

Topic 3: Information and Data

What is Information?

What is Data?

How do Computers Represent Information?

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What is Information?

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What is Information?

- Etymology: Latin, “to give form to” or “to form an idea of”
- Definition: The state of being of an object or system of interest

What is Data?

Information Processing

- A change of information in any manner detectable by an observer
- Using a computer?
 - Encode information into data
 - Process the data
 - Translate data back into information

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Storing Data

- All data in a computer is either a 0 or 1
 - Called a bit
 - Electrically, this is a switch that is either open or closed
- Encoding schemes translate integers, real numbers, letters, pictures, ... into bits

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Boolean Data

- Has two possible values
 - True
 - False
- Easily encoded using a single bit
 - 0: False
 - 1: True

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Integer Data

- How do we represent the numbers 5, 24, or 367 using only ones and zeros?

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Number Systems

- Decimal (Base 10)
 - 10 distinct symbols
 - Each digit is a factor of 10 larger than the digit to its right

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Number Systems

- Binary (Base 2)
 - 2 distinct symbols
 - Each digit is a factor of 2 larger than the digit to its right

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Counting in Binary

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Binary Numbers

- Consider the base 2 number 1001101_2
 - What base 10 number does it represent?

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Binary to Decimal

- Convert 1111_2 to base 10:
- Convert 100010_2 to base 10:
- Convert 0_2 to base 10:

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Decimal to Binary

- What sequence of bits represents the decimal number 12?

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The Division Algorithm

- Allows us to convert from Decimal to Binary
 - Let Q represent the number to convert
 - Repeat
 - Divide Q by 2, recording the Quotient, Q , and the remainder, R
 - Until Q is 0
 - Read the remainders from bottom to top

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Decimal to Binary

- What sequence of bits represents the decimal number 12?

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Decimal to Binary

- Convert 191_{10} to Binary:

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Decimal to Binary

- Convert 222 Base 10 to Base 2:

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Integer Data

- Base 10 integers can be represented using sequences of bits
 - Common sizes:
 - 8 bits (referred to as a byte)
 - 32 bits (referred to as a word)
 - 64 bits (referred to as a double word / long)
 - 16 bits (referred to as a half word / short)

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Negative Numbers

- How can we represent negative numbers?
 - Choose an encoding where we choose that some bit patterns represent positive numbers and others represent negative numbers
 - Simple Idea:
 - Left most bit is the sign – 0: positive, 1: negative
 - Rest of the bits represent the number
 - Other ideas:
 - One's Complement, Two's Complement, Base -2, Excess N, ...

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Other Bases

- A number system can have any base
 - Decimal: Base 10
 - Binary: Base 2
 - Octal: Base 8
 - Hexadecimal: Base 16
 - Vigesimal: Base 20
 - Base 6
 - Any other number we choose...

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Hexadecimal

- Convert 0xA1 to decimal:
- Convert 44 base 16 to decimal:
- Convert CAFE₁₆ to base 10:

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Hexadecimal

- Convert 507_{10} to base 16:

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Hexadecimal

- Convert 180_{10} to base 16:

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Utility of Hexadecimal

- Common to have groups of 32 bits
 - 32 bits is cumbersome to write
 - easy to make mistakes
- Use hexadecimal as a shorthand
 - 8 hex digits instead of 32 bits
 - Group bits from the right
 - Memorize mapping from binary to hex for values between 0 and F

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Utility of Hexadecimal

- Convert 0xF51A to binary
- Convert 1001001010101011010100 from binary to hex

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Representing Characters

- What characters do we need to be able to represent?

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Representing Characters

- Standard encoding scheme called ASCII
 - American Standard Code for Information Interchange
 - 7 bits per character
 - Includes printable characters
 - Includes “control characters” that impact formatting (tab, newline), data transmission (mostly obsolete)
 - Layout seems arbitrary, but actually contains some interesting patterns

