CMSC 216
Introduction to Computer Systems
Lecture 5
Intro. to C, completed, Arrays and Strings

Jan Plane & Alan Sussman
{jplane, als}@cs.umd.edu

Administrivia

- Project 1 questions?
  - due next Wednesday, 9/22
  - public tests available in public Grace directory, and submit server open

Chapter 5, Reek

OPERATORS

Comma operator

- Yes, the comma is an operator
- Evaluates left operand, then right operand
- Value of expression with comma is value of last operand
- Has lowest precedence of all operators
- So what gets stored in `i` after each statement? What does each statement evaluate to?

```
i = 1, 2, 3, 4;
i = (1, 2, 3, 4);
```

Precedence and associativity

- Different operators can fall on different precedence levels
- Ties among levels are settled by associativity rule for that level
- Some operators impose restrictions on evaluation order, but aside from that, compiler can optimize
- Full table in *Pointers on C*, pgs. 114-115

Lvalues and Rvalues

- An rvalue is anything that can appear on the right side of an assignment statement
  - virtually any expression
- An lvalue is anything that can appear on the left side of an assignment statement
  - values that represent a place to store a value
- The right and left sides of an assignment statement are treated differently
  - right hand side is a value, left hand side is a location to store a value (an address)

Implicit type conversion

- Arithmetic operators require their operands to be of the same type to perform the operation
- **`int`** is actually "smallest" type used
- There is a hierarchy of types (Reek, § 5.4.2)
  - floating-point numbers over integers
  - wide over small
  - unsigned over signed
- Operation result is of the new type
- What to do? **`2000000000 * 3`**

Mixed-type assignments

- RHS is converted to LHS type before storage
- Can mean either promotion or truncation

```
char a, b = 'b', c = 'c';
float f = 2.25, g = 4.9999;
unsigned int i, j;
unsigned char ch;
a = b + c; /* a = 98 + 99 = 197? */
i = f; j = g; /* i: 2; j: 4 */
i = ch = 0xabcd; /* i: 0xcd; ch: 0xcd */
```

Parts of Chapters 8 and 9, Reek

ARRAYS AND STRINGS

Arrays in C

- Much like Java (or many other languages)
  - All elements are the same type
  - Elements indexed by the subscript operator **`[]`**
- Sizes must be known at compile time (constant expressions only) and are static
- Can't assign to arrays (can initialize, though)
- Can use **`==`** and **`!=`**, but meaning isn't what you might think (wait until pointers)
- Syntax for creating arrays is slightly different
  - C: **`int a[5];`** creates array of 5 **`int`**s
  - Java: **`int[] a = new int[5];`** creates array of 5 **`int`**s

Array initialization

- Supply a list of values in braces, separated by commas:

```
int a[5] = {1, 1, 2, 3, 5};
```

- Occurs when array is first created
  - when this occurs depends on the array's storage class
  - also means you can't initialize after declaration
  - and you can't initialize with variable expressions
- Zeroes pad the array when initializer is short
- Use of an initializer allows size to be omitted
  - can't omit size otherwise when declaring local variables (parameters are an exception, though)
- Initializers with excess elements cause errors

Array initialization examples

```
int a[3]    = {1, 4, 7};
int b[5]    = {2, 8};
int c[]     = {3, 9, 5, 2 + 6};
int d[1000] = {0};
```

These are illegal (assuming **`i`** is an **`int`**):

```
int w[i];
int x[];
int y[4] = {2 * i, 3 + 2};
int z[5];  /* this alone is OK */
z = {1, 1, 2, 3, 5};
```

Parameters in C

- You can use parameters as variables, but why is it safe?
- In C, variables are passed by value – a copy is passed

```
int abs_value(int x) {
  if (x < 0)
    x = -x;
  return x;
}

int main() {
  int n = -17, a;
  a = abs_value(n);
  printf("%d %d\n", a, n);
  return 0;
}
```


Array parameters

- Array parameters act as if they were passed by reference (as we'll discuss later)
- If a function modifies elements of an array parameter, the array passed in **is** modified

```
void function(int a[]);
...
int array[10];
function(array);
```

- Sizes for array parameters are ignored – only types matter
  - so "**`void function(int a[12397]);`**" is equivalent to the above prototype

Array parameters, cont.

