CS11600: Introduction to Computer Programming (C++)

Lecture 5

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Outline

- Computer memory
- Lvalues and rvalues
- Arrays and strings
- Pointers
- Dynamic memory allocation

Memory

- Hierarchical memory organization:
  - Cache
  - RAM (main memory)
  - Hard disk (secondary storage)
  - Tape (tertiary storage)
- Our focus on RAM:
  - Think of it as a long list of bytes.

Heap and Stack

- The Stack:
  - When a function is called a new frame is pushed on the stack.
  - The frame contains parameters, local variables, and other info.
  - When a function call returns its frame is popped off the stack.
- The Heap:
  - For dynamically allocated memory.
- Heap and stack are on opposite end of memory and grow towards each other.

Lvalues and Rvalues

- Lvalue is *writable* memory location, i.e. can be assigned a value.
- Rvalue is data at memory location.
- Constants (constant variables and literal constants) have only rvalues.
- Variables have rvalues and lvalues.
  - Lvalue is used on the left side of assignments.
  - Rvalue is used on the right side of assignments.

Arrays

- Basic form:

```
Type name[size] = {val1,val2,…};
```

- Values are optional; the number of values must be less than `size` but not more.
- Size must be a constant integer expression.
- Examples:

```
int scores[20];
float gpas[] = {3.4, 3.6, 2.1, 4.0}
double prices[5] = {199.99, 201.11, 11.0}
```

Multidimensional Arrays

```
Type name[size1][size2]… = {{val1,val2,…},…};
```

- Example:

```
int grades[3][4] = {
  {10, 10, 10},
  {1, 1}
};
char hi[2][2][2] = {{{'h','e'}, {'l','l'}},
                    {{'o'}}
                   };
```


Accessing Arrays

- Access subscripts mimic array definition:

```
name[expr1][expr2]…
```

- The index expressions may involve variables and must evaluate to integers.
- Array subscripts start from 0!
- Examples:

`gpas[0]` is 3.4; `gpas[4]` is *undefined*
`grades[1][0]` is 1; `grades[2][2]` is *undefined*
`hi[0][1][0]` is ?

Strings

- Strings are represented as *NULL-terminated* one-dimensional arrays of `char`'s.
- Examples:

`char hello[] = "hello";` is equivalent to
`char hello[] = {'h','e','l','l','o','\0'};`

Pointers

- A pointer is a *memory address:*

```
Type *pname [= value];
```

- Accessing data pointed to by a pointer is called *dereferencing*:

```
*pname
```

- A pointer definition *does not* allocate memory for the data to which it points!
- A pointer can be initialized with a reference to already defined variable of the appropriate type.
- Examples

Pointers and Arrays

- Pointers and array are related by the following rule:

`name[i]` is equivalent to `*(name + i)`

- Example:

```
char hi = "hello";
```

`*hi` is 'h'; `*(hi+4)` is 'o';

Dynamic Memory Allocation

- Why do need it?
- Two operators:
  - **`new`** allocates memory.
  - **`delete`** de-allocates memory previously allocated with **`new`**.
- Memory is allocated on the heap.
- No garbage collection – delete what you allocated!

New

- Basic form:
  `new Type`
  - With initialization

  `new Type(value)`
- Returns a pointer to an object of `Type`.
- Example:

```
int *n = new int(5);
char *p;
p = new char;
```


New and Arrays

- Primary use of new is for allocating arrays of variable length and user-defined types.
- Syntax mimics array declaration:
  `new Type[size1][size2]…`
- `size1` can be a variable expression.
- Returns a pointer to the first element.
  - But memory is allocated for all elements!
- Examples.

Delete

- De-allocates memory allocated with `new`
  `delete ptr;`
  `delete [] ptr;` (for arrays)
- Example:

```
int *zips = new int[k];
zips[0] = 60611;
/* do something with zips */
delete [] zips;
```