Lecture 7: Data representation

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DATA REPRESENTATION

Problem Solving with Computers-I

https://ucsb-cs16-sp17.github.io/

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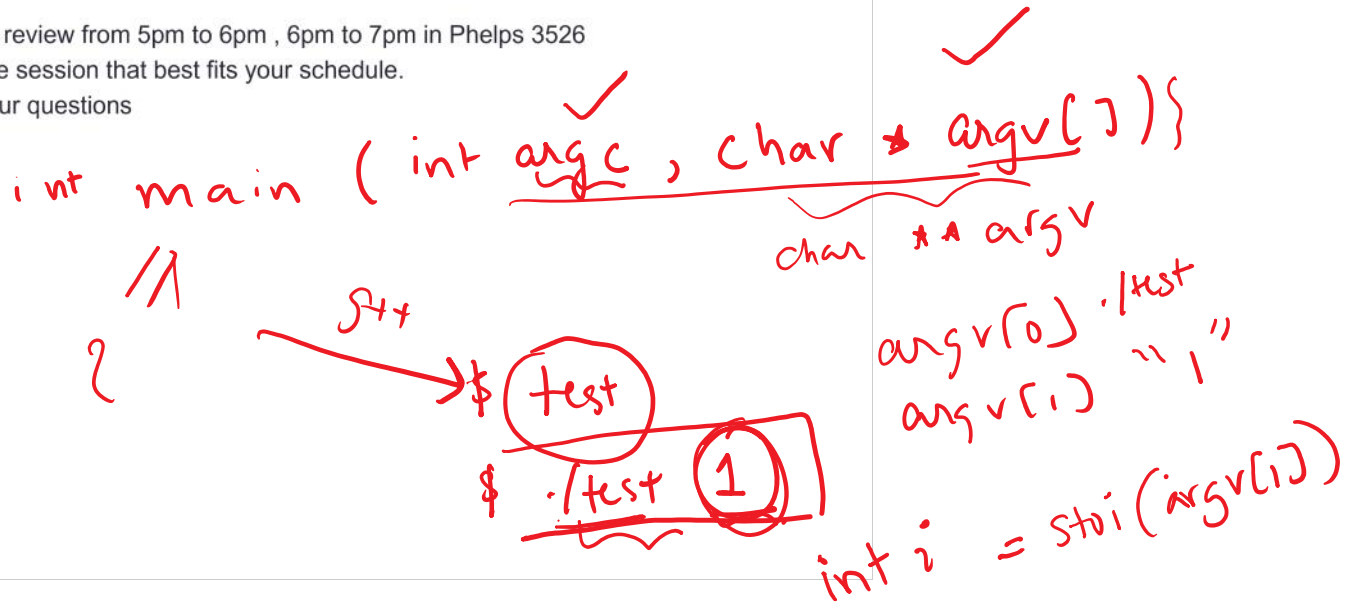
Announcements

- Midterm review from 5pm to 6pm , 6pm to 7pm in Phelps 3526
- Go to the session that best fits your schedule.
- Bring your questions



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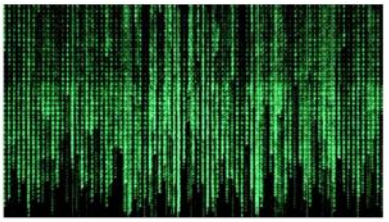
What does 'data' on a computer look like?

- Imagine diving deep into a computer
- Expect to see all your data as high and low voltages
- In CS we use the abstraction:
  - High voltage: 1 (true)
  - Low voltage: 0 (false)



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Decimal (base ten)

- Why do we count in base ten?
- Which base would the Simpson's use?

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External vs. Internal Representation

- External representation:
  - Convenient for programmer
- Internal representation:
  - Actual representation of data in the computer's memory and registers: Always binary (1's and 0's)

Positional encoding for non-negative numbers

- Each position represents some power of the base

Decimal
Base 10
0-9

e.g. 210_{10} = $2\times100 + 1\times10 + 0\times1$

$100 \quad 10 \quad 1$
$10^2 \quad 10^1 \quad 10^0$

Base 16 (hex)
0-9, A B C ... F

e.g. $256 \quad 16 \quad 1$

$= 2\times256 + 1\times16 + 0\times210_{16}$

Why is each base important??

