# CS4414 Recitation 2

## C++ Types and Containers

09/03/2021

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# C++ is strongly typed!

- A C++ **variable** has a name, a type, a value and an address in memory

```
int x = 5;
```

type

name

initial value

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- A C++ **variable** has a name, a type, a value and an address in memory

```
int x = 5;                  // declaration + initialization
```

- Later, you can use variable **x** in expressions such as,

```
int y = x + 1;              // initialization of y using x
x = 7;                      // reassignment
```

# Address and initial value

- Can obtain the **address** (represented in hex) with the **&** operator

```
std::cout << &x << std::endl;
                                // prints 0x7ffd55bdaa4
```

- What happens if you use an **uninitialized** variable?

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int x;
std::cout << x << std::endl;
```

# Address and initial value

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                                  // prints 0x7ffd55bdaa4
```

- What happens if you use an **uninitialized** variable?

```
int x;                            // undefined value
std::cout << x << std::endl;
                                  // prints 0 on my machine
```

# Types

- Primitive data types
  - bool
  - char
  - int
  - float
  - double
- Derived data types
  - pointer
  - array
  - function
- User-defined data types
  - struct
  - class

# Primitive data types

- **bool**: Represents two values – true and false
- **char**: a-z, A-Z, 0-9, special characters such as space, newline etc.
- **int**: Represents integer values
- **unsigned int**: Represents integer values >= 0
- **float, double**: Represents floating point numbers

# Each C++ type has a fixed size, but…

- the size is implementation defined in general
- Lots of integer types
  - int, short, unsigned int, long, long long, unsigned long…
  - even more: int8_t, int16_t, int32_t, int64_t,…
- Use sizeof(<type>) to find the size

```
long long int x = 0;
std::cout << sizeof(x) << std::endl;   // prints 8
std::cout << sizeof(long long int) << std::endl;
                                        // prints 8
```

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- 4 bytes = 32 bits
  A 32-bit datatype can represent $2^{32}$ distinct values
- A signed 4-byte integer can represent numbers from **$-2^{31}$** (-2, 147, 483, 648) to **$2^{31} - 1$** (2, 147, 483, 647)
- An unsigned 4-byte integer can represent numbers from **0** to **$2^{32} - 1$** (4, 294, 967, 295)
- **Tip**: Use fixed-width integer types defined in **cstdint**. 4-byte integers for normal use (int32_t, uint32_t) and 8-byte integers (int64_t, uint64_t) for representing larger values

# Operators

| | |
|---|---|
| • Arithmetic: a **+** b, a **–** b, a ***** b, … | int X int -> int |
| • Logical: **!**a, a **&&** b, a **\|\|** b | bool X bool -> bool |
| • Relational: a **==** b, a **<** b, a **>** b, a **<=** b, … | int X int -> bool |
| • Assignment: a **=** b, a **+=** b, a **/=** b, … | int X int -> int |
| • Increment: **++**a, **--**a, a**++**, a**--** | int -> int |

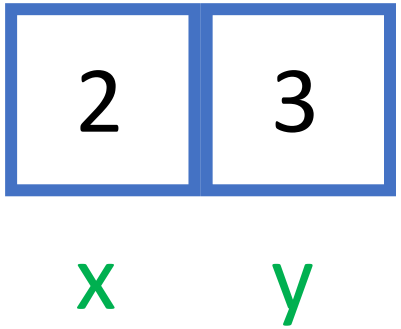
```
if (x + y < 7 && !(z > 10)) {
        // do something
}
```

# +=, -=, *=, /=, …

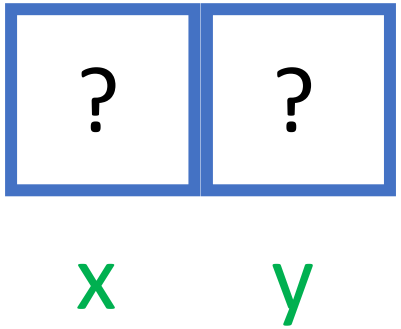
- x += y is equivalent to writing x = x +y
- can also use for bools: b1 |= b2

# More on increment and decrement

- Pre-increment (**++a**) and post-increment (**a++**) behave differently




```
x = ++y; or
x = y++;
```



