# CSE 351 Section 5 Solutions – Arrays and Buffer Overflow

Welcome back to section, we're happy that you're here ☺

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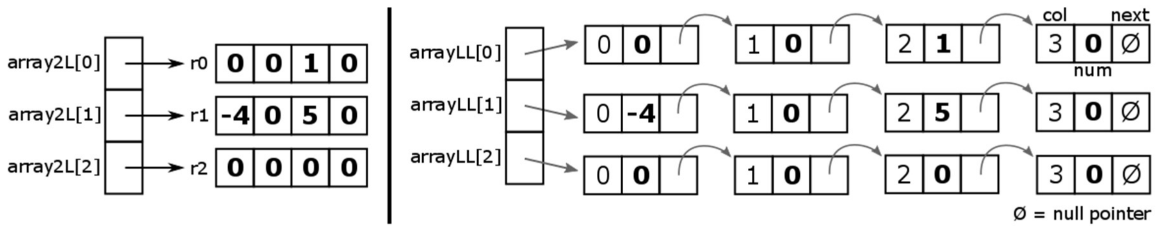
We have a two-dimensional matrix of integer data of size $M$ rows and $N$ columns. We are considering 3 different representation schemes:

1) 2-dimensional array **`int`** `array2D[][]`, // M*N array of ints
2) 2-level array **`int*`** `array2L[]`, and // M array of int arrays
3) array of linked lists **`struct node*`** `arrayLL[]`. // M array of linked lists (struct node)

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

| **`2-dimensional array:`** | **`2-level array:`** | **`Array of linked lists:`** |
|---|---|---|
| **`int`** `array2D[3][4];` | **`int`** `r0[4], r1[4], r2[4];`<br>**`int*`** `array2L[] = {r0,r1,r2};` | **`struct node`** `{`<br>    **`int`** `col, num;`<br>    **`struct node*`** `next;`<br>`};`<br>**`struct node*`** `arrayLL[3];`<br>`// code to build out LLs` |

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 `array2L` and `arrayLL`:



a) Fill in the following comparison chart:

| | 2-dim array | 2-level array | Array of LLs: |
|---|---|---|---|
| Overall Memory Used | M*N*sizeof(int) = 48 B | M*N*sizeof(int) + M*sizeof(int *) = 72 B | M*sizeof(struct node *) + M*N*sizeof(struct node) = 216 B |
| Largest *guaranteed* continuous chunk of memory | The whole array (48 B) | The array of pointers (24 B) > row array (16 B) | The array of pointers (24 B) > struct (16 B) |
| Smallest *guaranteed* continuous chunk of memory | The whole array (48 B) | Each row array (16 B) | Each struct node (16 B) |
| Data type returned by: | `array2D[1]`<br>`int *` | `array2L[1]`<br>`int *` | `arrayLL[1]`<br>`struct node *` |
| Number of memory accesses to get `int` in the *BEST* case | 1 | 2 | First node in LL: 2 |
| Number of memory accesses to get `int` in the *WORST* case | 1 | 2 | Last node in LL: 5 (we have to read `next`) |

b) Sam Student claims that since our arrays are relatively small ($N < 256$), we can save space by storing the `col` field as a **char** in **`struct node`**. Is this correct? If so, how much space do we save? If not, is this an example of internal or external fragmentation?

No. Alignment requirement of $K = 4$ for **`int`** `num` leaves 3 bytes of internal fragmentation between `col` and `num`.

c) Provide a scenario where a 2-dimensional array would be more useful and another where a 2-level array would be more useful.

- 2D Array - Creating a table or a matrix where all rows are the same size. This way memory accesses are reduced and less memory is required.

- 2-Level Array - When creating a list where different index sizes differ or sub-arrays are subject to replacement.  In other words, when the array is more flexible to changes.

d) Sam wants to create a 2-D matrix of the countries of the world that can be accessed alphabetically. Which implementation should Sam choose to represent this information? Describe what this implementation would look like.

$$\begin{bmatrix} Afghanistan & Albania & \dots & Azerbaijan \\ Bahamas & \dots & Burundi & --- \\ \vdots & \vdots & \vdots & \vdots \\ Zambia & Zimbabwe & --- & --- \end{bmatrix}$$

Sam should use a 2-level array since the amount of countries starting with a given letter will vary (i.e. there are more countries that start with A than Q). He could make an array of pointers from 0 to 25 which would point to custom-sized arrays of country names starting with each corresponding letter of the alphabet.

## Buffer Overflow

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`

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

| 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 |

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

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