

# **CS 241: Systems Programming**

## **Lecture 33. Variadic Functions**

Fall 2019

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# Student evals are online

Primary learning goals from course website

- ▶ the UNIX command line (in particular the BASH shell)
- ▶ a command line editor like Neovim, Emacs, or Nano
- ▶ Various command line utilities
- ▶ the Git version control system
- ▶ C compilers like Clang and GCC
- ▶ debuggers like GDB
- ▶ linting tools like shellcheck.

# More learning goals

## More learning goals

- ▶ how to write safe shell scripts (specifically BASH-flavored shell scripts);
- ▶ how and especially when to program in C;
- ▶ what undefined behavior is;
- ▶ what memory safety is;
- ▶ how to use Github;
- ▶ how to set up continuous integration with Travis-CI; and
- ▶ how to work with regular expressions.

# Projects

Completed project and 2 page report due on Friday!

Presentations are on Monday and Wednesday of next week

# Report

A two page (maximum!) write up

- ▶ standalone description of your project
- ▶ what you accomplished
- ▶ what you weren't able to get to
- ▶ what you found most challenging
- ▶ anything else you think I should know

# Demo and presentation

Last week of class (there will be a sign up for the day later in the semester)

Spend 7 minutes showing off and talking about your project

- ▶ 5 minutes of talking; 2 minutes of answering questions
- ▶ I know public speaking is *awful* (unless you enjoy it), but this is a super low-stakes way to get practice at it in a supportive environment
- ▶ Everybody must speak
- ▶ (Attendance at both days of presentations is mandatory, I will check with clickers)
- ▶ Tell us who you are, what you did, and how you did it (tell us what didn't work if you like)
- ▶ Show off some features
- ▶ 🙌🙌🙌 Get some applause 🙌🙌🙌

# Asking questions

Each presentation has 2 minutes of question time built in

**You** must ask questions

Strategies for asking good questions

- ▶ During each presentation, think of a question and write it down so you don't forget
- ▶ Think about how the project might be extended or design choices made; ask about those
- ▶ Ask about some particular functionality
- ▶ Don't be a jerk or a show off (not that anyone here would be); ask polite questions

# Variable Arguments

Need a way to handle variable length argument lists

- ▶ `printf`, `scanf`, etc.
- ▶ `execl`
- ▶ `open`, `fcntl` — additional parameter when given specific flags

Ideally, have argument checking for fixed parameters

- ▶ type checking catches many errors
- ▶ allows for compiler optimizations



# Variable arguments in C

Two mechanisms (used to be) available:

```
#include <varargs.h>
```

- ▶ Old style, not supported — do not use!

```
#include <stdarg.h>
```

- ▶ New style — do use!

# Types

Somewhere in `stdarg.h` there is

```
typedef /* stuff */ va_list;
```

Need one of these for argument pointer

```
va_list ap;
```

# Function prototypes

Use "... " in function prototype

```
void varfoo(char const *fmt, ... );
```

Variable arguments must be

- ▶ At the end
- ▶ Following at least one non-variable argument

# Using variable arguments

Three macros used

- `va_start(va_list ap, last)`
- `va_arg(va_list ap, type)`
- `va_end(va_list ap)`

There's a fourth one that's rarely used

- `va_copy(va_list dest, va_list src)`

# va\_start

Macro used to initialize argument pointer

```
va_start(ap, last);
```

- `ap` — argument pointer
  - initialized to the first argument
- `last` — argument before variable arguments

# va\_arg

Macro used to access arguments

Returns next parameter in list; advances to the next position

Needs to know type for forward movement and reading

```
double dbl = va_arg(ap, double);
```

# va\_end

Macro to clean environment up when done

```
va_end(ap);
```

Each `va_start()` and `va_copy()` must be paired with a `va_end()` in the same function

When implementing a function with a variable number of arguments, how does the programmer know how many arguments there are?

- A. Use the `va_number(va_list ap)` macro
- B. Format string specifies the number of arguments
- C. An explicit "sentinel" value is used at the end of the argument to mark the end
- D. The number of additional arguments is passed as a parameter
- E. *Some* mechanism must be used to indicate how many there; it varies by function



What happens if the program accesses more arguments than were passed to the function or an argument of the wrong type?

- A. This is prevented by the type system (i.e., a compiler error)
- B. The default value of 0 is returned
- C. A garbage value is returned
- D. The program segfaults
- E. It's undefined behavior

```

void strange_print(int next, ...) {
    va_list ap;

    va_start(ap, next);
    while (1) {
        switch (next) {
            case 'i': printf("%d", va_arg(ap, int)); break;
            case 'f': printf("%f", va_arg(ap, double)); break;
            case 's': printf("%s", va_arg(ap, char *)); break;
            default: va_end(ap); return;
        }
        next = va_arg(ap, int);
    }
}

```

```

strange_print('i', 37, 's', "text", 'f', .25, 0);

```

# Open (from musl libc)

Open takes a third parameter (the file system permissions) when creating a file

```
int open(const char *filename, int flags, ...) {
    mode_t mode = 0;
    if ((flags & O_CREAT) || (flags & O_TMPFILE) == O_TMPFILE) {
        va_list ap;
        va_start(ap, flags);
        mode = va_arg(ap, mode_t);
        va_end(ap);
    }
    // ...
}
```

# Implementing printf via vfprintf

```
int printf(char const *fmt, ...) {  
    va_list ap;  
    va_start(ap, fmt);  
    int ret = vfprintf(stdout, fmt, ap);  
    va_end(ap);  
    return ret;  
}
```

Implementing `vfprintf` involves reading the format string character by character and deciding what argument to read next based on the character after a `%`

# In-class exercise

<https://checkoway.net/teaching/cs241/2019-fall/exercises/Lecture-33.html>

Grab a laptop and a partner and try to get as much of that done as you can!