File I/O and Strings

CSC 230 : C and Software Tools

NC State Department of Computer Science

Topics for Today

- File I/O
- Parsing input : the rest of the story
- Working with Strings
  - Direct string manipulation
  - String length
  - Copying strings
  - Comparing strings
  - Parsing numbers from strings

File I/O

- Our good friend, stdio.h, also includes support for file I/O

```
#include <stdio.h>
```

- We just need to ask it to open a new file.

```
FILE *stream = fopen( "file-name.txt", "r" );
```

Path to the file you want.

Mode String (reading, writing, etc).

- This creates a new *stream* and returns a *file pointer* for working with it.
  - Or it returns NULL on failure.

File Mode

- When you open a file, the second parameter says how you want to access it.

```
FILE *fp = fopen( “file-name.txt”, “r” );
```

Mode String	Access Type
r	Open for reading
w	Open for writing (created and truncated)

More mode strings later.

Reading and Writing

- We have versions of printf( ) for writing to any stream.

```
int fprintf(FILE *stream, const char *format, ...);
```

Stream you want to write to.

The rest is just like printf.

- We have a similar version of scanf( )

```
int fscanf(FILE *stream, const char *format, ...);
```

Same here, just one new parameter at the start.

Finishing I/O

- Streams perform *buffering*
  - They keep I/O characters in memory to avoid costly system calls to the OS
- You need to tell the system when you're done with a file.

```
int fclose( FILE *stream );
```

  - This will flush any buffered data.
  - Forgetting to close a file is called a *file leak*

File Input Example

- An example, reading a list of numbers:

```
FILE *fp = fopen( "numbers.txt", "r" );
if ( !fp ) {
  …
}

int total = 0;

int val;
while ( fscanf( fp, "%d", &val ) == 1 )
  total += val;

fclose( fp );

printf( "Total: %d\n", total );
```

I want to open for reading.

I want to read from a file, instead of standard input.

I'm all done with this file.

File Output Example

- An example, writing a file of numbers.

```
FILE *fp = fopen( "output.txt", "w" );
if ( !fp ) {
  ...;
}

for ( int i = 0; i < 25; i++ )
  fprintf( fp, "%f\n", i * i * 3.141592653589793 );

fclose( fp );
```

I want to open for writing.

I want to write to a file instead of standard output.

All done, flush any buffered output.

Leaking Files

- There's typically a limit on the number of open files you can have
  - That's why leaking files is bad
- I have a test for this: `openTest.c`
  - It opens files over and over until it can't create any more
  - Let's give it a try

Three Streams for Free

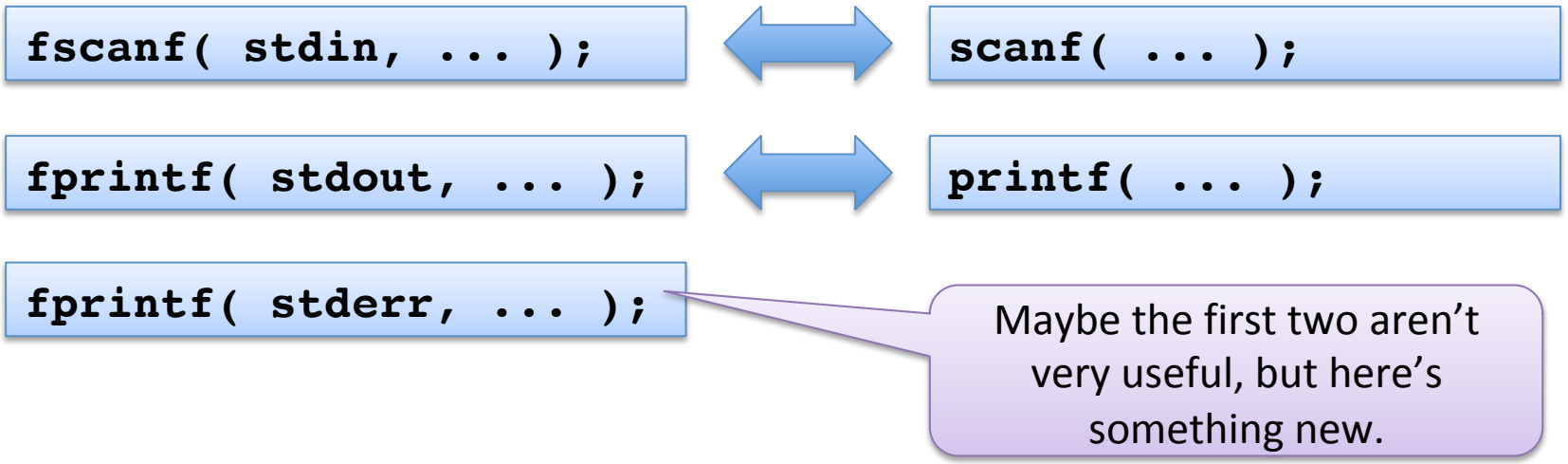
- When you call fopen(), you get back a stream

```
FILE *stream = fopen( "file-name.txt", "r" );
```