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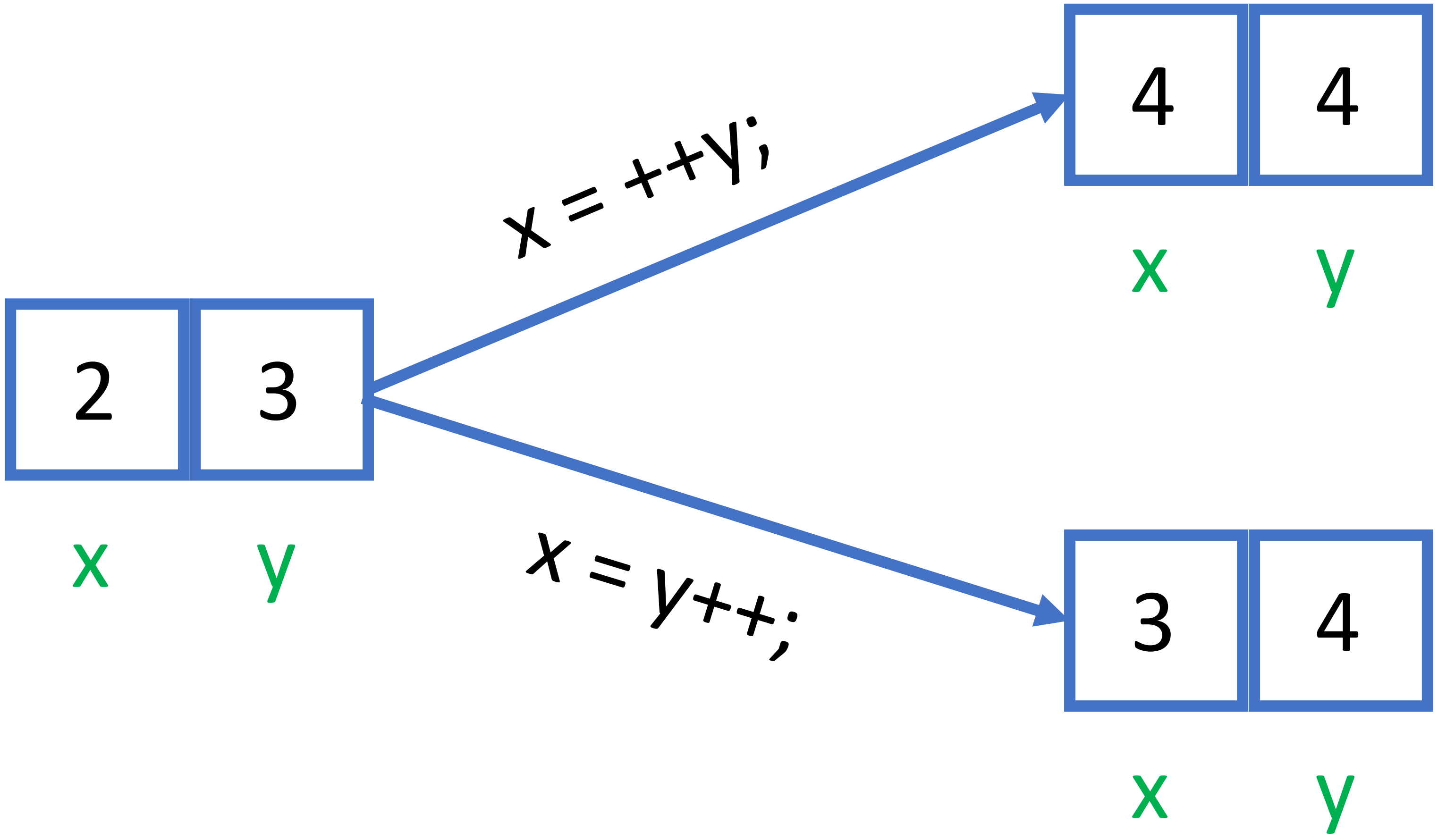

# Implicit conversions

- false is 0, true is 1. Any non-zero int is true, int 0 is false

```
if (my_int) {}      // equivalent to if (my_int != 0)
```

- Implicit conversion from char to int (using ASCII codes)

```
isdigit(ch): ch >= 48 && ch <= 57
```

# Implicit conversions

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- Implicit conversion from char to int (using ASCII codes)

```
isdigit(ch): ch >= 48 && ch <= 57
```

written better as,

```
isdigit(ch): ch >= '0' && ch <= '9'
```

# C++ auto keyword and const qualifier

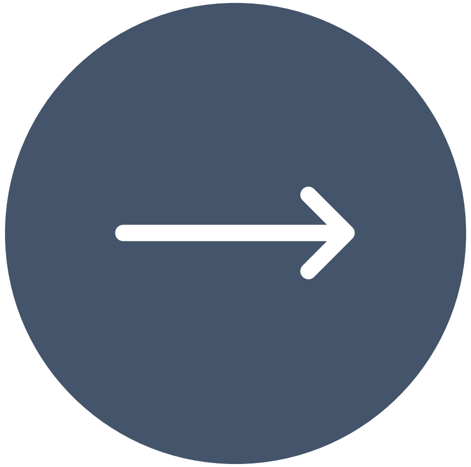
- Compiler infers type of variable defined with the **auto** keyword

```
int max (int x, int y);     // function declaration
auto m = max (x, y);        // m is an int,
                            // the return type of max
```

