CSE 351 Section 6 – Arrays, Structs, & Buffer Overflow

Welcome back to section. We're happy that you're here ☺

Arrays

- Arrays are contiguously allocated chunks of memory large enough to hold the specified number of elements of the size of the datatype. Separate array allocations are not guaranteed to be contiguous.
- 2-dimensional arrays are allocated in row-major ordering in C (i.e. the first row is contiguous at the start of the array, followed by the second row, etc.).
- 2-level arrays are formed by creating an array of pointers to other arrays (i.e. the second level).

We have a two-dimensional matrix of integer data of size M rows and N columns. We are considering 2 different representation schemes:

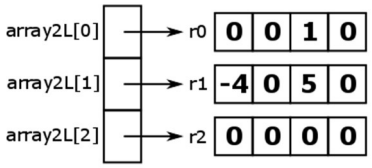
1) 2-dimensional array `int array2D[][]` // M*N array of ints
2) 2-level array `int* array2L[]` // M array of int arrays

Consider the case where $M = 3$ and $N = 4$. The declarations are given below:

2-dimensional array:	**2-level array:**
`int array2D[3][4];`	`int r0[4], r1[4], r2[4];` `int* array2L[] = {r0,r1,r2};`

For example, the diagrams below correspond to the matrix $\begin{bmatrix} 0 & 0 & 1 & 0 \\ -4 & 0 & 5 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$ for `array2D` and `array2L`:

0	0	1	0	-4	0	5	0	0	0	0	0
[0][0]	[0][1]	[0][2]	[0][3]	[1][0]	[1][1]	[1][2]	[1][3]	[2][0]	[2][1]	[2][2]	[2][3]



Array Exercise:

	2-dim array	2-level array
Overall Memory Used	M*N*sizeof(int) = 48 B	M*N*sizeof(int) + M*sizeof(int*) = 72 B
Largest *guaranteed* continuous chunk of memory	The whole array (48 B)	The array of pointers (24 B) > row array (16 B)
Smallest *guaranteed* continuous chunk of memory	The whole array (48 B)	Each row array (16 B)
Data type returned by:	`array2D[1]` int *	`array2L[1]` int *
Number of memory accesses to get `int` in the *BEST* case	1	2
Number of memory accesses to get `int` in the *WORST* case	1	2

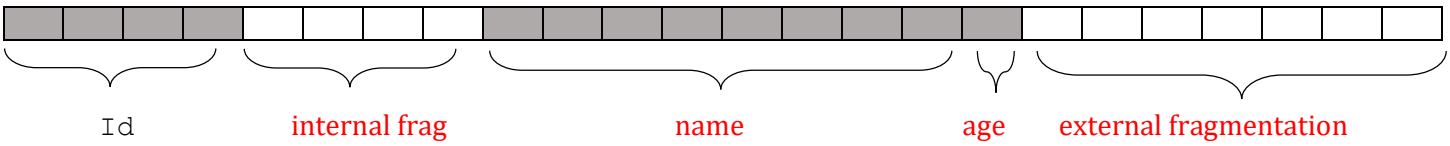
Structs

- Structs are contiguously allocated chunks of memory that hold a programmer-defined collection of potentially disparate variables.
- Individual fields appear in the struct in the order that they are declared
- Each field follows its variable alignment requirement, with internal fragmentation added between fields as necessary.
- The overall struct is aligned according to the largest field alignment requirement, with external fragmentation added at the end as necessary.

Structs Exercise:

```
struct Student {
  int id;
  char* name;
  char age;
};
```

a) Fill in which bytes are used by which variables and label the rest as internal or external fragmentation. The first variable "id" is given.



b) What is the size of `struct Student`? **24 bytes**

c) Give a reordering of the fields in `struct Student` such that there is no internal fragmentation

```
struct Student {
      char* name;
      int id;
      char age;

};
```

d) How much external fragmentation does this new `struct Student` have? **3 bytes**

e) What is the size of this new `struct Student`? **16 bytes** (smaller than before)

Buffer Overflow Exercise:

3. Consider the following C program:

```
void main() {
  read_input();
}

int read_input() {
  char buf[8];
  gets(buf);
  return 0;
}
```

Here is a diagram of the stack at the beginning of the call to read_input():

Address	Value (hex)
%rsp+15	00
%rsp+14	00
%rsp+13	00
%rsp+12	00
%rsp+11	00
%rsp+10	~~40~~ 00 (null terminator)
%rsp+9	~~AF~~ 73
%rsp+8	~~3B~~ 72
%rsp+7	71
%rsp+6	70
%rsp+5	6F
%rsp+4	6E
%rsp+3	6D
%rsp+2	6C
%rsp+1	6B
%rsp+0	6A

a) What is the value of the return address stored on the stack?

0x40AF3B

Assume that the user inputs the string "`jklmnopqrs`"

b) Write the values in the stack before the "return 0;" statement is executed. Cross out the values that were overwritten and write in their new values.
(Hint: use the ASCII table at the bottom to convert from letters to bytes)

c) What is the new return address after the call to gets()?

0x7372

d) Where will execution jump to after the "`return 0;`"?

It will try to jump to 0x7372, but it will crash with a segfault

e) How many characters would we have to enter into the command line to overwrite the return address to `0x6A6B6C6D6E6F`?

14 = 8 for padding (the length of buf) + 6 for the length of the address in bytes. A null terminator is appended, but it's okay because the upper bytes were going to be 0x00 anyway

f) Create a string that will overwrite the return address, setting it to `0x6A6B6C6D6E6F`

"`abababababonmlkj`" (The first 8 characters don't matter since they're just padding)

In Lab 3, we are given a tool called `sendstring`, which converts hex digits into the actual bytes

```
>echo "61 62 63" | ./sendstring
abc
```

g) If we want to overwrite the return address to a stack address like 0x7FFFFFAB1234, we need to use a tool like sendstring to send the correct bytes.
Why can't we just manually type the characters like we did earlier with "`jklmnopqrs`"?

There is no character in ASCII we can type that will give us a byte value of 0x7F, 0xFF, or 0x12

Char	Hex
a	61
b	62
c	63
d	64
e	65
f	66
g	67
h	68
i	69
j	6A
k	6B
l	6C
m	6D
n	6E
o	6F
p	70
q	71
r	72
s	73
t	74
u	75
v	76
w	77
x	78
y	79
z	7A

Check out the Lab 3 video on Phase 0 before you start the lab! It's linked on the Lab 3 page