CMSC201
Computer Science I for Majors

Lecture 22 – Binary (and More)

Last Class We Covered

- Dictionaries
  - Creating
  - Accessing
  - Manipulating
  - Methods
- Dictionaries vs Lists

Any Questions from Last Time?

Today's Objectives

- To understand how data is represented and stored in memory
  - Binary numbers
    - Floating point errors
  - ASCII values
- To see the benefits of short circuit evaluation
- To learn about other programming languages

Binary Numbers

Binary Numbers

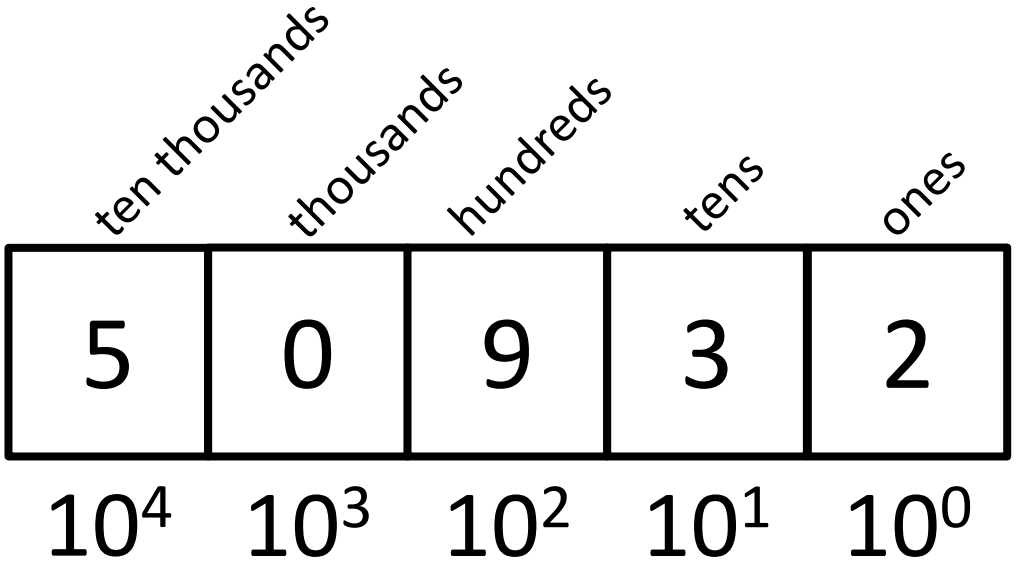
- Computers store all information (code, text, images, sound,) as a binary representation
  - "Binary" means only two parts: 0 and 1
- Specific formats for each file help the computer know what type of item/object it is
- But why use binary?

Decimal vs Binary

- Why do we use decimal numbers?
  - Ones, tens, hundreds, thousands, etc.
- But computers don't have fingers…
  - What do they have instead?
- They only have two states: "on" and "off"

Decimal Example

- How do we represent a number like 50,932?



$$
\begin{aligned}
2 \times 10^0 &= 2 \\
3 \times 10^1 &= 30 \\
9 \times 10^2 &= 900 \\
0 \times 10^3 &= 0000 \\
5 \times 10^4 &= 50000 \\
&\text{------} \\
\text{Total:} &\quad 50932
\end{aligned}
$$

Decimal uses 10 digits, so…

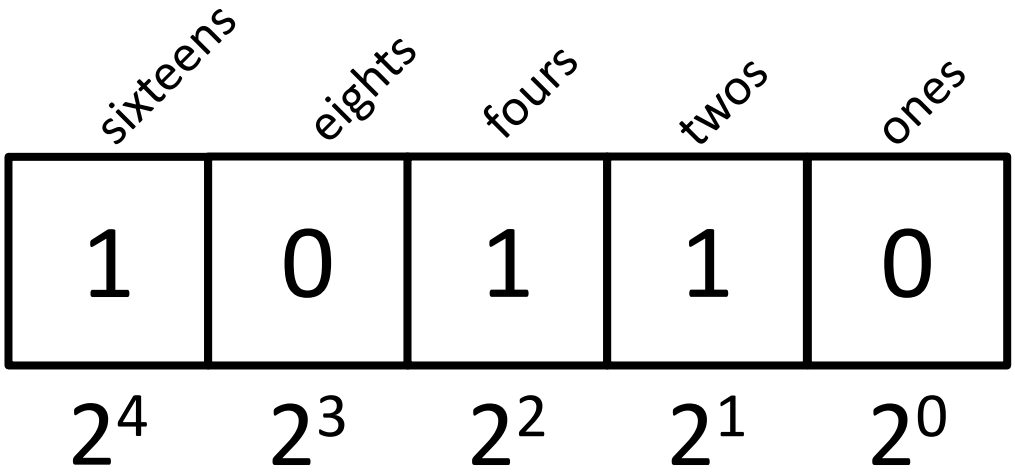
Another Decimal Example

6	7	4	9	3
10^4	10^3	10^2	10^1	10^0
10000	1000	100	10	1
60000	7000	400	90	3

60000+7000+400+90+3 = 67493

Binary Example

- Let's do the same with 10110 in binary



$0 \times 2^0 = 0$
$1 \times 2^1 = 2$
$1 \times 2^2 = 4$
$0 \times 2^3 = 0$
$1 \times 2^4 = 16$
--
Total: 22

