ECS 36A, May 28, 2024

Pseudorandom Numbers

- int rand(void)
  - Generate pseudorandom number between 0 and RAND_MAX inclusive
  - **This function is dangerous — avoid it!!** In older versions, it is *not* pseudorandom in the low order bits. (On newer Linux systems, it's OK)
- long random(void)
  - Generate pseudorandom number between 0 and $2^{31}-1$ inclusive
- All require a starting point – called a *seed*

Pseudorandom Number Seeds

- void srand(unsigned int seed)
  - Initialize the *rand*() pseudorandom number generator with *seed*
- void srandom(unsigned int seed)
  - Initialize the *random*() pseudorandom number generator with *seed*
- Pick *seed* as randomly as possible
- There are defaults, useful for regenerating the same sequence for debugging
  - rand/srand default seed is 1
  - random/srandom default seed is 1

Random Numbers

- Linux has a pool of bits generated from sources such as hardware timings and other natural sources that are considered random
  - They are *not* generated by an algorithm as pseudorandom numbers are

```
getrandom(void *buf, size_t sz, unsigned int flags)
```

- Generates *sz* random bytes and store them in the given *buf*
- Returns number of bytes stored in *buf*
- Flags:
  - **GRND_NONBLOCK** prevents getrandom() from blocking; if it would block it returns –1 and sets errno to **EAGAIN**
  - **GRND_RANDOM** draws from a random source more limited than the one used when this flag is given (avoid using this one)

Example Use

```
unsigned int rnd;
int count;
count = getrandom(&rnd, sizeof(unsigned int), GRND_NONBLOCK);
if (count == -1)
      perror("getrandom");
else
      for(i = 0; i < count; i++)
            printf("0x%02x\n", count, (rnd>>i)&0xff);
```

String Functions

- strcpy, strcat, strcmp, strncpy, strncat, strncmp, strlen
  - You've seen these
- char *strdup(char *s): make a duplicate of string s
  - Space is malloc'ed
- char *strchr(char *s, int c): return pointer to first occurrence of character c in s; NULL if not there
- char *strrchr(char *s, int c): like strchr, but points to last occurrence
- char *strstr(char *s, char *t): like strchr, but looks for first occurrence of string *t*

String Functions

- char *strtok(char *s, char *delim): breaks a string into a sequence of 0 or more nonempty tokens (substrings)
  - On first call, s points to string to be parsed
  - On subsequent calls for the same string, set s to NULL
  - delim is a string of characters that delimit tokens
  - strtok returns NULL when there are no more tokens to return
  - strtok *always* returns a nonempty token
  - Warning: strtok overwrites delimiters with '\0', so don't give it a read-only string
- int strcasecmp(char *a, char *b): useful for homework; look it up