- Your program gets three streams at startup, you've been working with them all semester
  - **`stdin`** : standard input (from the terminal by default)
  - **`stdout`** : standard output (to the terminal by default)
  - **`stderr`** : standard error (also to the terminal by default)
- These are all global variables declared in **`stdio.h`**

Using the Standard Streams

- With names for our standard streams
  - This gives us alternative ways to do terminal I/O.



- Printing to stderr is a standard way of reporting, well, errors.
  - Why? We can redirect it differently from stdout.

Using stderr

- We can use stderr for any error reports

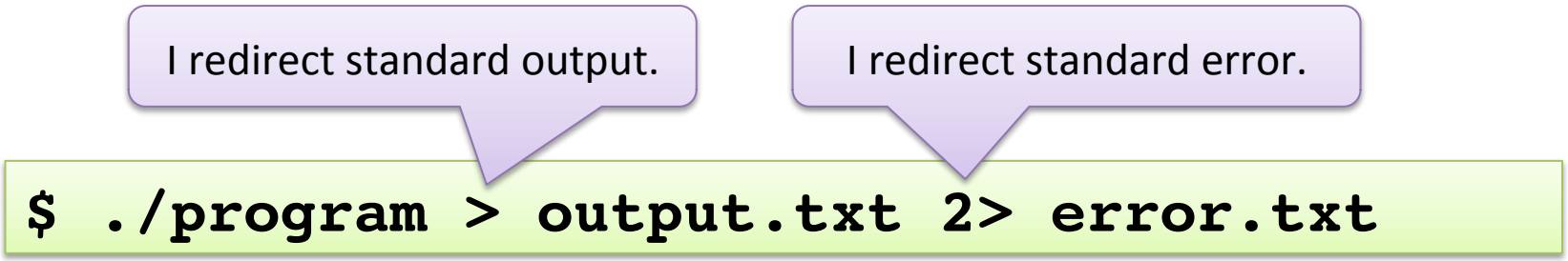
```
FILE *fp = fopen( "numbers.txt", "r" );
if ( !fp ) {
  fprintf( stderr, "Can't open input file\n" );
  exit( 1 );
}

int len = 0;
if ( fscanf( input, “%d”, &len ) != 1 ) {
  fprintf( stderr, “Can’t read input length\n” );
  exit( 1 );
}

 . . .
```

Redirecting Streams

- From the shell, we can choose to redirect streams differently.



- Or the same

- This syntax is dependent on your shell, but this is what bash uses.

Reading Strings

- You already know:
  - We can use scanf() to read into strings (character arrays).

```
char str[ 100 ];

scanf( "%s", str );
```

This will read a sequence of non-whitespace characters.

Notice, no &.

  - Why no & on the str parameter?
    - scanf() just needs to change the contents of the character array, not where it points.

Reading Strings Without Buffer Overflow

- You already know:
  - This can buffer overflow, if the user enters a long string of non-whitespace characters.

```
char str[ 100 ];

scanf( "%s", str );
```

- Something new, input field width
  - Specify a field width to limit the number of characters read.

```
char str[ 100 ];

scanf( "%99s", str );
```

Read up to 99 characters. Good, we still have room for the null terminator.

All of this works for scanf() and fscanf().

String Parsing Options

- The %s format specifier reads space-delimited words.
- scanf() supports a subset of regular expression syntax.
  - Using square brackets we can define a *character class*, a set of exactly what characters to match.

```
scanf( "%[abc]", str );
```

Match a sequence of one or more a, b and c characters.

Doesn't skip spaces.

Character Class Examples

```
scanf( "%[abc]", str );
```

```
bcabbxaccb
```

This will return zero matches.

```
zero
```

```
scanf( "%[ 0123456789]", str );
```

```
123 456 xyz 789
```

You'll get this last space.

String Parsing Options

- Inside the brackets, we can specify ranges of characters.

```
scanf( "%[A-Z]", str );
```

Match any capital letter.

