Arrays and Strings

ENEE 140

Prof. Tudor Dumitraș
Assistant Professor, ECE
University of Maryland, College Park

http://ter.ps/enee140

Today's Lecture

- Where we've been
  - Scalar data types (`int, long, float, double, char`)
  - Integer and floating point arithmetic
  - Basic control flow (`while` and `if`)
  - Functions
  - Random number generation
- Where we're going today
  - Vector data types: arrays, strings, enums
  - Composite data types: struct
  - *Defensive programming and* `assert()`
  - *Coding style*
  - *Project 1 Q&A*
- Where we're going next
  - Complex programs

Scalar vs. Vector Data Types

- We've seen

  `char, int, long, float, double`

  – These are **scalar** data types: a variable holds a single value

- **Vector** data types: hold a series of scalar variables of the same type

  – Must specify the **size N** of the array

```
int     a[10];      int array with N=10 elements
long    b[10];      long array with N=10 elements
float   c[10];      float array with N=10 elements
double  d[10];      double array with N=10 elements
char    e[10];      string with up to 9 characters (!)
```

  – Accessing array elements: **index** between **0** and **N-1**

```
a[0] = 0;           first element
a[9] = 0;           last element
```

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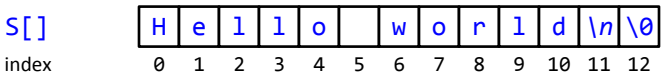
Strings

- Strings are character arrays, with some special rules

  – You can initialize strings using string literals (use double quotes)

```
char s[] = "Hello world\n";      size of s[] is implicit
```



  – The character `'\0'` indicates the end of the string

```
char s[10];          must account for '\0' => can only store 9 chars
```

  – You can read and write strings using scanf and printf

    • Use the `%s` format modifier

```
char s[] = "Hello world\n";
printf("The string is: %s", s);
```

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Initialization vs. Assignment

- Arrays and strings can be initialized, but **can not assigned**

```
char s1[] = "ENEE 140";
```
s1 is declared and initialized

```
char s2[10];
```
s2 is declared but not initialized

```
s2 = "ENEE 140";
```
error! (cannot assign strings)

- Instead, arrays **can be copied**

```
#include <string.h>
```
needed for strncpy

```
strncpy(s2, "ENEE 140", 10);
```
must specify the size of s2[]

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Reading Strings

- `scanf`: input string stops at whitespace or at the max field width

```
char s[10];
scanf("%9s", s);
```
specify field width 9 to allow for '\0' terminator
note: `s` instead of `&s`

- `fgets`: read whole line up to specified size – 1

```
fgets(s, 10, stdin);
```
stdin is the standard input stream (more on this later)

  - The '\n' character will be included in s[]
  - `fgets()` returns NULL on EOF or error

- Read input line-by-line, until EOF is encountered

```
while (fgets(s, 10, stdin) != NULL) { … }
```

- Use a string as input source

```
sscanf(s, "%d", &i);
```
read integer i from string s[]

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Writing Strings

- printf: use %s format specifier

```
char str[] = “world”;
printf(“Hello %s\n", str);
```

- fputs: print only the string

```
fputs(str, stdout);
```
stdout is the standard output stream

- Use a string as output:

```
sprintf(str, “%3d”, i);
```
write integer i into str[]

  - **Important: Must be careful not to exceed the size of str[]!**

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Common Programming Mistakes

- Accessing or modifying elements outside the array bounds
  - Incorrect

```
int  a[10];
a[-1] = 0;
a[10] = 0;
```
index can be 0 … 9
index out of bounds
index out of bounds

```
char s[10];
scanf("%s", s);
```
can store up to 9 characters (index 0…8)
read string of infinite length

  - Correct

```
a[i] = 0;
scanf("%9s", s);
```
where 0 <= i < 10
specify field width;

- **This is one of the most common security vulnerabilities in software!!**

Defensive Programming

- Good programming practice:
  - Think about relationships among the variables in your program
  - Determine conditions (e.g. a == b+1) that must be true at various steps, if your program is correct
  - Force the program to stop when these conditions are violated, then test the program with a variety of inputs to make sure that this doesn't happen
  - This approach is called "defensive programming"

