CS 240 Laboratory 7
Pointers and Introduction to gdb/valgrind

- Predict results of pointer code
- Write some pointer code
- Analyze incorrect code
- Start to use GNU debugger ***gdb***
  - see what is going on "inside" a program while it executes
  - display values of variables and examine contents of memory
  - understand the effect of your programs on the hardware of the system
  - Start to use **Valgrind** memory error detection tool to indicate problems with memory allocation/deallocation and access

Pointers

A *pointer* is a variable that contains the address of another variable.

Since a pointer contains the address of an item, it is possible to access the item "indirectly" through the pointer. For example,

```
int x;
int* px;
px = &x;
```

means *px* contains the address of *x*, or "points" to *x*.

Similarly,

```
int y = *px;
```

means that *y* gets the value stored at the address in *px* (the value *px* "points" to).

Pointer Arithmetic

If *p* is a pointer, then *p++* increments *p* to point to the next element of whatever kind of object *p* points to. So, the actual number by which p gets increments is a multiple of the size in bytes of the object pointed to.

```
int *p;
p++;
```

results in *p* being incremented by the size of an integer in bytes on the particular machine on which the operation is performed.

If the word size is 32 bits, p is incremented by 4.

If the word size is 64 bits, p is incremented by 8.

Multiple Dereferencing and Memory Models

The following declaration allocates space in memory for an array of *pointers* (specifically, 3 *pointers* to *char*s):

char* commandA[3];

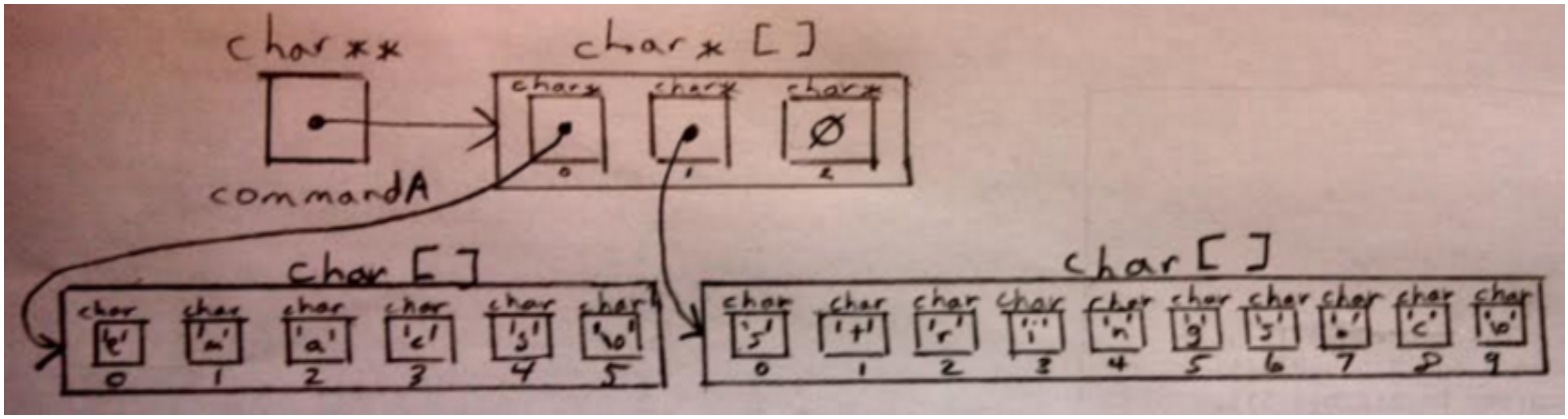
You can also dereference more than once with the use of multiple operators (remember that arrays and pointer can be used interchangeably). For example:

char** commandPtr = commandA;

