Memory, Data, & Addressing II

CSE 351 Winter 2024

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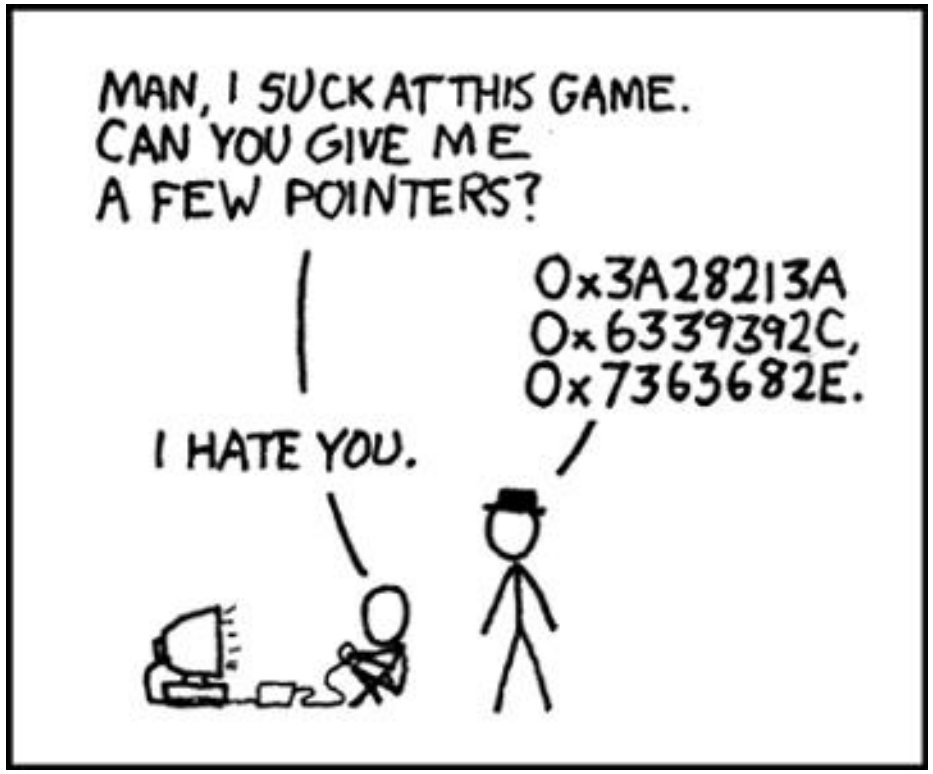


http://xkcd.com/138/

Relevant Course Information

- Lab 0 due today @ 11:59 pm
  - *You will revisit the concepts from this program in future labs!*
- HW2 due Wednesday, HW3 due Friday
  - Autograded, unlimited tries, no late submissions
- Lab 1a released today, due next Monday (1/15)
  - Pointers in C (requires course material through bit shifting in Lesson 5)
  - Last submission graded, can optionally work with a partner
    - One student submits, then add their partner to the submission
  - Short answer "synthesis questions" for after the lab

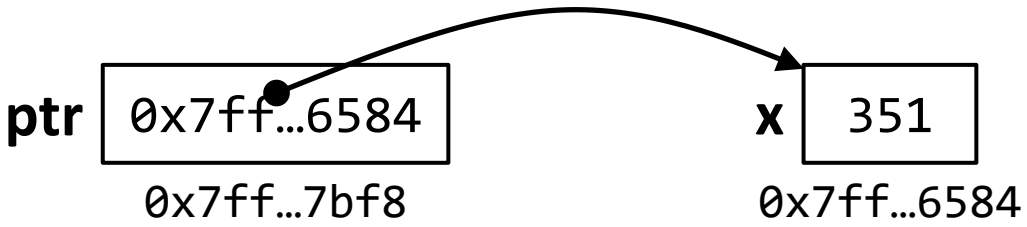
Late Days

- You are given 5 late day tokens for the whole quarter
  - Tokens can only apply to Labs
  - Can earn up to 2 more via answering lecture polling questions
- Count lateness in *days* (even if just by a second)
  - Special: weekends count as *one day*
  - No submissions accepted more than two days late
- Late penalty is 10% deduction of your score per day
  - Only late labs are eligible for penalties
  - Penalties applied at end of quarter to *maximize* your grade
- Use at own risk – don't want to fall too far behind
  - Intended to allow for unexpected circumstances