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0	0000	0000	NUL	32	0010	0000	64	0100	0000	@	96	0110	0000	`
1	0000	0001	SOH	33	0010	0001	65	0100	0001	A	97	0110	0001	a
2	0000	0010	STX	34	0010	0010	66	0100	0010	B	98	0110	0010	b
3	0000	0011	ETX	35	0010	0011	67	0100	0011	C	99	0110	0011	c
4	0000	0100	EOT	36	0010	0100	68	0100	0100	D	100	0110	0100	d
5	0000	0101	ENQ	37	0010	0101	69	0100	0101	E	101	0110	0101	e
6	0000	0110	ACK	38	0010	0110	70	0100	0110	F	102	0110	0110	f
7	0000	0111	BEL	39	0010	0111	71	0100	0111	G	103	0110	0111	g
8	0000	1000	BS	40	0010	1000	72	0100	1000	H	104	0110	1000	h
9	0000	1001	TAB	41	0010	1001	73	0100	1001	I	105	0110	1001	i
10	0000	1010	LF	42	0010	1010	74	0100	1010	J	106	0110	1010	j
11	0000	1011	VT	43	0010	1011	75	0100	1011	K	107	0110	1011	k
12	0000	1100	FF	44	0010	1100	76	0100	1100	L	108	0110	1100	l
13	0000	1101	CR	45	0010	1101	77	0100	1101	M	109	0110	1101	m
14	0000	1110	SO	46	0010	1110	78	0100	1110	N	110	0110	1110	n
15	0000	1111	SI	47	0010	1111	79	0100	1111	O	111	0110	1111	o
16	0001	0000	DLE	48	0011	0000	80	0101	0000	P	112	0111	0000	p
17	0001	0001	DC1	49	0011	0001	81	0101	0001	Q	113	0111	0001	q
18	0001	0010	DC2	50	0011	0010	82	0101	0010	R	114	0111	0010	r
19	0001	0011	DC3	51	0011	0011	83	0101	0011	S	115	0111	0011	s
20	0001	0100	DC4	52	0011	0100	84	0101	0100	T	116	0111	0100	t
21	0001	0101	NAK	53	0011	0101	85	0101	0101	U	117	0111	0101	u
22	0001	0110	SYN	54	0011	0110	86	0101	0110	V	118	0111	0110	v
23	0001	0111	ETB	55	0011	0111	87	0101	0111	W	119	0111	0111	w
24	0001	1000	CAN	56	0011	1000	88	0101	1000	X	120	0111	1000	x
25	0001	1001	EM	57	0011	1001	89	0101	1001	Y	121	0111	1001	y
26	0001	1010	SUB	58	0011	1010	90	0101	1010	Z	122	0111	1010	z
27	0001	1011	ESC	59	0011	1011	91	0101	1011	[	123	0111	1011	{
28	0001	1100	FS	60	0011	1100	92	0101	1100	\	124	0111	1100	
29	0001	1101	GS	61	0011	1101	93	0101	1101	]	125	0111	1101	}
30	0001	1110	RS	62	0011	1110	94	0101	1110	^	126	0111	1110	~
31	0001	1111	US	63	0011	1111	95	0101	1111	_	127	0111	1111	DEL

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Representing More Characters

- Limitation of ASCII?
 - Only supports Latin character set
 - No support for accents, additional character sets
 - Solutions?

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Representing More Characters

- UTF-8
 - Another encoding scheme for characters
 - Variable length – 1, 2, 3 or 4 bytes per character
 - Compatible with ASCII
 - Consider each byte
 - Left most bit is 0? Usual ASCII Character
 - Left most bits are 110? 2 byte character
 - Left most bits are 1110? 3 byte character
 - Left most bits are 11110? 4 byte character

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UTF-8 Character Examples

Q: 0101 0001

π: 1100 1111 1000 0000

©: 1100 0010 1010 1001

♫: 1111 0000 1001 1101 1000 0100 1001 1110

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Representing Real Numbers

- Standard Representation: IEEE 754 Floating Point
 - Express the number in scientific notation
 - -0.0002589 becomes -2.589×10^{-4}
 - Encode three pieces of information

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Problems with Real Numbers

- How many real numbers are there?
- How many real numbers are there between 0 and 1?
- How many values can be represented by 32 or 64 bits?
- What's the problem?

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Encoding Images

- Common Techniques
 - Vector Images
 - Raster Images

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Representing Colors

- How do we represent a color as a sequence of bits?

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Recall

- Inside a computer:
 - Integers are represented by bits
 - Characters are represented by bits
 - Real numbers are approximated by bits
 - ...
 - Without context, the bits are just data
- Adding context transforms the data into information

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Where Are We Going?

- We know:
 - Information can be encoded as data
 - Computers manipulate data
 - Data can be put into context to make it information
- Next up:
 - More ways of controlling the computer so that it will manipulate data the way we want it to

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