Binary uses 2 digits, so our base isn't 10, but…

Binary to Decimal Conversion

- Step 1: Draw Conversion Box
- Step 2: Enter Binary Number
- Step 3: Multiply
- Step 4: Add

1	0	0	0	1	1	0	1
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1
128	0	0	0	8	4	0	1

128 + 0 + 0 + 0 + 8 + 4 + 0 + 1 = 141

Exercise: Converting From Binary

- What are the decimals equivalents of…

```
101
1111
100000
101010
0010 1010
1000 0000
```

Longer binary numbers are often broken into blocks of four digits for the sake of readability

Exercise: Converting From Binary

- What are the decimals equivalents of…

```
101          = 4+0+1                = 5
1111         = 8+4+2+1              = 15
100000       = 32+0+0+0+0+0         = 32
101010       = 32+0+8+0+2+0         = 42
0010 1010    = 32+0+8+0+2+0         = 42
1000 0000    = 128+...+0+0          = 128
```

Decimal to Binary Conversion

- Step 1: Draw Conversion Box
- Step 2: Compare decimal to highest binary value
- Step 3: If binary value is smaller, put a 1 there and subtract the value from the decimal number
- Step 4: Repeat until 0

Convert 163 to binary

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1
1	0	1	0	0	0	1	1

163-128 = 35 35-32 = 3 3-2=1 1-1=0

Converting to Binary

- What are the binary equivalents of…

  9

  27

  68

  216

  255

Converting to Binary

- What are the binary equivalents of…

```
9     = 1001 (or 8+1)
27    = 0001 1011 (or 16+8+2+1)
68    = 0100 0100 (or 64+4)
216   = 1101 1000
        (or 128+64+16+8)
255   = 1111 1111
        (or 128+64+32+16+8+4+2+1)
```

Binary Tips and Tricks

- Some "sanity checking" rules for conversions:

1. Binary can only be 1 or 0
   - If you get "2" of something, it's wrong
2. Odd numbers must have a 1 in the ones column
   - Why? (And what's the rule for even numbers?)
3. Each column's value is the sum of all of the previous columns (to the right) plus one
   - In decimal, what column comes after 999?

Floating Point Errors

Division: Floats and Integers

- Floats (decimals) and integers (whole numbers) behave in two different ways in Python
  - And in many other programming languages
- Biggest difference is how division works
  - Python 3 automatically performs decimal division
    - Have to explicitly call integer division
  - Floats also automatically perform decimal division

Division Examples

- What do the following expressions evaluate to?

1. `4 /  3    = 1.3333333333333333`
2. `4 // 3    = 1`
3. `4 // 3.0  = 1.0`
4. `8 /  3    = 2.6666666666666667`
5. `8 /  2    = 4.0`
6. `5 /  7    = 0.7142857142857143`
7. `5 // 7    = 0`

Floating Point Errors

- In base 10, some numbers are approximated:
  - 0.66666666666666666666666667…
  - 3.14159265358979323846264338328…
- The same is true for base 2
  - 0.00011001100110011001100… (0.1 in base 10)
- This leads to rounding errors with floats
  - **General rule**: Don't compare floats for equality after you've done division on them!

ASCII Values

ASCII Values

- ASCII is how text is represented in computers
  - Just like binary is how numbers are represented
- In ASCII, every character has a unique, individual numerical code
  - Lowercase and uppercase characters are separate
  - Codes go from 0 to 127
    - Why 127?