Memory & Data II

Lesson Summary (1/2)

- Pointers are data objects that hold addresses
  - Type of pointer determines size of thing being pointed at, which could be another pointer
  - & = "address of" operator
  - * = "value at address" or "dereference" operator
  - NULL is a constant for a pointer to "nothing"
- Can visualize using box-and-arrow diagrams:



&ptr = 0x7ff…7bf8
ptr = 0x7ff…6584
*ptr = 351

&x = 0x7ff…6584
x = 351
*x = ??? (segfault, likely)

Lesson Summary (2/2)

- Arrays are adjacent locations in memory storing the same type of data
  - Strings are null-terminated arrays of characters (ASCII)
- Pointer arithmetic scales by size of target type
  - Convenient when accessing array-like structures in memory: `a[i]` ↔ `*(a + i)`
  - Be careful when using – particularly when *casting* variables

&a[i] ↔ a+i

str	0x33	0x35	0x31	0x00

"351"

&str → 0x7ff…7bf8;

&str+1 = &str[1] = 0x7ff…7bf9

(int*)(&str)+1 = 0x7ff…7bfc

Lesson Q&A

- Learning Objectives:
  - Define pointers and their significance in computer memory organization.
  - Declare, initialize, and manipulate pointers in C using address-of, dereference, and arithmetic operators.
  - Handle I/O operations with C strings, accounting for the null character.

- What lingering questions do you have from the lesson?
  - Chat with your neighbors about the lesson for a few minutes to come up with questions

Memory & Data II – Practice

Polling Questions (1/2)

- ```
  int x = 351;
  char* p = &x;
  int ar[3];
  ```

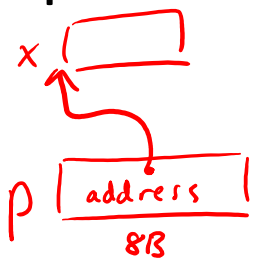
- How much space does the variable p take up?

  A. 1 byte

  B. 2 bytes

  C. 4 bytes

  D. 8 bytes



- Which of the following expressions evaluate to an address?