Memory Functions

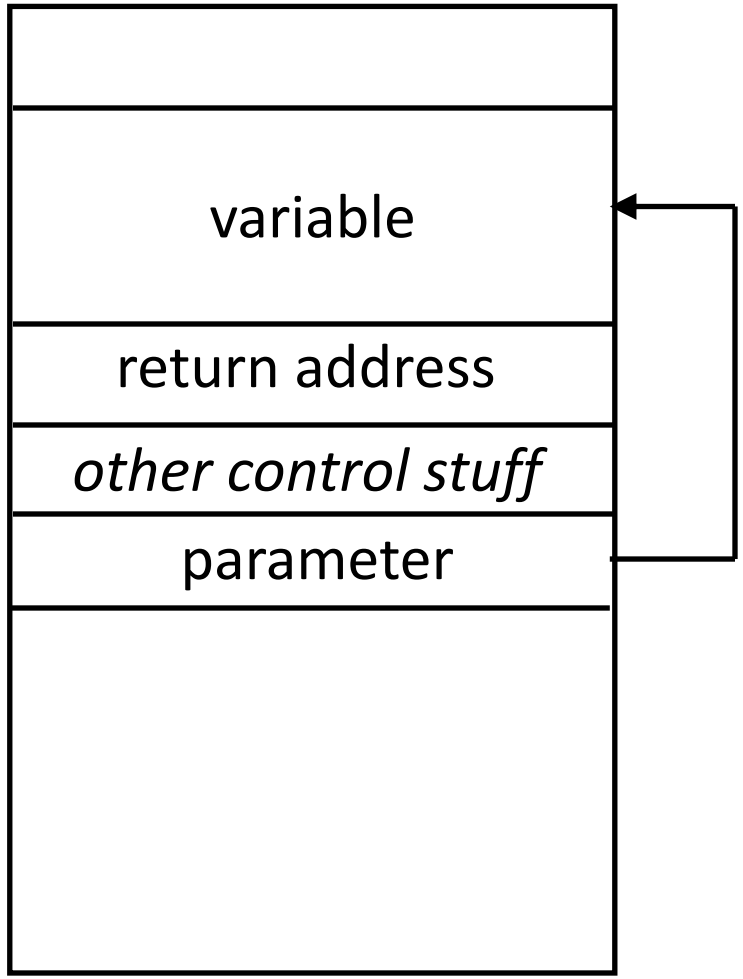
- void *memcpy(void *dest, void *src, unsigned int n): copy n bytes from src to dest
  - Behavior undefined if src, dest overlap
- int memcmp(void *s1, void *s2, unsigned int n): compare first n bytes of s1 and s2; returns negative, zero, positive depending on whether s1 is less than, equal to, greater than s2

Math Functions

- double floor(double d), double ceil(double d): round d down, up to the nearest integer
- double log(double d), double log10(double d): return the natural log, base 10 log of d
- double exp(double d), double pow(double m, double e): return e^d, m^e
- double sin(double d): compute sine of *d* in radians
  - same with cos, tan
- double atan(double x): return principal value of arctan of d
  - In range [–π/2, +π/2)
- double atan2(double x, double y): return arctan of y/x
  - Handles cases where x is 0; returns value in range [-π, π]

Bug: Stack Smashing

- Problem: failure to check input length
- Going back to the stack, here is what it looks like when a function is called:



The Program bad.c

```
#include <stdio.h>
char *gets(char *);
int main(void)
{
	int above = 100;
	char input[24];
	int below = 200;
	printf("BEFORE INPUT: above = %#010x; below =  %#010x\n", above, below);
	if (gets(input) == NULL){
		fprintf(stderr, "Unexpected EOF\n");
		return(1);
	}
	printf(" AFTER INPUT: above = %#010x; below =  %#010x\n", above, below);
	return(0);
}
```