- **const** keyword before a variable declaration fixes its value to the initial value

```
const double pi = 3.14; // good for readability
```

# More in future recitations



POINTERS

CLASSES

# Exercise: Explain the error!

```cpp
#include <iostream>

class myClass {
public:
  void print () {
    std::cout << "My integer is: " << myInt << std::endl;
  }

private:
  int myInt = 10;
};


int main() {
  const myClass myObj;
  myObj.print();
}
```

```
~ $
~ $ g++ program.cpp -o program
program.cpp: In function ‘int main()’:
program.cpp:16:15: error: passing ‘const myClass’ as ‘this’ argument discards
qualifiers [-fpermissive]
   16 |   myObj.print();
      |               ^
program.cpp:5:8: note:   in call to ‘void myClass::print()’
    5 |   void print () {
      |        ^~~~~
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# Exercise: Explain the error!

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public:
  void print () {
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```

- print function can potentially change the state of a myClass object, so it cannot be called on a const object
- To assert that print cannot change object state, change it to void print () const { … }

# Follow up: What happens when myInt is incremented in the const print function?

```
~ $
~ $ g++ program.cpp -o program
program.cpp: In member function ‘void myClass::print() const’:
program.cpp:7:5: error: increment of member ‘myClass::myInt’ in read-only obje
ct
    7 |     myInt++;
      |     ^~~~~
~ $
```

# Part II : Containers

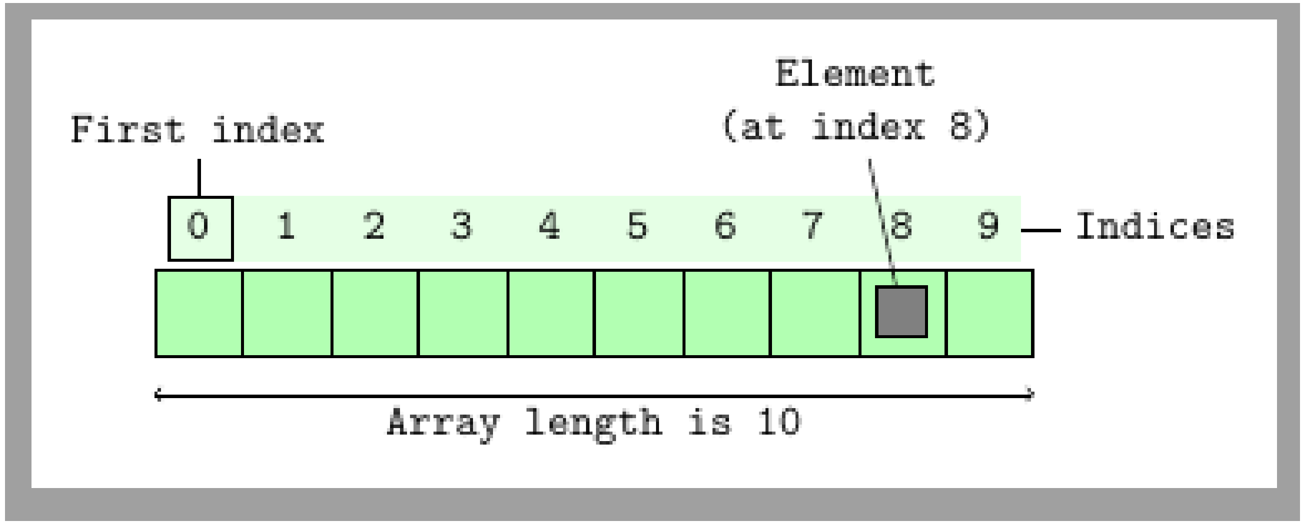
Standard Template Library

- Collection of classes and functions for general-purpose use
- Provides container types (list, vector, map, …), pair, tuple, string, thread and many other functionalities
- Available in the std namespace

# std::vector<T> and std::array<T, N>

- T is a template parameter
- std::vector<int> is a vector of integers, std::vector<char> is a vector of characters
- T can be a class or other C++ container.