- We can combine ranges and individual characters.

```
scanf( "%[a-zA-Z.]", str );
```

Match lower-case or capital letters or dot.

```
abc.XYZ.123
```

String Parsing Options

- You can negate a character class by starting it with a ^

```
scanf( "%[^A-Z]", str );
```

Match a sequence of anything but capital letters.

```
scanf( "%[^A-PR-Z]", str );
```

Same as above, but will also match Q.

```
abcQ123Wxyz
```

String Parsing Options

- Using *, we can tell scanf to match a format specifier, but not save it:

```
scanf( "%*s%s", str );
```

Skip spaces, then save the next word in str.

Match a word (but don't store it)

- Really, this works with any format specifier.

```
scanf( "%*d%d", &val );
```

```
scanf( "%*[a-z]%20[A-Z]", str );
```

Skipping Whitespace

- Any whitespace in a format string … matches any amount of whitespace.

```
scanf( "%c", &ch );
```

I'll read the next character, even if it's whitespace

```
scanf( " %c", &ch );
```

I'll skip all whitespace, then read a character

```
scanf( "%[0-9]", str );
```

I'll read just digits.

```
scanf( " %[0-9]", str );
```

I'll skip whitespace, then read digits.

Skipping Whitespace

- Be careful, stray whitespace can give seemingly strange behavior.

```
scanf( "%d%d\n", &a, &b );
```

OK. You want me to skip whitespace after reading these ints.

I better not return until I'm sure I have it all.

Matching Literal Characters

- Literal characters will match copies of themselves.

```
scanf( "%d+%d", &a, &b );
```

```
25+72
25 + 72
```

I'll match the +, but I won't skip spaces before it.

```
scanf( "%d +%d", &a, &b );
```

But I will.

```
scanf( "%d %%", &a );
```

Need to match a literal %? We got that.

Marking Your Spot

- The %n conversion specification tells scanf() to report how many characters it's read so far.

```
scanf( "%d +%n%d", &a, &n, &b );
```

```
25+72
  317 + 214
```

Put the report here.

- The %n doesn't count in the return value.
- This is kind of useful with scanf() and fscanf()
- It will be more useful with sscanf() … later.

Working with Strings

- Ok. You've read in a string.
- Now, what can you do with it?
- Well, a string is an array of characters, so you could access its characters directly.

```
int spaces = 0;
for ( int i = 0; str[ i ] != '\0'; i++ ) {
  if ( str[ i ] == ' ' )
    spaces++;
}
```

Where Does it End?

- The null terminator lets us pass strings to functions
  - Without a separate parameter for their length.

```
void redact( int len, char str[] );
```

You may need this for other arrays … but usually not with strings.

The null terminator lets you find where the string ends.

```
void redact( char str[] );
```

Where Does it End?

- The null terminator evaluates to false.

```
void redact( char str[] )
{
   for ( int i = 0; str[ i ]; i++ )
      if ( str[ i ] >= '0' &&
           str[ i ] <= 'z' )
        str[ i ] = '#';
}
```

Copying Strings

- You can't copy between strings with the assignment operator.

```
char buffer[100] = "abc123";
buffer = "Welcome to C";
```

This works, at initialization time, but not for assignments in general.

- This doesn't work for arrays … and strings are stored in arrays … so ☹
- … but, there are library functions to help us out ☺

Help from the Standard Library

- The C standard library offers functions to work with strings.
- String functions are declared in the string.h header:

```
#include <string.h>
```

- All these functions expect null terminated strings.
- Today, we'll look at functions to:
  - Measure string length
  - Copy between strings
  - Compare strings
  - Convert strings to ints, doubles, longs, etc.

