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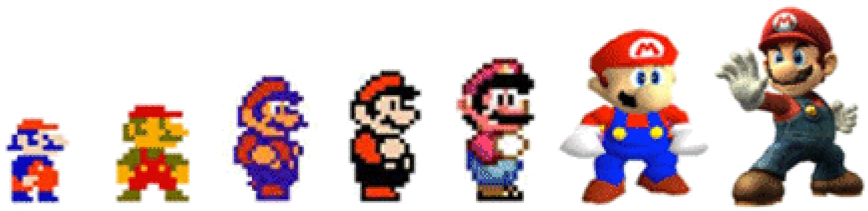
ECE 120 Worksheet 1: Binary Representation



1. Consider the progressive improvement of computer graphics (like the evolution of Mario drawn above). Why does increasing from one or two bits per pixel to 24 to 32 bits per pixel alter the quality of graphics so much? What are these bits encoding?

With more bits, we can encode more colors. Thus, with 2 bits, we can only represent 4 distinct colors whereas with 24 bits we can represent 2^{24} colors, which makes graphics to look more realistic.

2. Consider the bit sequence 10111010. What does the sequence represent? Create a list of possible interpretations

This bit pattern can represent many things, depending on our interpretation. Thus, we can interpret it as an unsigned integer representation of decimal number 186, signed magnitude representation of decimal number -58, 1's complement representation of decimal number -69, or 2's complement representation of decimal number -70.

Unsigned binary representation of integer numbers

- Let's look how integers, such as 1, 2, 3, and so on can be represented using binary digits 0 and 1
- Decimal numbers use base 10 positional notation, e.g., 564 means that there are 5 hundreds, 6 tenths, and 4 ones. Each digit's position in the number defines if this number is ones, or tenths, or hundreds…
  - 564 can be writes as 5*100 + 6*10 + 4, or alternatively, $\mathbf{5}*10^2 + \mathbf{6}*10^1 + \mathbf{4}*10^0$
  - Here 10 is the *base* of the numerical system used
  - Alternatively, 564 can be written as 564_{10}
- Binary numbers work the same way using just two digits, 0 and 1, using base 2 positional notation
  - 00110 can be written as $\mathbf{0}*2^4+\mathbf{0}*2^3+\mathbf{1}*2^2+\mathbf{1}*2^1+\mathbf{0}*2^0$
  - Notation 00110_2 means that the number is written in binary form
  - By the way, $00110_2 = 6_{10}$
  - With k bits we can represent 2^k positive integers, ranging from 0 to 2^k-1

Unsigned binary to decimal conversion

- Recall that a binary integer number consisting of k bits is written in the form $a_{k-1}a_{k-2}…a_1a_0$ where a_i is either 0 or 1
  - Example: 11000111_2
- Compute the decimal number as follows:
  - $A_{10} = a_{k-1}*2^{k-1} + …a_1*2^1 + a_0*2^0$
- Example: convert 0111001_2 to the decimal notation:
  - The magnitude is $0*2^6+1*2^5+1*2^4+1*2^3+0*2^2+0*2^1+1*2^0=32_{10}+16_{10}+8_{10}+1_{10}=57$

Decimal to unsigned binary conversion

- The textbook describes a method based on comparing with descending powers of 2 and subtracting
- A simpler technique is based on short division by 2 with remainder
  - Start by writing the number to be converted
  - Divide it by 2
  - Write ***quotient*** of the division underneath the number
  - Write ***remainder*** of the division next to the number
  - Repeat last 3 steps until the quotient becomes 0
  - Write down the sequence of remainders, starting from the bottom, this is your answer
- Example: $156_{10}=?_2$

```
156  0
 78  0
 39  1
 19  1
  9  1
  4  0
  2  0
  1  1
  0  0
```

  - The answer is $156_{10}=010011100_2$

3. Write the following decimal numbers using 8-bit unsigned representations. Show your work.

   a) 67 b) 85

a)

$67_{10} = 64 + 2 + 1 = 2^6 + 2^1 + 2^0 = 01000011_2$

b)

$85_{10} = 64 + 16 + 4 + 1 = 2^6 + 2^4 + 2^2 + 2^0 = 01010101_2$

4. Write the decimal numbers represented by each of the following unsigned binary patterns. Show your work.

   a) 01101001 b) 10001110

   a) $01101001_2 = 105_{10}$

   b) $10001110_2 = 142_{10}$