Binary

CSE 120 Winter 2020

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Lime is laying off about 100 people and ceasing operations in 12 markets

Lime is hoping to achieve profitability this year by laying off about 14% of its workforce and ceasing operations in 12 markets, Axios first reported.

“Financial independence is our goal for 2020, and we are confident that Lime will be the first next-generation mobility company to reach profitability,” Lime CEO Brad Bao said in a statement to TechCrunch. “We are immensely grateful for our team members, riders, Juicers and cities who supported us, and we hope to reintroduce Lime back into these communities when the time is right.”

That means Lime is shutting down in Atlanta, Phoenix, San Diego, San Antonio, Linz, Bogotá, Buenos Aires, Montevideo, Lima, Puerto Vallarta, Rio de Janeiro and São Paulo.

https://techcrunch.com/2020/01/09/lime-is-laying-off-about-100-people-and-ceasing-operations-in-12-markets/

Binary Numbers

CSE 120 Winter 2018

Instructor: Justin Hsia

Teaching Assistants: Anupam Gupta, Cheng Ni, Eugene Oh, Sam Wolfson, Sophie Tian, Teagan Horkan

URB-E's launching a scooter sharing network at college campuses and hotels

"URB-E, the startup that creates foldable electric scooters, is launching a transportation system designed to promote scooter sharing on colleges campuses and other large residential developments.

"Because these properties purchase the system upfront from URB-E they can decide on their own pricing structure, so a hotel could provide free access to guests while a college campus or apartment complex could customize their own pricing structure."

- https://techcrunch.com/2018/01/10/urb-es-launching-a-scooter-sharing-network-on-college-campuses-and-hotels/

Administrivia

- Assignments:
  - Symbolic Lightbot (checkoff) due tonight (1/10)
  - Lightbot Functions (submit) due Monday (1/13)
  - Make sure you read the specifications carefully!

Lecture Outline

- **Binary Worksheet: Part 1**
- Decimal, Binary, and Hexadecimal
- Binary Encoding
- Binary Worksheet: Part 2

- Hints:

$2^0 = 1$	$2^1 = 2$	$2^2 = 4$	$2^3 = 8$
$2^4 = 16$	$2^5 = 32$	$2^6 = 64$	$2^7 = 128$
$2^8 = 256$	$2^9 = 512$	$2^{10} = 1024$	

Lecture Outline

- Binary Worksheet: Part 1
- **Decimal, Binary, and Hexadecimal**
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Decimal Numbering System

- Ten symbols: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

- Represent larger numbers as a sequence of digits
  - Each digit is one of the available symbols

- Example: 7061 in decimal (base 10)
  - $7061_{10} = (7 \times 10^3) + (0 \times 10^2) + (6 \times 10^1) + (1 \times 10^0)$

1000's place 100's place 10's place "one's place"

Octal Numbering System

- Eight symbols: 0, 1, 2, 3, 4, 5, 6, 7
  - Notice that we no longer use 8 or 9
- Base comparison:
  - Base 10: `0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12…`
  - Base 8: `0, 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13, 14…`
- Example: What is 7061_8 in base 10?
  - $7061_8 = (7 \times 8^3) + (0 \times 8^2) + (6 \times 8^1) + (1 \times 8^0) = 3633_{10}$

