 20;  
  
void printStudentInfo(Student student) {  
    cout << student.name << " from " << student.state;  
    cout << " (" << student.age << ")" << endl;  
}
```

Return information together

```
Student lookupStudent() {  
    Student s;  
    s.name = "Ethan";  
    s.state = "CA";  
    s.age = 20;  
    return s;  
}
```

```
Student foundStudent = lookupStudent();  
cout << foundStudent.name << endl;    // Ethan
```

Abbreviated Struct Notation

```
Student s;  
s.name = "Ethan";  
s.state = "CA";  
s.age = 20;
```



```
Student s = {"Ethan", "CA", 30};  
// note that order is based on the original struct order!  
// generally prefer this syntax for initialization
```


 **Questions?** 

Pairs

(and maybe tuples)

A **pair** is a struct with two fields.

```
int main() {  
    std::pair<bool, Student> query_result;  
    query_result.first = true;  
    Report current = query_result.second;  
}
```

 **std::pair** is a **template**. You can use any type inside it; type goes in the <>. (We'll learn more about templates in a future lecture.)

Common use case: return success + result


```
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("Keith");
```



std::make_pair is a generic way to make a pair without explicitly writing a type!

A **tuple** is a struct with lots of fields.

```
int main() {  
    std::tuple<string, int, int> query_result;  
    string name = std::get<1>(query_result);  
    int num = std::get<2>(query_result);  
}
```

 **std::tuple is uncommon.** We won't use it much in future lectures.
(Datatypes like `std::vector` are generally more useful.)

 Yes, `std::get` is a template. Don't worry too much about this.

Live Code Demo:

Quadratic.cpp

a general quadratic equation can always be written:

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

the solutions to a general quadratic equation are:

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

Returning Multiple Things

Let's return a `std::pair` of the form `<does_solution_exist, <sol1, sol2>>`:

```
std::pair<bool, std::pair<double, double>> quadratic (int a, int b, int c) {  
    double inside = b*b - 4*a*c;  
    std::pair<double, double> blank;  
    if (inside < 0) return std::make_pair(false, blank);  
  
    std::pair<double, double> answer = std::make_pair( (-b+sqrt(inside))/2,  
                                                       (-b-sqrt(inside))/2 );  
    return std::make_pair(true, answer);  
}
```

Returning Multiple Things

Here's how we would use this:

```
int main() {  
    int a, b, c;  
    std::cin >> a >> b >> c;    // this gets input  
    std::pair<bool, std::pair<double, double>> = quadratic(a, b, c);  
    if (result.first) {  
        std::pair<double, double> solutions = result.second;  
        std::cout << solutions.first << solutions.second << endl;  
    } else {  
        std::cout << "No solutions found!" << endl;  
    }  
}
```


Type Deduction with auto

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");
```

Answers: int, double, char, char* (a C string), 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.

Type Deduction using auto



Don't be ambiguous or the compiler won't get what you mean...

```
auto wrong();           // this won't work
void wrong(string a, auto b) { // neither will this work
    return a * b;
}
```

When should we use auto?

Flashback

Typing these types out is a pain...

```
int main() {  
    int a, b, c;  
    std::cin >> a >> b >> c;  
    std::pair<bool, std::pair<double, double>> result = quadratic(a, b, c);  
    bool found = result.first;  
    if (found) {  
        std::pair<double, double> solutions = result.second;  
        std::cout << solutions.first << solutions.second << endl;  
    } else {  
        std::cout << "No solutions found!" << endl;  
    }  
}
```

Auto to the rescue!

Much easier to read.

```
int main() {  
    int a, b, c;  
    std::cin >> a >> b >> c;  
    auto result = quadratic(a, b, c);  
    bool found = result.first;  
    if (result.first) {  
        auto solutions = result.second;  
        std::cout << solutions.first << solutions.second << endl;  
    } else {  
        std::cout << "No solutions found!" << endl;  
    }  
}
```

Don't overuse `auto`

...but use it to shorten long types

Structured Binding

Structured binding lets you initialize **directly** from the contents of a struct

Before

```
auto p = std::make_pair("s", 5);  
string a = s.first;  
int b = s.second;
```

After

```
auto p = std::make_pair("s", 5);  
auto [a, b] = p;  
// a is of type string  
// b is of type int  
  
// auto [a, b] = std::make_pair(...);
```



This works for regular structs, too. Also, no nested structured binding.

A better way to use quadratic

Let's apply structured binding:

```
int main() {  
    int a, b, c;  
    std::cin >> a >> b >> c;  
    auto [found, solutions] = quadratic(a, b, c);  
    if (found) {  
        auto [x1, x2] = solutions;  
        std::cout << x1 << " " << x2 << endl;  
    } else {  
        std::cout << "No solutions found!" << endl;  
    }  
}
```



This is better is because it's *semantically clearer*: variables have clear names.