10 11 12 15

When you write a number from here on, be sure to specify the base

0x → hex
0b → binary
$_{10}$ → decimal

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101_5 = ? In decimal

A. 26

B. 51

C. 126

D. 130

$1\ 0\ 1 = 25 \times 1 + 1 = 26$

$25\ \ 5\ \ 1$

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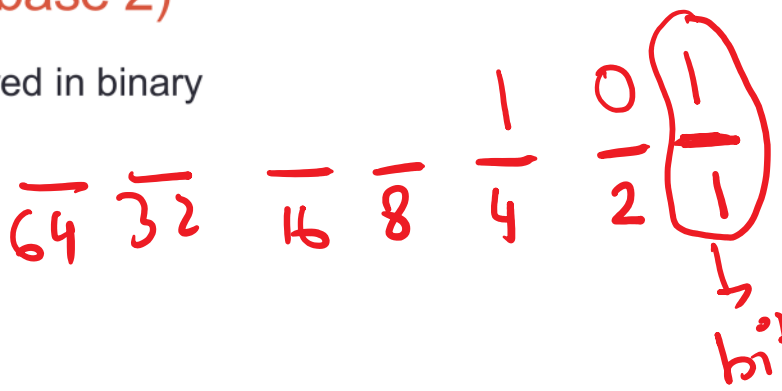
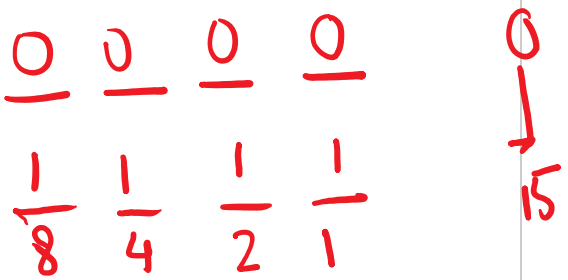
Binary representation (base 2)

- On a computer all data is stored in binary
- Only two symbols: 0 and 1
- Each position is called a *bit*
- *Bits take up space*
- 8 bits make a *byte*
- *Example of a 4-bit number*



A bit is just a placeholder
Its value maybe 1 or 0



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Converting between binary and decimal

Binary to decimal: $1\ 0\ 1\ 1\ 0_2 = ?_{10}$

16 8 4 2 1

16 + 4 + 2 = 22_{10}

int i = 0b10110;

Decimal to binary: $34_{10} = ?_2$

32 / 2

int i = 0x1A

16 1

64 32 16 8 4 2 1

1 0 0 0 1 0

16 + 10 + 1

= 26_{10}

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Hex to binary

- Each hex digit corresponds directly to four binary digits
- Programmers love hex, why?

$25B_{16}$ = ? In binary

00	0	0000
01	1	0001
02	2	0010
03	3	0011
04	4	0100
05	5	0101
06	6	0110
07	7	0111
08	8	1000
09	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111

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Hexadecimal to decimal

$25B_{16}$ = ? Decimal

256 16 1

2 → 256 + 5×16 + 11×1

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Hexadecimal to decimal

- Use polynomial expansion
- $25B_{16}$ = 2*256 + 5*16 + 11*1 = 512 + 80 + 11
  = 603
- Decimal to hex: $36_{10}=?_{16}$

