

Topic 3: Information and Data

What is Information?

What is Data?

How do Computers Represent Information?

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Textbook

- Recommended Exercises
 - Starting Out with Python (2nd or 3rd Edition)
 - Chapter 1 Exercises: 3, 4 and 5
- Recommend Reading
 - Starting Out with Python (2nd or 3rd Edition)
 - Section 1.3
 - Appendix C

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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

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What is Data?

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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 $CAFE_{16}$ 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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Representing Characters

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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