- You generally have to pass array size along with the array
- Functions only know about the elements of an array – the size of an array parameter isn't known

```
void multiply_array(int factor, int arr[], int ct) {
  int i;
  for (i = 0; i < ct; i++)
    arr[i] *= factor;
}

int main() {
  int a[] = {1, 2, 3};
  multiply_array(5, a, 3);
  printf("[%d, %d, %d]\n", a[0], a[1], a[2]);
  return 0;
}
```


Use of symbolic constants

- #define preprocessor directive

```
#define name value
```

- All occurrences of **`name`** in the source file are replaced by **`value`**
- Used to define constants for things such as array sizes and other values to improve program maintainability

```
#define ARR_SIZE 3
int main() {
  int i, a[ARR_SIZE] = {1, 2, 3};
  multiply_array(5, a, ARR_SIZE);
  printf("[%d", a[0]);
  for (i = 1; i < ARR_SIZE; i++)
    printf(", %d", a[i]);
  printf("]\n");
  return 0;
}
```

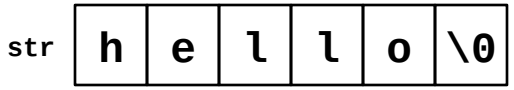
Strings in C

- There is no String type in C
- In C, a string is defined as a sequence of characters that is followed by a byte with the value zero
  - often called: "zero byte", "null byte", "NUL"
  - represented as the character literal **`'\0'`**
  - "null byte" is NOT the same thing as "null pointer"
- Since arrays are contiguous in memory, and **`char`**s are all one byte in size, we can use arrays of **`char`**s to hold strings
- **`printf()`** format specifier for strings is **`%s`**

String initialization

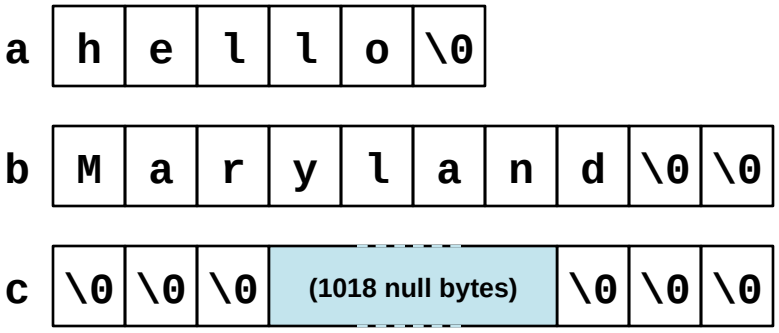
- Because character arrays are so closely related to strings, they can be initialized with string literals as well as standard array initializers
- But don't forget that the null byte needs to be stored as well
- Example:

```
char str[6] = "hello";
```



More examples of string initialization

```
char a[] = "hello";
char b[10] = "Maryland";
char c[1024] = "";
```



Basic string library functions

- C has many different functions for working with strings; to use these, you must **`#include <string.h>`**
- We're only covering a small subset here; if you ever want to see all of them, more information can be found in the string.h man page
  - Note: the prototypes there are slightly different than what we'll be covering here, because we haven't covered pointers yet, but functionality is the same

String library functions, cont.

- String length:

  `size_t strlen(char str[]);`

  – returns the length of the string pointed to by the string passed in as a parameter

  – string length is the number of characters in the string, **not counting** the null byte

  – Example:

```
char str[] = "ice cream";
printf("\"%s\": %d chars\n", str, strlen(str));
```

Output:

```
"ice cream": 9 chars
```


A possible `strlen()` implementation

```
size_t strlen(char str[]) {
  size_t i;
  for (i = 0; str[i]; i++)
    ;
  return i;
}
```

- The integer type **`size_t`** is discussed in the project #1 handout
- What would happen if you passed an uninitialized character array into this function?