$$\underline{0}\ \underline{2}\ \underline{4}$$
$$256\ 16\ 1$$

Choose a multiple of the highest power of 16 that "fits" in 36

Subtract the result from 36 e.g. 36 - 2*16 = 36-32 = 4

Repeat the process on the remainder

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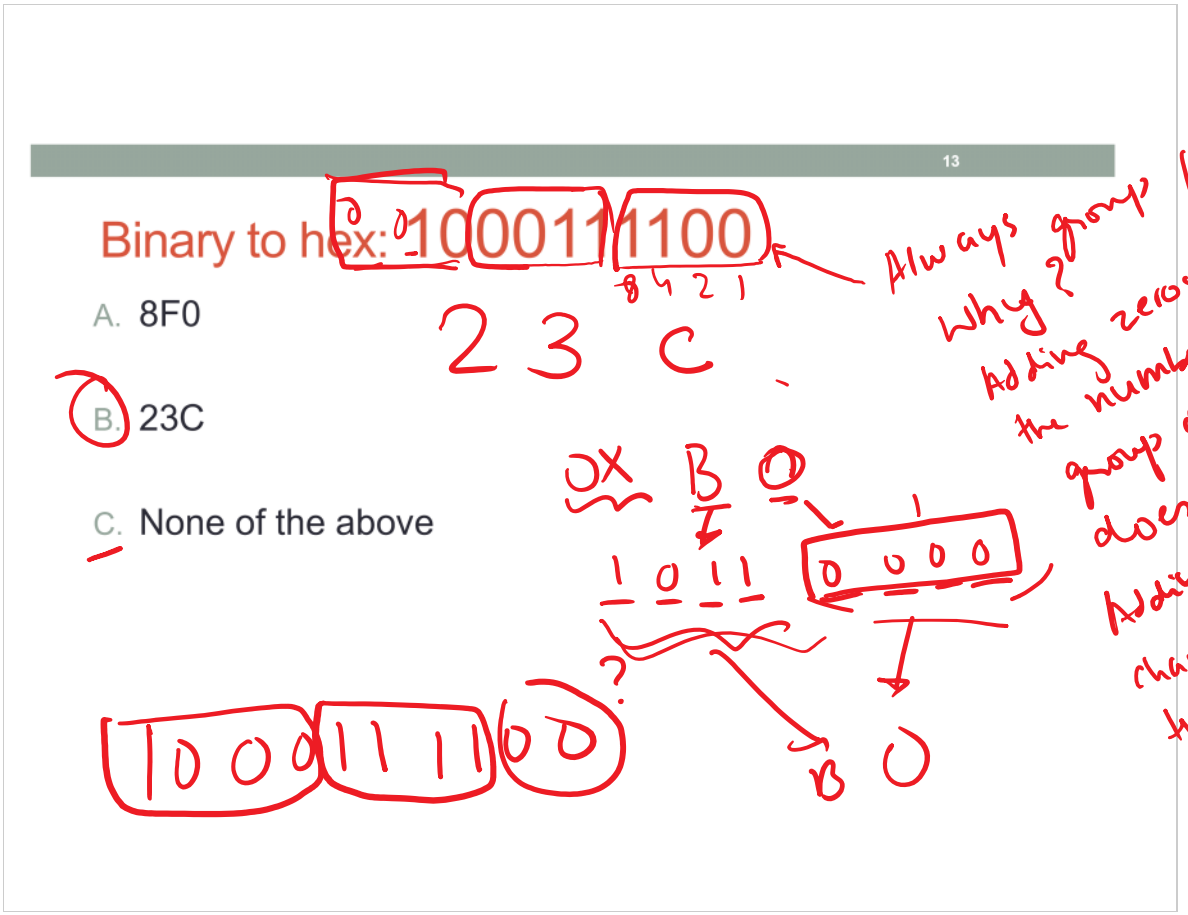

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BIG IDEA: Bits can represent anything!!

Numbers	Binary Code
0	00
1	01
2	10
3	11

We arrived at this using positional encoding

In general we could use an arbitrary mapping

0 → 11
1 → 10
2 → 00
3 → 01

Colors: red, blue, green

Numbers → Code
0 → 00
1 → 01
2 → 10

How many (minimum) bits are required to represent the numbers 0 to 3? 2

With 2 bits we can write 4 unique binary codes

Each code may represent a number, color or character depending on the context

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BIG IDEA: Bits can represent anything!!

Colors	Binary code
Red	00
Green	01
Blue	10

How many (minimum) bits are required to represent the three colors? 4 bits

BIG IDEA: Bits can represent anything!!

Characters

‘a’ → 0 0 0
‘b’ → 0 0 1
‘c’ 0 1 0
‘d’ 0 1 1
‘e’ 1 0 0

N bits can represent at most 2^N things

N bits → 2^N unique bit patterns

1-bit: 0, 1

2 bits: 00 → red, 01 → blue, 10 → green, 11 → purple

3 bits: 000 0, 001, 010, 011, 100, 101, 110, 111 7

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What is the minimum number of bits required to represent all the letters in the English alphabet?

A. 3
B. 4
C. 5
D. 6
E. 26

→ 32 → 26 unique letters in the alphabet

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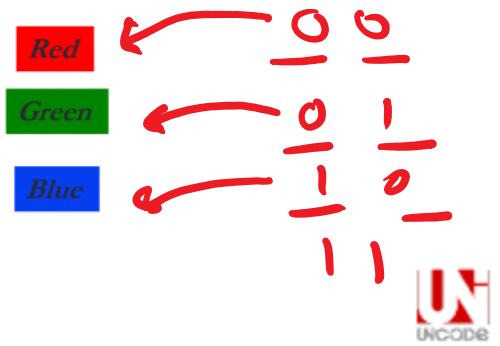
BIG IDEA: Bits can represent anything!!

- Logical values?
  - 0 ⇒ False, 1 ⇒ True
- colors ?
- Characters?
  - 26 letters ⇒ 5 bits ($2^5 = 32$)
  - upper/lower case + punctuation ⇒ 7 bits (in 8) ("ASCII")
  - standard code to cover all the world's languages ⇒ 8,16,32 bits ("Unicode") www.unicode.com
- locations / addresses? commands?
- MEMORIZE: N bits ⇔ at most 2^N things



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What is the maximum positive value that can be stored in a byte?

A. 127

B. 128

C. 255

D. 256

8 bits → 2^8 (256) unique binary codes

0 → smallest number

1

2

⋮

255 → largest number : 1111 1111

char c; (1 byte)

int c; (4 bytes)

char c = 10; ✓