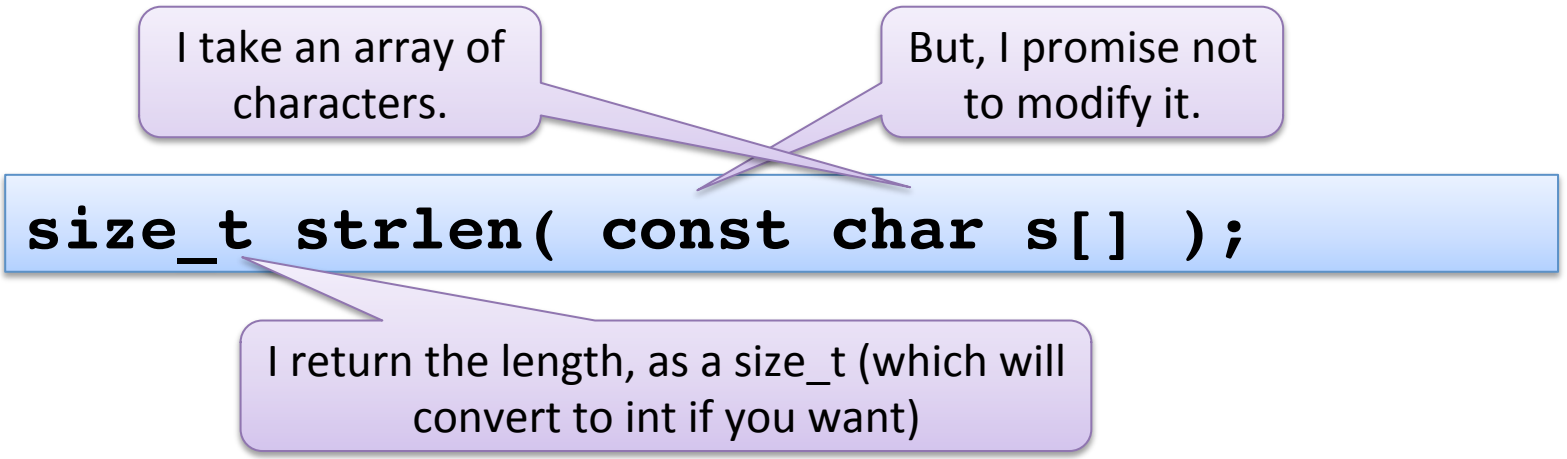
String Length

- We have strlen() to obtain string length:

```
size_t strlen( const char s[] );
```

  - Counts characters up to (but not including) the null terminator.

- The prototype tells us a lot about the function



String Length

- It's easy to use:

```
int len = strlen( name );
```

- It's not too smart.
  - It just looks for the null terminator.
  - So, it has a cost that's linear in the string length.
- This is a bad way to iterate over a string:

```
for ( int i = 0; i < strlen( word ); i++ )
    ...;
```

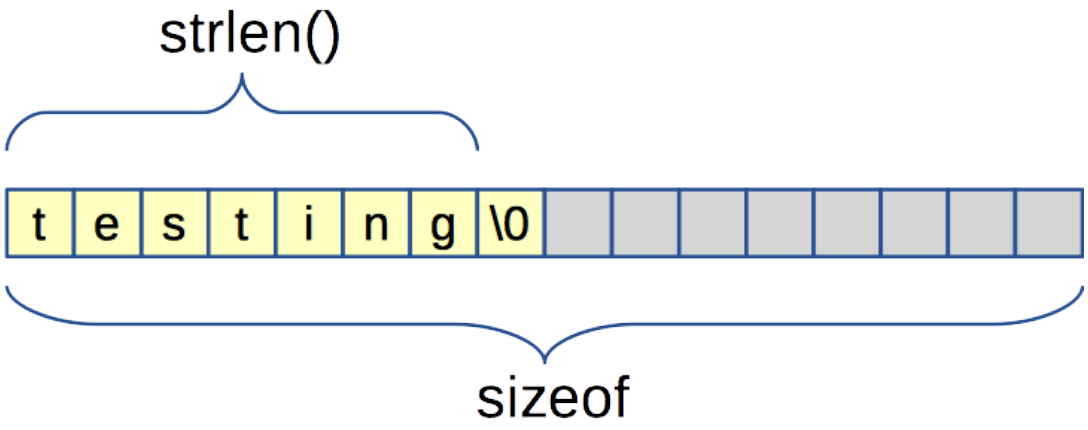
- This is much more efficient (and maybe easier)

```
for ( int i = 0; word[ i ]; i++ )
    ...;
```

strlen() vs sizeof

- Sometimes, people have some confusion between strlen() and sizeof.

```
char buffer[ 16 ] = “testing”;
```



strlen() vs sizeof

```
char buffer[ 16 ] = “testing”;

size_t s = sizeof buffer;

size_t n = strlen( buffer );

buffer[ 1 ] = ‘\0’;
n = strlen( buffer );
s = sizeof buffer;
```

I’m an operator, usually evaluated at compile time.

I don’t depend on what’s in the string. I’ll say 16.

I’m a function call, executed at runtime.

I’ll say 7. I depend on what’s in the string.

Now, I’ll say 1.