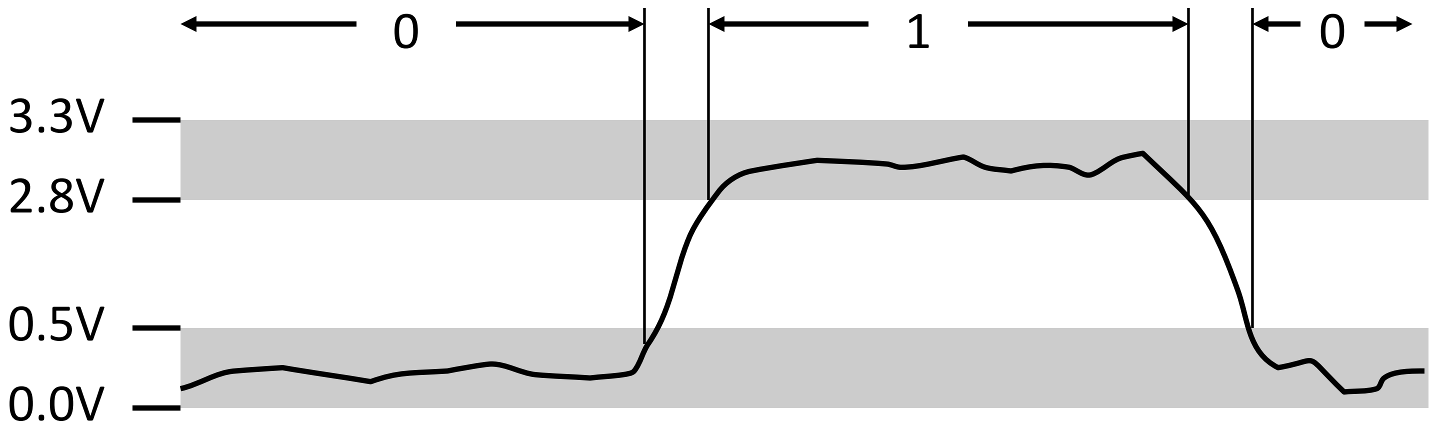
Binary and Hexadecimal

- Binary is base 2
  - Symbols: 0, 1
  - Convention: $2_{10} = 10_2 =$ 0b10 "this is in binary"
- Example: What is 0b110 in base 10?
  - 0b110 = $110_2 = (1 \times 2^2) + (1 \times 2^1) + (0 \times 2^0) = 6_{10}$
- Hexadecimal (hex, for short) is base 16
  - Symbols? 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F (A = 10, B = 11, . . . F = 15)
  - Convention: $16_{10} = 10_{16} =$ 0x10
- Example: What is 0xA5 in base 10?
  - 0xA5 = $A5_{16} = (10 \times 16^1) + (5 \times 16^0) = 165_{10}$

    160 + 5 = 165

Aside: Why Base 2?

- Electronic implementation
  - Easy to store with bi-stable elements
  - Reliably transmitted on noisy and inaccurate wires



- Other bases possible, but not yet viable:
  - DNA data storage (base 4: A, C, G, T) is a hot topic
  - Quantum computing

Base Comparison

- Why does this matter?
  - *Humans* think about numbers in **base 10**, but *computers* "think" about numbers in **base 2**
  - Binary encoding is what allows computers to do all of the amazing things that they do!

decimal binary hex

Base 10	Base 2	Base 16
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

Lecture Outline

- Binary Worksheet: Part 1
- Decimal, Binary, and Hexadecimal
- **Binary Encoding**
- Binary Worksheet: Part 2

Numerical Encoding

- **AMAZING FACT: You can represent *anything* countable using numbers!**
  - Need to agree on an encoding
  - Kind of like learning a new language

- <u>Examples</u>:
  - Decimal Integers: 0→0b0, 1→0b1, 2→0b10, etc.
  - English Letters: CSE→0x435345, yay→0x796179
  - Emoticons: 😃 0x0, 😞 0x1, 😎 0x2, 🤠 0x3, 😈 0x4, 🙋 0x5

Binary Encoding

- With N binary digits, how many "things" can you represent?
  - Need N binary digits to represent n things, where $2^N \geq n$
  - Example: 5 binary digits for alphabet because $2^5 = 32 > 26$

- A binary digit is known as a bit
- A group of 4 bits (1 hex digit) is called a nibble
- A group of 8 bits (2 hex digits) is called a byte
  - 1 bit → 2 things, 1 nibble → 16 things, 1 byte → 256 things

So What's It Mean?

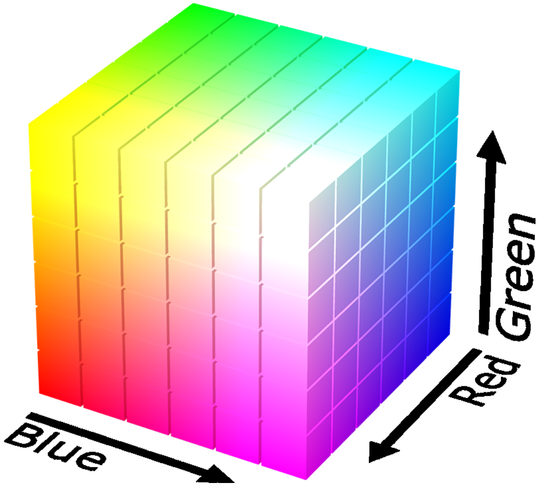
- *A sequence of bits can have many meanings!*