A Program Run

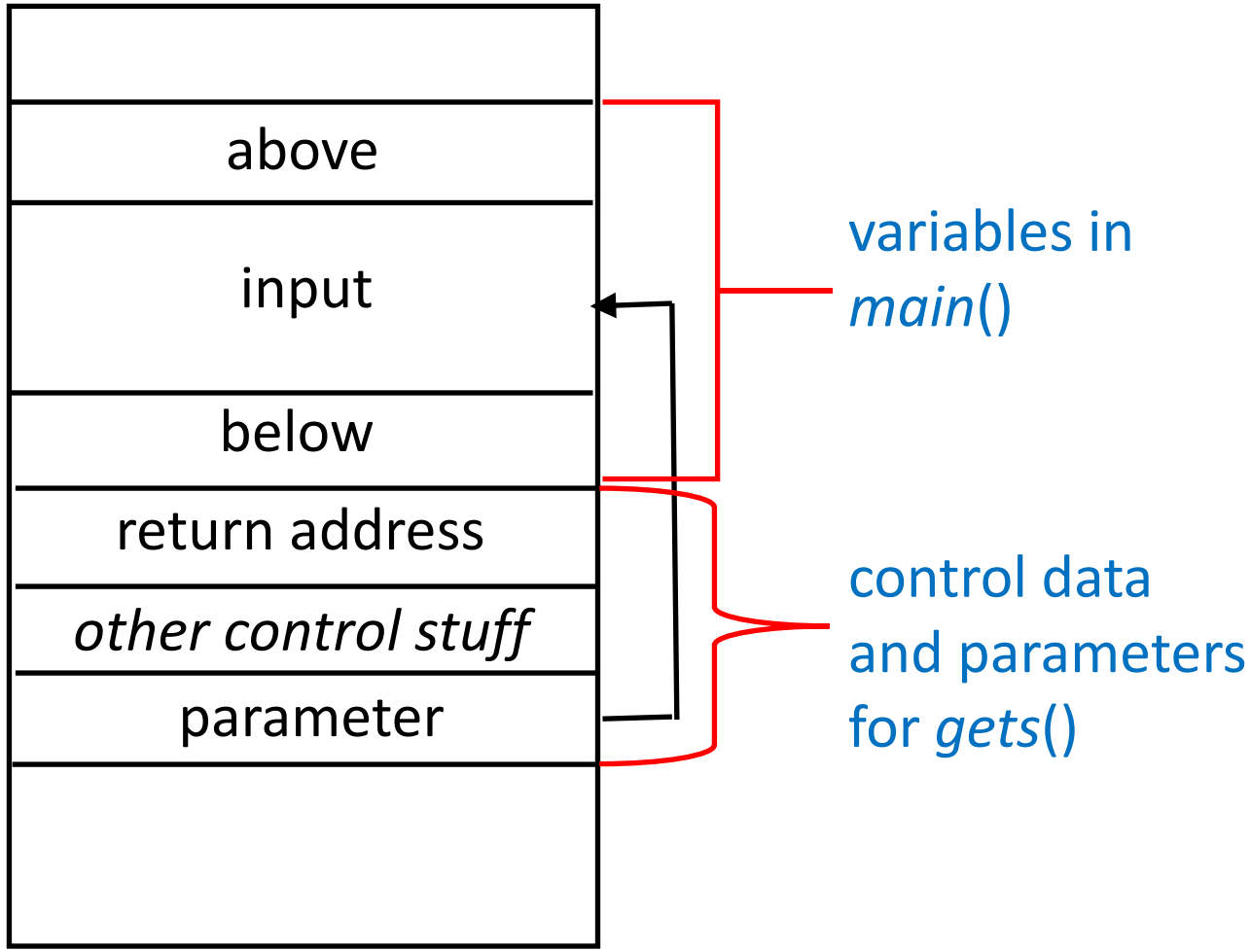
- `BEFORE INPUT: above = 0x00000064; below =  0x000000c8`
- `aaaaaaaaaaaaaaaaaaaaaaaaaa`
- `AFTER INPUT: above = 0x00000064; below = 0x00006161`

26 a's (overflowing input by 2 chars)

'a' is represented by the number 0x61 in the computer

May Change Variable Values Unexpectedly

- Here is the stack frame after *gets* is called



Writing a Program with Random Numbers

- Monty Hall problem:
- In a game, Monty asks a contestant to pick one of three doors. Behind one is a valuable prize; behind the other two are joke prizes (like a goat or a wheelbarrow full of mud).
- The contestant picks a door.
- Monty says, "Before I show you what is behind that door let me show you what is behind one of the doors you did not select". They pick such a door, it is opened, and behind it is a joke prize.
- Monty asks if the contestant wants to switch to the other, unopened door.
- The problem asks, should the contestant do so?

Programming Step 1

- First, we decide how to represent the doors
  - 3 doors, so call them 1, 2, and 3
- How do we determine which one has the good prize?
  - Let's pick one of the doors at random
- Which door does the contestant pick?
  - We can do this
  - We can have the computer select randomly among the 3 doors
- What happens if the contestant:
  - Switches?
  - Doesn't switch?

Programming Step 2

- First draft of program: human does everything:

1. Human picks where the prize goes
2. Human picks which door the contestant picks
3. Human picks door to open (it *cannot* be the one with the prize)
4. Human decides whether to switch

- This lets us create the framework for the program.

