Data Representation

Interpreting bits to give them meaning

Part 1: Numbers, Bases, and Binary

Notes for CSC 100 - The Beauty and Joy of Computing
The University of North Carolina at Greensboro

What you should be working on...

Start:

- Homework 1: handout today - due Monday, Sept 18
- Reading *Blown to Bits* Chapter 2 - reflection due Mon, Sept 11

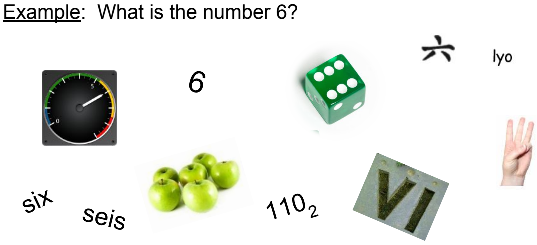
Before Friday:

- Lab 4 Pre-Lab work (shorter than previous - use time to *practice*!)

What is a number?

Question: You've been working with numbers (almost) all your life - what *are* they?

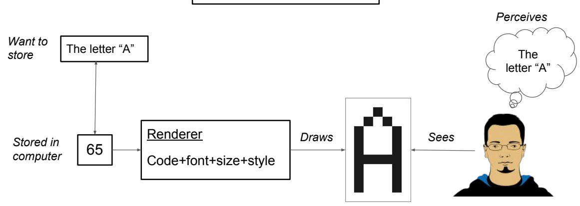
Example: What is the number 6?



Brief Side-Track - Characters and Unicode

Everything stored in a computer is a number - how do you store text?

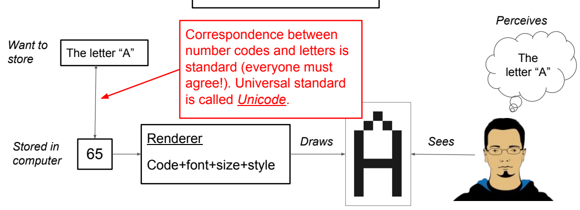
Remember this?
Koan 1: It's All Just Bits.



Brief Side-Track - Characters and Unicode

Everything stored in a computer is a number - how do you store text?

Remember this?
Koan 1: It's All Just Bits.



Strings and Rendering Numbers

A *character* is a displayable symbol (letter, digit, punctuation, …)
A *string* is a sequence of characters

Storing/displaying the string "Hello!":

Character:	H	e	l	l	o	!
Unicode:	72	101	108	108	111	33

Storing/displaying the number 4723:

Character:	4	7	2	3
Unicode:	52	55	50	51

So to display a number, the computer:

1. Computes digits
2. Converts to Unicode vals
3. Sends those to display with font/size/color/style information
4. The display draws shapes

You (usually) don't to worry about this, because….

Strings and Rendering Numbers

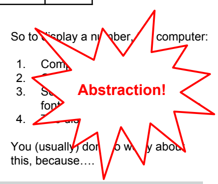
A *character* is a displayable symbol (letter, digit, punctuation, …)
A *string* is a sequence of characters

Storing/displaying the string “Hello!”:

Character:	H	e	l	l	o	!
Unicode:	72	101	108	108	111	33

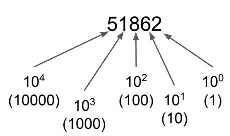
Storing/displaying the number 4723:

Character:	4	7	2	3
Unicode:	52	55	50	51



Decimal Representation

Most common written representation of numbers is "decimal notation":



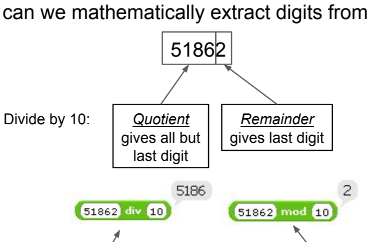
"Representation" is the converse of "Abstraction"

Makes abstractions concrete

Question: Why powers of ten?
Equivalently, why are there 10 different digits?

Decimal Representation

How can we mathematically extract digits from a number?



This is like a division operation, but throws away any remainder or fractional part - not provided by Snap! - think about how to make it!

“mod” gives the remainder after a division

Binary Representation

The powers used in the representation (also, number of different "digits") is called the ***base***.

- "Decimal" is base 10
- "Binary" is base 2

This number is written in binary

1 0 0 1 1

Instead of "digits" have "bits"

2^4 (16) 2^3 (8) 2^2 (4) 2^1 (2) 2^0 (1)

Numbers below the dashed line are all written in decimal (because they're for our benefit).