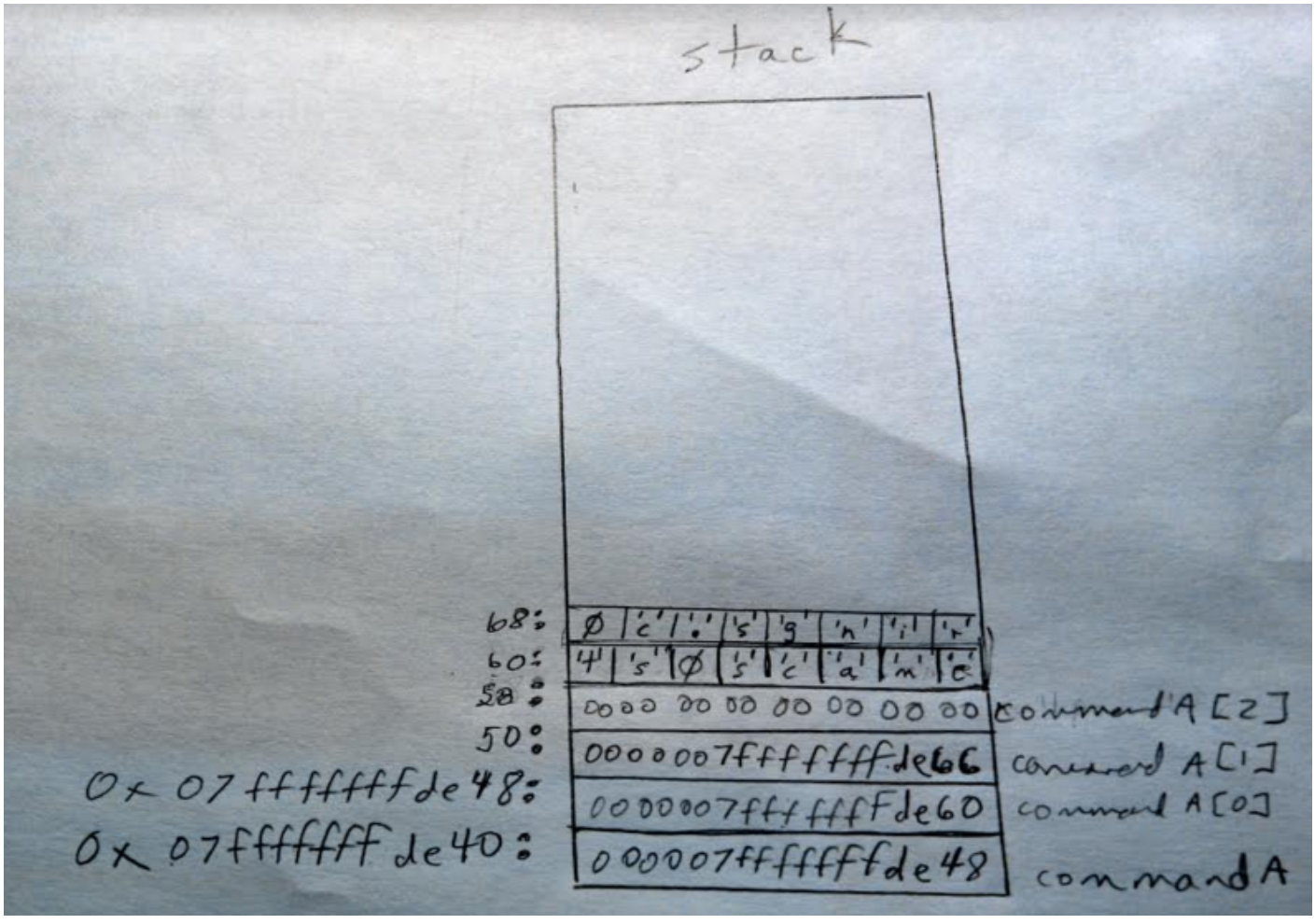
If the following statements were executed to initialize some strings (arrays of characters):

commandA[0] = "emacs";
commandA[1] = "strings.c";
commandA[2] = NULL;

You could use the following diagram to model the data (the directed arrows indicate a *pointer*, or *address*):



Another way to understand how memory is organized here is to use our model of memory from lecture:



Evaluate C Pointer Expressions

For each row, evaluate the expression in the first column, and make a prediction for the **type** and the **numeric value** of the expression in the second and third column:

- for pointer types, write the *numeric address* (what you would get from printf("%p", ...))
- assume a machine with 32-bit addresses and integers and little endian storage
- **`char* p = (char*) 0x1100;`**
- **`char* q = (char*) 0x1110;`**

	Type	Numeric value
0. p	char *	0x1100
1. &p[1]		
2. &p[-1]		
3. &p[0]		
4. &p[1] - &p[0]		
5. &p[8]		
6. (p + 1) - p		
7. &p[16] - p		
8. q - p		
9. sizeof(p)		
10. sizeof(*p)		
`int* ip = (int*) p;` `//assume this statement is executed before evaluating the next statements`		
11. &ip[0]		
12. &ip[1]		
13. &ip[1] - &ip[0]		
14. (char*) &ip[1] - p		
15. sizeof(ip)		
16. sizeof(*ip)		
17. &ip[sizeof(int)]		
18. ip + sizeof(int)		
19. ip + 1		
20. p + sizeof(int)		
`int* iq = (int*) q;` `//assume this statement is executed before evaluating the next statements`		
21. iq - ip		
22. &iq[-1] - ip		
`p[0] = p[1] = p[2] = p[3] = 0;` `//assume this statement is executed before evaluating the next statement`		
23. *ip		
`*(char*) ip = 1;` `//assume this statement is executed before evaluating the next statement`		
24. *ip		

***((char*) ip + 1) = 1;**//assume this statement is executed before evaluating the next statements		
25. p[1]		
26. *ip		
***((char*) ip) = 2;** //assume this statement is executed before evaluating the next statements		
27. *((char*) ip)		
28. *ip		

GNU Debugger (gdb)

Tutorials and manuals:

http://wellesleycs240.bitbucket.org/tools.html

Commands

Can be shortened to a single letter, or repeated by entering <return> at the prompt):

- Compile C program with **–g** option to create debugging information
- Run the program under **gdb**

  $ **gdb testprog**

  (gdb) **run**

- Set breakpoints

  (gdb) **break main**

- Step/next statement by statement through your program

  (gdb) **step**
  (gdb) **next**

(gdb) **cont** -- continue execution

- Display/print code or values of variables and arguments

  (gdb) **list**
  (gdb) **print x**
  (gdb) **info locals**
  (gdb) **info args**

- (gdb) **`quit`** or **`Ctrl-d`** **`--`** to exit.

- To find a bug:

  1. Set breakpoints at the start of every function
  2. Restart the program and step line-by-line until you locate the problem exactly.
  3. If program is stuck (infinite loop) **`Ctrl-c`** terminates the action of any gdb command that is in progress and returns to the gdb prompt.
- Execute statements/expressions during execution to tweak program execution state

  (gdb) **set var i = 2**

- Display/print binary and hexadecimal representation of variables and arguments

  (gdb) **print /x result** -- uses hex representation
  (gdb) **print /t result** -- uses binary representation