First Version – monty1.c

- Written as outlined above
- Oops . . . There's a bug:

```
Select door where prize is > 1

Select door for contestant > 2

I will show you door 3

Does contestant switch doors? > y

y or n please! > y

You picked door 1, but the prize is behind door 1 -- you
win!
```

- Let's use *gdb* to debug it

First Version – monty1.c

- Aha! We forgot to eat the rest of the line after scanf reads the entered number!
- We'll fix this in the next version
- Returning to the design . . .

First Version – monty1.c

- Looks pretty complicated – can we simplify it?
  - We go through an awful lot to figure out what door the contestant switches to, if they switch
  - Do we really need to do this?

First Version – monty1.c

- Looks pretty complicated – can we simplify it?
  - We go through an awful lot to figure out what door the contestant switches to, if they switch
  - Do we really need to do this?
- It doesn't matter what door they pick – what matters is whether they wind up picking the prize door

Second Version – monty2.c

- Try another approach using that observation

1. Human picks where the prize goes
2. Human picks which door the contestant picks
3. Human picks door to open (it *cannot* be the one with the prize)
4. If user decides to switch:
    a. If user picked prize door, they lose
    b. If user did not pick prize door, they win

Third Version – monty3.c

- Now we add randomness
- Wherever user asked for a number, generate a random one
  - So we change `ask_user()` to return a random number of 1, 2, or 3
- Consider whether it is necessary to show which door Monty shows

Third Version – monty3.c

- Now we add randomness
- Wherever user asked for a number, generate a random one
  - So we change `ask_user()` to return a random number of 1, 2, or 3
- Consider whether it is necessary to show which door Monty shows
- It isn't; all we care about is whether the contestant switches their selection of doors

Fourth Version – monty4.c

- We delete the `monty_shows_door()` routine
- Next, do we need to ask user whether to switch?

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Fourth Version – monty4.c

- We delete the `monty_shows_door()` routine
- Next, do we need to ask user whether to switch?
- No; we can get the relevant result utilizing symmetry
- If the user does not switch:
  - If the first selected door is the same as the prize door, a win
  - If the first selected door is the not same as the prize door, a loss
- If the user switches:
  - If the first selected door is the same as the prize door, a loss
  - If the first selected door is the not same as the prize door, a win

Fifth Version – monty5.c

- We rewrite the main() routine to implement the above
- Now we can delete `switch_or_not()`
- Program is messy, though, so need to clean it up

Sixth Version – monty6.c

- We clean up some things and add a clearer statement of the output
- Now our program works – for 1 game. So we still cannot answer our question.
- To do so, we need to play a *lot* of games, counting how many win with switching and how many win without switching, and compare the numbers against the total number of games played
- To do this, we make a loop of what is in main()
- For now, we'll assume 10,000 games

Seventh Version – monty7.c

- Some more clean up
- First, delete print message for the random number routine and rename it appropriately
- Next, the two routines picking the prize and contestant door are 1 line once you remove the printf statements, so put the line into the main function

Seventh Version – monty7.c

- Some more clean up
- First, delete print message for the random number routine and rename it appropriately
- Next, the two routines picking the prize and contestant door are 1 line once you remove the printf statements, so put the line into the main function
- Do we always want 10,000 runs – maybe when you get to 100,000 or 1,000,000 games, the ratio between the switching and not switching becomes closer to 0.5 or something else?

Eighth Version – monty8.c

- Make the 10,000 games a macro and define it at the head of the file
- This way, we can change the number without searching the program for the number

Eighth Version – monty8.c

- Make the 10,000 games a macro and define it at the head of the file
- This way, we can change the number without searching the program for the number
- But to change the number we have to edit the source code and recompile it. We should allow the user to change it without doing this.

Ninth (and Final) Version – monty9.c

- We can either read the number as input or as a command-line argument
  - monty9.c implements the latter
  - The former is left as an exercise to the student 🙂
- Whichever you choose, do *not* forget to check for errors!
  - If the argument is not present, use a default value
  - If there is more than 1 number given, report an error