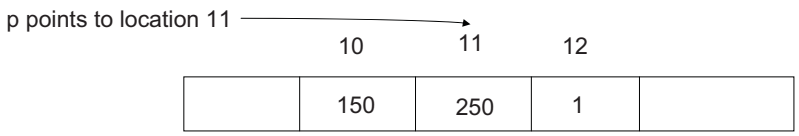
C++

pointers

Pointers

- A pointer is a variable storing the location or address of a memory cell



Pointer operators

- *P is the variable pointed to by P
- &X is the address of X
- **&** is the **address of** operator
- ***** is the **dereferencing** operator
- Suppose P1 = &X and P2 = &Y, then:
  - P1 = P2 means that P1 now points to Y
  - *P1 = *P2 means that X has the same content as Y

Pointer operators - example

- int X; // X is an integer
  int* P; // P is a pointer to an integer
  P = &X; // P stores the address of X
  *P = 5; // sets the value of the memory location pointed to by P to 5
- At the end of the example: X == 5 and P points to X

Classical error with pointer

- int* P, Q; // P is a pointer but not Q
- Instead of: int *P, *Q; // P and Q are pointers
- Use **typedef** to avoid such error:
  typedef int* IntPtr; // now IntPtr is a new name for the type int*
  IntPtr P, Q; // P and Q are both pointers

Static and dynamic memory allocation

- The following code allocates **memory statically** (i.e. at compile time):
  int X, Y;
  int* P;
- Memory allocated during execution is known as **dynamically allocated memory**:
  P = new int; // P points to a memory cell containing an integer

Dynamic memory allocation

- Dynamically allocated memory is allocated in a special area of memory called **heap**
- In C++ dynamically allocated memory is obtained with **new**
- If new can not allocate sufficient memory, it throws a bad_alloc exception or returns NULL; (default is to throw an exception)

Example

```
// …
int* p;
try {
  p = new int;
} catch (bad_alloc&) {
  std::cout << “error allocating memory”
            << std::endl;
}
// …
```

```
#include <new>
// …
int* p;
p = new (nothrow) int;
if (p == NULL) {
  std::cout << “error allocating memory”
            << std::endl;
}
// …
```

Delete

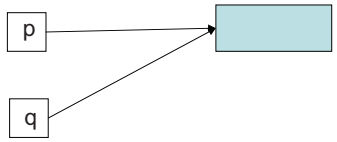
- The heap has a limited amount of space, so unused allocated memory needs to be returned to the heap
- If P is a pointer, the associated memory can be deleted by:
  delete(P);
- This statement deletes the memory area P points to.
  - **It does not modify P**.
  - After executing delete(P), the value of P is **undefined**.

Malloc and free

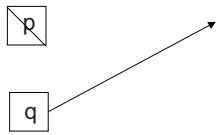
- new and delete are specific for C++
- malloc and free, the functions used to allocate and free memory in the heap in C are also available in C++
- It is **not recommended** to use malloc and free.

Common problems with pointers

- **Dangling pointer**:
  int* p; int* q;
  p = new int;
  q = p;

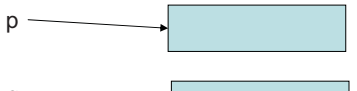


  delete p;
  p = null;
- This leaves q in an undefined state

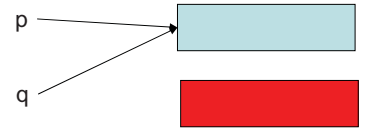


Common problems with pointers

- Memory leak: it happens when we lose the address of space allocated in the heap
- Example:
  int* p; int* q;
  p = new int;
  q = new int;



  q = p;

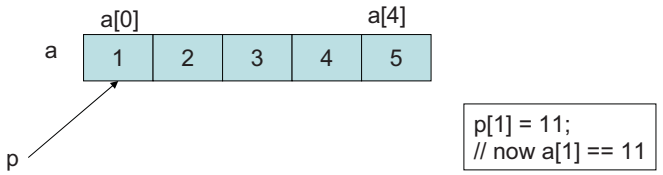


Common problems with pointers

- The two previously mentioned problems with pointers are sources of most of the corrupted memory problems when programming in C++ (and C as well)
- There exist some tools that help developers tracking such problems: purify, valgrind
- Try to limit the usage of pointers in the code

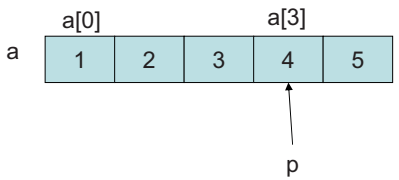
Arrays and pointers

- To some extent we can think of an array name as a pointer to the beginning of the array in memory:
  int a[5] = {1, 2, 3, 4, 5};
  int* p;
  p = a; // p points to a[0]



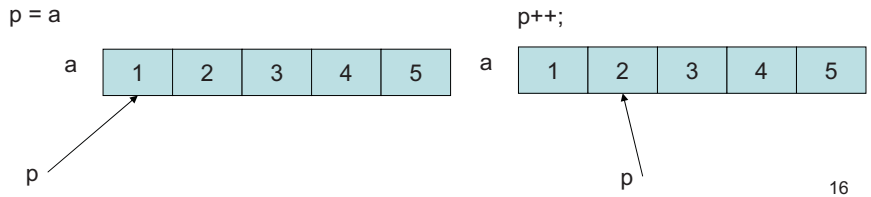
Arrays and pointers

- It is of course possible to start from a different location:
  p = &(a[3]);
- Now: p[0] would refer to a[3], p[1] to a[4], etc



Arithmetic on pointers

- Arithmetic on pointers is different (than for example) arithmetic on integers
- Type* p;
  p = p + i; // now p stores the address of p + i * sizeof(Type)
- p++; // corresponds to the address p + sizeof(Type)
- Examples:



Dynamic allocation of Arrays

- **p = new T[n]** will allocate an array of n objects of type T. It returns a pointer to the beginning of the array.
- delete[] p will destroy the array to which p points and return the memory to the heap.
  p must point to the beginning of the allocated array otherwise the result of delete[] p is undefined.
- Always use delete[] to free memory allocated for an array. **DO NOT USE DELETE** in that case.