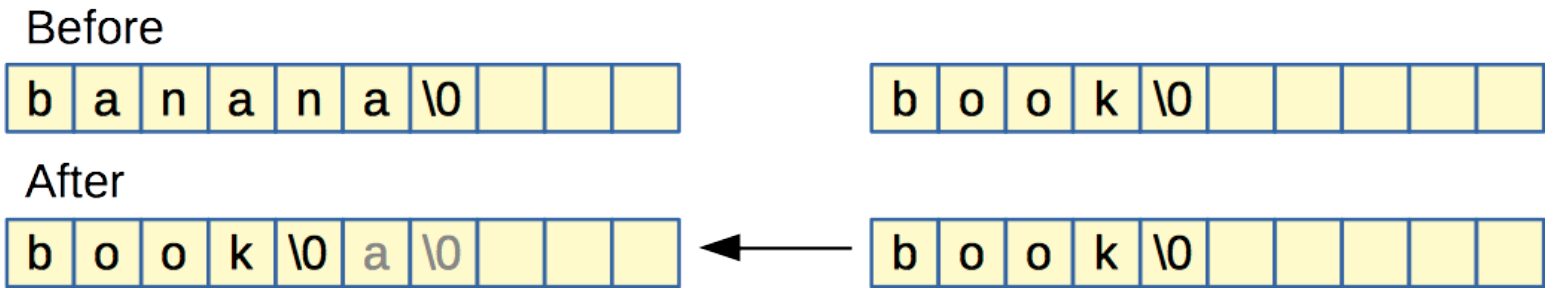
But still 16 here.

Copying Strings

- We have strcpy() to copy strings:

```
char *strcpy(char dest[], const char src[]);
```

  - Copies from src to dest, up to and including the null terminator.
  - Return a pointer to the start of the destination string (in case you want to do something else with it)



Copying Strings

- We can copy from literal strings

```
strcpy( myString, “Greetings Program” );
```

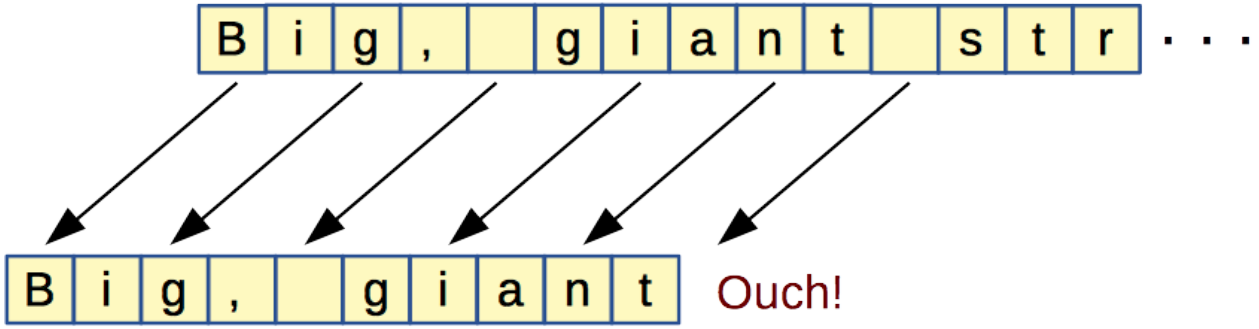
- We can copy from one char array to another.

```
strcpy( myString, name );
```

Copying Strings

- But, there's a potential for buffer overflow:

```
strcpy( myString, "Big, giant string that you "
"weren't planning for and you don't have enough "
"room to store" );
```



Comparing Strings

- We have strcmp() to compare strings:

```
int strcmp(const char s1[], const char s2[]);
```

  - Lexicographically compares strings s1 and s2, returning:
    - Less than zero if s1 is before s2
    - Zero if they are equal
    - Greater than zero if s1 is after s2
  - Stops when it hits a null terminator or a character on which they differ.

Comparing Strings

- We can use it to compare strings for equality:

```
if ( strcmp( name1, name2 ) == 0 )
  ...;
```

- It's easy to make a mistake if you just use strcmp() as a truth value.

```
if ( strcmp( passwd, "joshua" ) )
  printf( "They're equal\n" );
```

Oops. I guess they're not equal.

Parsing Numeric Values

- We can parse strings as numeric values
- Say you want to parse an int out of a string?
  - atoi() will do that for you (declared in **stdlib.h**)

```
int atoi(const char str[]);
```

String goes in here.

int comes out here.

Parsing Numeric Values

- atoi() has some friends, for other types of conversions
  - There's atof() for parsing strings as doubles.

```
double atof(const char str[]);
```

  - There's atol() for parsing strings as long ints.

```
long atol(const char str[]);
```

  - There's atoll() for parsing strings as long long ints.

```
long long atoll(const char str[]);
```

- These functions are OK (but I almost never use them)

Problems with atoi() and Friends

- Given an invalid parameter value, these functions return zero.
- So, you can't tell the difference between:

```
int x = atoi( "0" );
```

and

```
int x = atoi( "garbage" );
```

- Later, we'll see a general-purpose way to do all these conversions.