$1 * 2^4 + 0 * 2^3 + 0 * 2^2 + 1 * 2^1 + 1 * 2^0 = 16 + 2 + 1 =$ ***19***

Converting decimal to binary

Algorithm: we keep dividing by the base (2), recording remainders and keeping quotients.

Operation	*Quotient*	*Remainder*
43 / 2	21	1
21 / 2	10	1
10 / 2	5	0
5 / 2	2	1
2 / 2	1	0
1 / 2	0	1

First bit found is last bit in binary representation.

1 0 1 0 1 1

Using subscripts to denote base:
$43_{10} = 101011_2$

Converting decimal to binary

Algorithm: we keep dividing by the base (2), recording remainders and keeping quotients.

Operation	*Quotient*	*Remainder*
43 / 2	21	1
21 / 2	10	1
10 / 2	5	0
5 / 2	2	1
2 / 2	1	0
1 / 2	0	1

First bit found is last bit in binary representation.

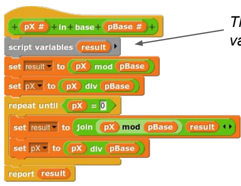
How would you implement this in Snap!?

1 0 1 0 1 1

Using subscripts to denote base:
$43_{10} = 101011_2$

Number to Representation (base ≤ 10)

Snap! Reporter block: number in, string out...



This is new! More about script variables in this week's lab.

Examples from earlier slides

Link to code....

Converting decimal to binary

Just like the Snap! code, we keep dividing by the base (2), recording remainders and keeping quotients.

Operation	*Quotient*	*Remainder*
43 / 2	21	1
21 / 2	10	1
10 / 2	5	0
5 / 2	2	1
2 / 2	1	0
1 / 2	0	1

1 0 1 0 1 1

Practice problems:

1_{10} = _______$_2$
6_{10} = _______$_2$
8_{10} = _______$_2$
12_{10} = _______$_2$
23_{10} = _______$_2$
31_{10} = _______$_2$

Using subscripts to denote base:
$43_{10} = 101011_2$

Converting binary to decimal

Keep a position and a value, and at each step move position to right, multiply value by 2 and add the new bit.

Start position: Leftmost bit	*Start value: 1*
101101	1
101101	1*2 + 0 = 2
101101	2*2 + 1 = 5
101101	5*2 + 1 = 11
101101	11*2 + 0 = 22
101101	22*2 + 1 = 45

So $101101_2 = 45_{10}$

Some terminology:

Leftmost bit is "most significant bit" or "msb"

Rightmost bit is "least significant bit" or "lsb"

Converting binary to decimal

Keep a position and a value, and at each step move position to right, multiply value by 2 and add the new bit.

Start position: Leftmost bit *Start value: 1*

101101	1
101101	1*2 + 0 = 2
101101	2*2 + 1 = 5
101101	5*2 + 1 = 11
101101	11*2 + 0 = 22
101101	22*2 + 1 = 45

So $101101_2 = 45_{10}$

Practice problems:

$11_2 =$ ______$_{10}$
$1001_2 =$ ______$_{10}$
$11011_2 =$ ______$_{10}$
$10001_2 =$ ______$_{10}$
$11111_2 =$ ______$_{10}$
$101011_2 =$ ______$_{10}$

Counting in binary without converting

Picture an odometer with only two values, 0 and 1

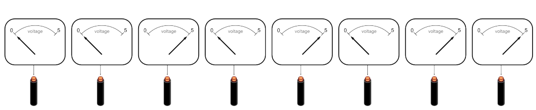
When any wheel goes from 1 to 0, turn the one to the left

0000	$= 0_{10}$	1000	$= 8_{10}$
0001	$= 1_{10}$	1001	$= 9_{10}$
0010	$= 2_{10}$	1010	$= 10_{10}$
0011	$= 3_{10}$	1011	$= 11_{10}$
0100	$= 4_{10}$	1100	$= 12_{10}$
0101	$= 5_{10}$	1101	$= 13_{10}$
0110	$= 6_{10}$	1110	$= 14_{10}$
0111	$= 7_{10}$	1111	$= 15_{10}$

Why binary?

In electronics, you can measure voltages on wires

- Consider 8 wires
- Each with at either 0 volts or 5 volts



Interpreting 0V as 0, and 5V as 1, get: 00101011_2 (= 43_{10})

Voltages can turn on/off switches to create logic circuits

For Future Classes

Some questions for later classes:

Are there useful bases other than binary?

How are pictures or sound clips represented?

Until then:

Practice with this! Binary is the basic language of electronic computers, so if you want to understand modern computers you must be comfortable with their language.

And to answer students' favorite question:

Yes, this will be on the test.