  A. x + 10 → int

  B. p + 10 → char *

  C. &x + 10 → int *

  D. *(&p) → char *

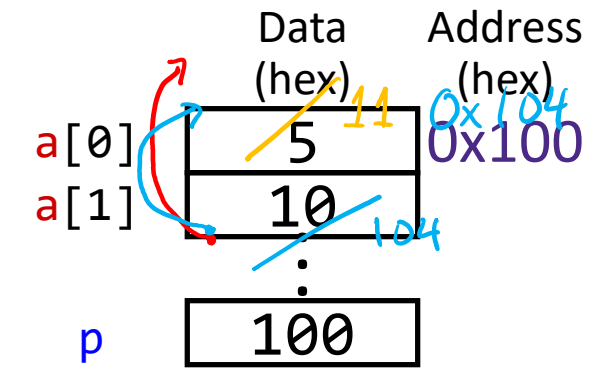
  E. ar[1] → int

  F. &ar[2] → int *
  ```

Polling Questions (2/2)

- The variable values after Line 3 executes are shown on the right. What are they after Line 5?

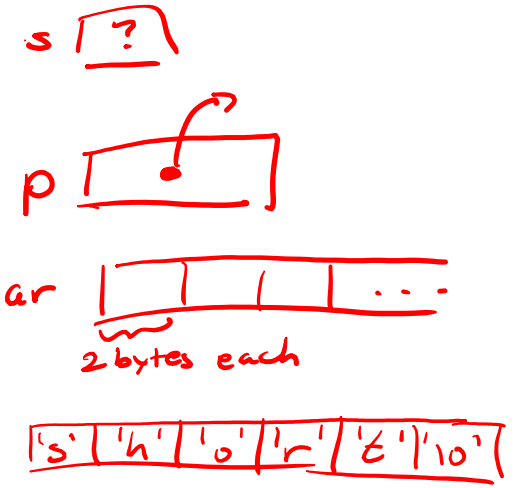
```
1  void main() {
2    int a[] = {0x5,0x10};
3    int* p = a;
4    p = p + 1;
5    *p = *p + 1;
6  }
```



	p	a[0]	a[1]
(A)	0x101	0x5	0x11
(B)	0x104	0x5	0x11
(C)	0x101	0x6	0x10
(D)	0x104	0x6	0x10

Homework Setup

- How much memory (in bytes) is allocated for the following?
  - `short s;` 2 bytes
  - `short* p;` 8 bytes
  - `short ar[351];` 702 bytes
  - `"short"` 6 bytes



all valid:

```
p = &s;
p = &ar;
p = "short";
```

Memory & Data II – Context

Examining Data Representations

- Code to print byte representation of data
  - Treat any data type as a *byte array* by **casting** its address to `char*`
  - C has unchecked casts !! DANGER !!

```
void show_bytes(char* start, int len) {
  int i;
  for (i = 0; i < len; i++)
    printf("%p\t0x%.2hhX\n", start+i, *(start+i));
  printf("\n");
}
```

format string

pointer arithmetic on char*

- `printf` legend:
  - Special characters: `\t` = Tab, `\n` = newline
  - Format specifiers: `%p` = pointer,
    `%.2hhX` = 1 byte (`hh`) in hex (`X`), padding to 2 digits (`.2`)

Examining Data Representations

- Code to print byte representation of data
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```
void show_bytes(char* start, int len) {
  int i;
  for (i = 0; i < len; i++)
    printf("%p\t0x%.2hhX\n", start+i, *(start+i));
  printf("\n");
}
```

```
void show_int(int x) {
  show_bytes( (char *) &x, sizeof(int));
}
```

int*

"cast" (treat as)

4 bytes

show_bytes Execution Example

```
int x = 123456; // 0x00 01 E2 40
printf("int x = %d;\n", x);
show_int(x);    // show_bytes((char *) &x, sizeof(int));
```

- Result (Linux x86-64):
  - **Note:** The addresses will change on each run (try it!), but fall in same general range

```
int x = 123456;
0x7fffb245549c  0x40
0x7fffb245549d  0xE2
0x7fffb245549e  0x01
0x7fffb245549f  0x00
```

Java References

- In Java, everything that is not a primitive data type is an *object*
  - An object variable is actually a *"reference"* – a restricted pointer

```
class Record { ... }
Record x = new Record();
```

- Reference restrictions:
  - No pointer arithmetic, just reassignment
    - Reassignment must adhere to rules set by typing system (*e.g.*, inheritance)
  - References can only be "dereferenced" in ways that match class definition
    - *e.g.*, calling a method, accessing a field in object
- All higher-level languages use pointers/addresses under the hood, but likely abstracted away from the programmer

Discussion Question

- Discuss the following question(s) in groups of 3-4 students
  - I will call on a few groups afterwards so please be prepared to share out
  - Be respectful of others' opinions and experiences

- Brainstorm some reasons why you think the designers of C (released in 1972) gave its programmers access to "raw" pointers.
  - What might these reasons say about the implicit *values* embedded in C?

Group Work Time

- During this time, you are encouraged to work on the following:
  1) If desired, continue your discussion
  2) Work on the homework problems
  3) Work on the lab (if applicable)

- Resources:
  - You can revisit the lesson material
  - Work together in groups and help each other out
  - Course staff will circle around to provide support