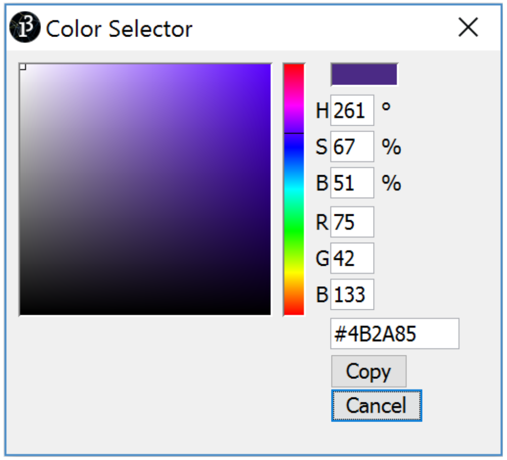
- Consider the hex sequence 0x4E6F21
  - Common interpretations include:
    - The decimal number 5140257
    - The characters "No!"
    - The background color of this slide
    - The real number 7.203034×10^{-39}

- It is up to the program/programmer to decide how to **interpret** the sequence of bits

Binary Encoding – Colors

- RGB – Red, Green, Blue
  - Additive color model (light): byte (8 bits) for each color
  - Commonly seen in hex (in HTML, photo editing, etc.)
  - Examples: **Purple**→0x4B2A85, **Gold**→0xBAA47B, **Orange**→0xE2661A, **Turqoise**→0x33997E





Binary Encoding – Characters/Text

"yay" ⇒ 0x79
0x61
0x79

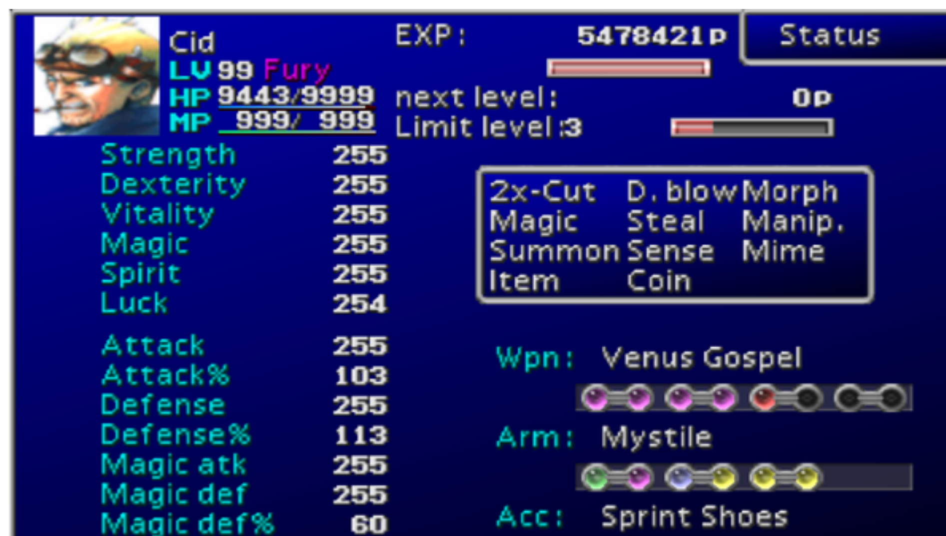
- ASCII Encoding (www.asciitable.com)
  - American Standard Code for Information Interchange

Dec	Hx	Oct	Char		Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL	(null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH	(start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX	(start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX	(end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT	(end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ	(enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK	(acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL	(bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS	(backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB	(horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF	(NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT	(vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF	(NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR	(carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO	(shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI	(shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE	(data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1	(device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2	(device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3	(device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4	(device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK	(negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN	(synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB	(end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN	(cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM	(end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB	(substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC	(escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS	(file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS	(group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS	(record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US	(unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

Binary Encoding – Video Games

- As programs run, in-game data is stored somewhere
- In many old games, stats would go to a maximum of 255
- Pacman "kill screen"
  - http://www.numberphile.com/videos/255.html



Binary Encoding – Files and Programs

- At the lowest level, all digital data is stored as bits!