- Assert: a tool for defensive programming

```
#include <assert.h>
assert(condition);
```

exits the program if *condition* is false

  - Use assert() liberally
  - Assertions allow you to diagnose mistakes in your program
  - They also make your assumptions clear to other programmers who will read your code

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Defensive Programming – Example

- Use defensive programming to prevent common mistakes related to arrays and strings

```
#include <assert.h>

int a[10];
assert(i>=0 && i<10);
a[i]=0;
```

exits before accessing index out of bounds

- Turn off all assertions at compile time

```
gcc –NDEBUG myprogram.c
```

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The `sizeof` Operator for Vector Data Types

- Yields the number of bytes required to store the array or string
  - Array dimension x size of base type

```
char a[10];
int b[10];
sizeof(a)                    10
sizeof(b)                    40
```

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String Functions

- Convenient operations on strings

```
#include <string.h>

strlen(s);                   length of s
strncpy(dst, src, n);        copy up to n characters from src to dst
strncat(dst, src, n);        concatenate dst and src
strncmp(s1, s2, n);          compare s1 and s2
```

- Common programming mistake
  - Using `strcpy`, `strcat`, `strcmp`, etc.
  - These functions do not allow you to specify the size of the destination string
  - **Always use the strn* functions instead of the str* functions!**

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enum

- Enumeration constant: list of constant enumeration values

```
enum answer {NO, YES};
```
variables of type answer can take 2 values: NO or YES

```
enum months {JAN=1, FEB, MAR, APR,
             MAY, JUN, JUL, AUG,
             SEP, OCT, NOV, DEC};
```
FEB is 2, MAR is 3, etc.

```
int current_month = FEB;
```

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Composite Data Types

- Structures: encapsulate multiple variables
  - May have different types

```
struct cartesian_coord {
      int     x;
      int     y;
};
struct polar_coord {
      int     radius;
      float   angle;
};

struct cartesian_coord a;
struct polar_coord b;
```
variables of composite type

```
b.radius = 1;
b.angle = M_PI_2;
a.x = b.radius * cos(angle);
a.y = b.radius * sin(angle);
```
accessing members
π / 2
0
1

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Coding Style

- Programs are meant to be read by humans
  - Code reviews are a common practice in the industry
- Good coding style makes programs more readable
  - Examples of what **not to do**: http://www.ioccc.org/
- There is no "right" coding style
  - Choose a style and be consistent

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Coding Style: Examples

- Explain what the program does in a comment at the top
- Explain what each function does in comments before the function definition
- Use concise, meaningful names for variables and constants
  - If you have many variables, also add short comments describing the purpose of some of the variables
- Follow normal English rules when possible for better readability of your code
  - Write complete sentences in your comments
  - Leave a space after each comma and semicolon (e.g. in printf(), scanf(), for)
  - Leave a space on each side of a binary operator (e.g. =, ==, +)
- Indent code consistently
  - CLion and Eclipse try to do this automatically
- If you have long, nested {…} blocks, add a comment after the enclosing bracket
  - Indicate which block you are closing (the while block, the if block, etc.)

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Coding Style: Examples

- Place braces {} in a consistent manner:

```
for ( i = 0; i < 100; i++) {
    statements;
}
```

OR

```
for ( i = 0; i < 100; i++)
{
    statements;
 }
```

- When you prompt the user for input, first print out a message describing what is expected
- Check for errors and corner-cases throughout the program (more about this later)
- Use simple statements as much as possible
  - Avoid statements like `sum = a++ + --b*2`

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Review of Lecture

- What did we learn?
  - Arrays
  - Strings
  - String I/O (`printf` and `scanf` with `%s`)
  - `enum`
  - `struct`
  - *Coding style*
  - *Defensive programming*
- Next lecture
  - Complex programs
- Assignments for this week
  - Read **K&R Chapters 4.3, 4.4, 4.5, 4.6, 4.8, 4.9, 4.11**
  - Weekly challenge: **`trim_strings.c`**
  - Homework: **`lab07.pdf`** (on http://ter.ps/enee140), due on March 11 at 11:59 pm
  - **Quiz 6**, due on Monday (after Spring Break) at 11:59 pm
  - Reminder: Project 1 due on Monday, March 21 (after the Spring Break)

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