  E.g., std::vector<std::vector<int>>,
  std::vector<std::map<int, std::string>>…

# Array – a fundamental datatype




- O(1) access given the index (or position) of the element
- Stores elements contiguously (in continuous memory locations)
- Elements are accessed starting with position 0 (0-based indexing)
- How to access the element at a given position in O(1) time?

# The size of an array is constant in C++

- std::array<int, 10> my_array = {1, 2, 3};
  defines an integer array of size 10
- The size must be fixed at compile-time
- Elements accessed using the [] operator. For e.g., **my_array[2]** is **3**
- Note: No bounds checking!
- Question: What happens if you do **my_array[20]** with only **3** elements?

# std::vector<T> - A dynamic-sized array

- Main problem: How to support inserting elements efficiently?
- Concept of size vs. capacity

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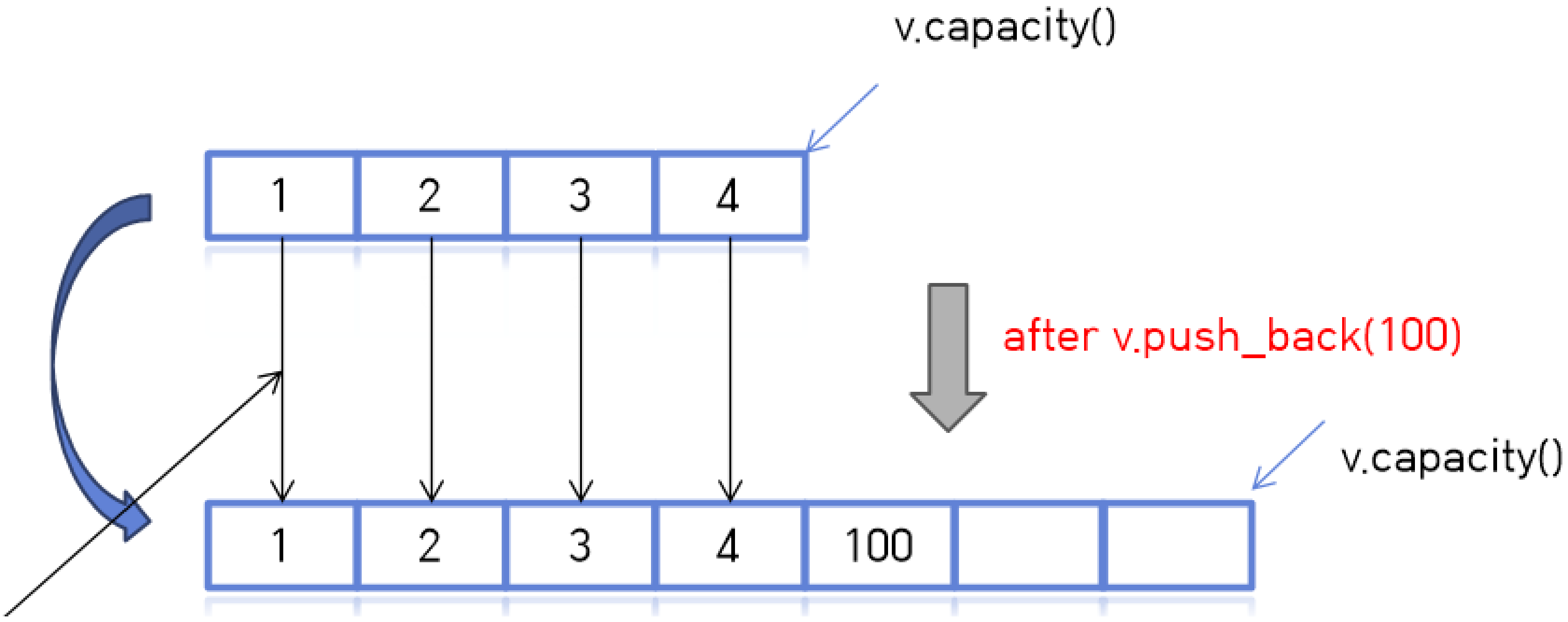
- Concept of size vs. capacity
- Reallocates elements when capacity is exceeded



# Complexity of std::vector<T>::**push_back**

- Most push_backs will be O(1) (when size < capacity)
- Some will have linear complexity (when the vector is reallocated)
- Amortized O(1) complexity with exponential growth in capacity
- What about the complexity of inserting at a random position in the vector?

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- Amortized O(1) complexity with exponential growth in capacity
- What about the complexity of inserting at a random position in the vector?

```
std::vector<T>::insert (iterator pos, const T& value)
```

Must shift elements to the right! Linear complexity

# Exercise

- Pick a large N (> 1 million)
- Program A: Creates a vector of N elements and assigns **vec[i] = i** for each **i** in a for-loop
- Program B: Creates an empty vector and calls **vec.push_back(i)** N times in a for-loop
- Program C: Creates an empty vector and calls **vec.insert(vec.begin(), N – i -1)** N times in a for-loop
- Measure the time taken by A, B, and C