- Layers of abstraction keep everything comprehensible
  - Data/files are groups of bits interpreted by program
  - Program is actually groups of bits being interpreted by your CPU

- Computer Memory Demo
  - Can try to open files using a text editor
  - From vim: `%!xxd`

giraffe.jpg

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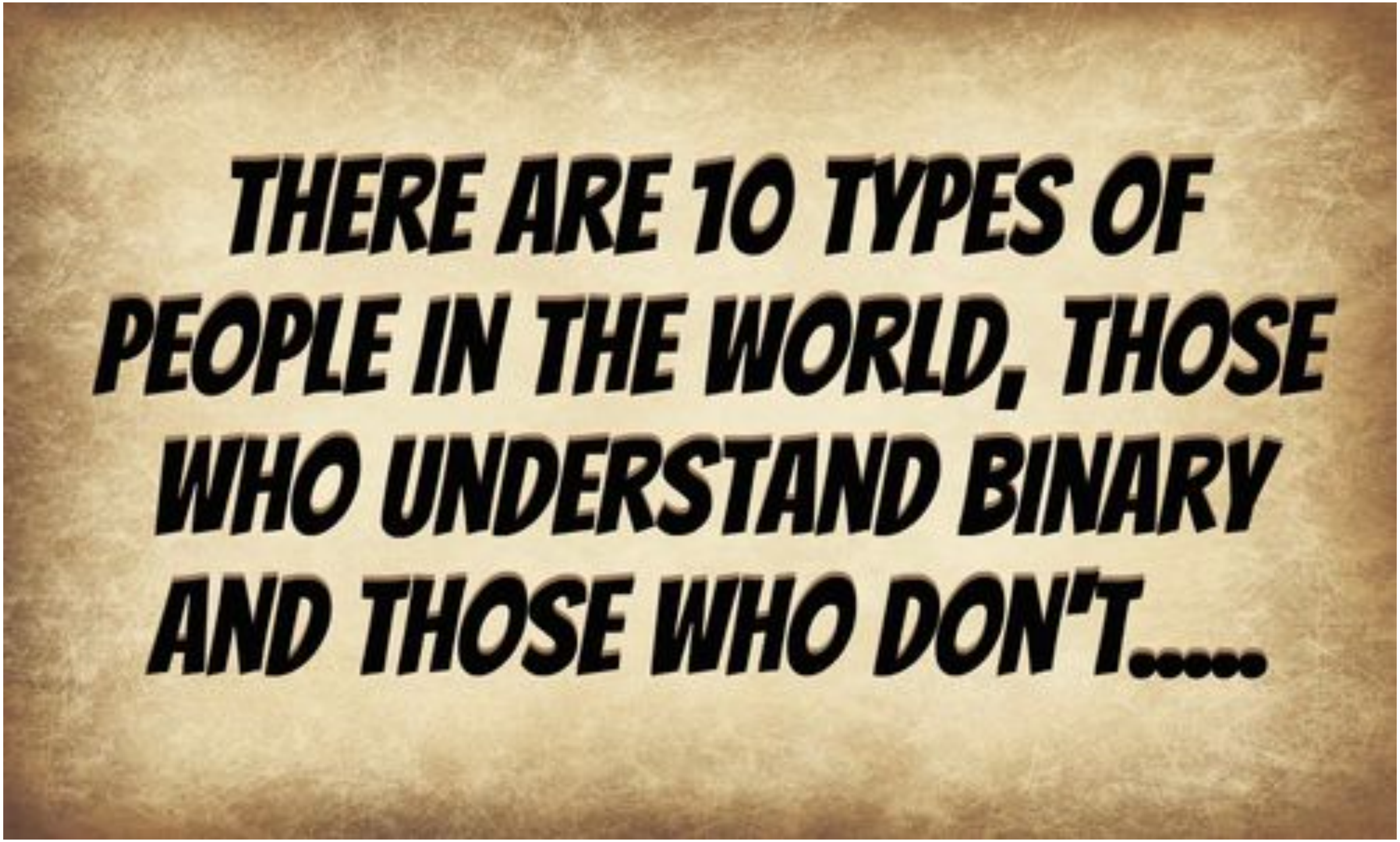
Summary

- Humans think about numbers in decimal; computers think about numbers in binary
  - Base conversion to go between them
  - Hexadecimal is more human-readable than binary
- All information on a computer is binary
- Binary encoding can represent *anything*!
  - Computer/program needs to know how to interpret the bits

Summary


THERE ARE 10 TYPES OF
PEOPLE IN THE WORLD, THOSE
WHO UNDERSTAND BINARY
AND THOSE WHO DON'T.....