ASCII TABLE

Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
0	0	[NULL]	32	20	[SPACE]	64	40	@	96	60	`
1	1	[START OF HEADING]	33	21	!	65	41	A	97	61	a
2	2	[START OF TEXT]	34	22	"	66	42	B	98	62	b
3	3	[END OF TEXT]	35	23	#	67	43	C	99	63	c
4	4	[END OF TRANSMISSION]	36	24	$	68	44	D	100	64	d
5	5	[ENQUIRY]	37	25	%	69	45	E	101	65	e
6	6	[ACKNOWLEDGE]	38	26	&	70	46	F	102	66	f
7	7	[BELL]	39	27	'	71	47	G	103	67	g
8	8	[BACKSPACE]	40	28	(	72	48	H	104	68	h
9	9	[HORIZONTAL TAB]	41	29	)	73	49	I	105	69	i
10	A	[LINE FEED]	42	2A	*	74	4A	J	106	6A	j
11	B	[VERTICAL TAB]	43	2B	+	75	4B	K	107	6B	k
12	C	[FORM FEED]	44	2C	,	76	4C	L	108	6C	l
13	D	[CARRIAGE RETURN]	45	2D	-	77	4D	M	109	6D	m
14	E	[SHIFT OUT]	46	2E	.	78	4E	N	110	6E	n
15	F	[SHIFT IN]	47	2F	/	79	4F	O	111	6F	o
16	10	[DATA LINK ESCAPE]	48	30	0	80	50	P	112	70	p
17	11	[DEVICE CONTROL 1]	49	31	1	81	51	Q	113	71	q
18	12	[DEVICE CONTROL 2]	50	32	2	82	52	R	114	72	r
19	13	[DEVICE CONTROL 3]	51	33	3	83	53	S	115	73	s
20	14	[DEVICE CONTROL 4]	52	34	4	84	54	T	116	74	t
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85	55	U	117	75	u
22	16	[SYNCHRONOUS IDLE]	54	36	6	86	56	V	118	76	v
23	17	[ENG OF TRANS. BLOCK]	55	37	7	87	57	W	119	77	w
24	18	[CANCEL]	56	38	8	88	58	X	120	78	x
25	19	[END OF MEDIUM]	57	39	9	89	59	Y	121	79	y
26	1A	[SUBSTITUTE]	58	3A	:	90	5A	Z	122	7A	z
27	1B	[ESCAPE]	59	3B	;	91	5B	[	123	7B	{
28	1C	[FILE SEPARATOR]	60	3C	<	92	5C	\	124	7C	|
29	1D	[GROUP SEPARATOR]	61	3D	=	93	5D	]	125	7D	}
30	1E	[RECORD SEPARATOR]	62	3E	>	94	5E	^	126	7E	~
31	1F	[UNIT SEPARATOR]	63	3F	?	95	5F	_	127	7F	[DEL]

Image from wikimedia.org

A TABLE

"control" characters

uppercase letters

Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
0	0	[NULL]	32	20	[SPACE]	64	40	@	96	60	`
1	1	[START OF HEADING]	33	21	!	65	41	A	97	61	a
2	2	[START OF TEXT]	34	22	"	66	42	B	98	62	b
3	3	[END OF TEXT]	35	23	#	67	43	C	99	63	c
4	4	[END OF TRANSMISSION]	36	24	$	68	44	D	100	64	d
5	5	[ENQUIRY]	37	25	%	69	45	E	101	65	e
6	6	[ACKNOWLEDGE]	38	26	&	70	46	F	102	66	f
7	7	[BELL]	39	27	'	71	47	G	103	67	g
8	8	[BACKSPACE]	40	28	(	72	48	H	104	68	h
9	9	[HORIZONTAL TAB]	41	29	)	73	49	I	105	69	i
10	A	[LINE FEED]	42	2A	*	74	4A	J	106	6A	j
11	B	[VERTICAL TAB]	43	2B	+	75	4B	K	107	6B	k
12	C	[FORM FEED]	44	2C	,	76	4C	L	108	6C	l
13	D	[CARRIAGE RETURN]	45	2D	-	77	4D	M	109	6D	m
14	E	[SHIFT OUT]	46	2E	.	78	4E	N	110	6E	n
15	F	[SHIFT IN]	47	2F	/	79	4F	O	111	6F	o
16	10	[DATA LINK ESCAPE]	48	30	0	80	50	P	112	70	p
17	11	[DEVICE CONTROL 1]	49	31	1	81	51	Q	113	71	q
18	12	[DEVICE CONTROL 2]	50	32	2	82	52	R	114	72	r
19	13	[DEVICE CONTROL 3]	51	33	3	83	53	S	115	73	s
20	14	[DEVICE CONTROL 4]	52	34	4	84	54	T	116	74	t
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85	55	U	117	75	u
22	16	[SYNCHRONOUS IDLE]	54	36	6	86	56	V	118	76	v
23	17	[ENG OF TRANS. BLOCK]	55	37	7	87	57	W	119	77	w
24	18	[CANCEL]	56	38	8	88	58	X	120	78	x
25	19	[END OF MEDIUM]	57	39	9	89	59	Y	121	79	y
26	1A	[SUBSTITUTE]	58	3A	:	90	5A	Z	122	7A	z
27	1B	[ESCAPE]	59	3B	;	91	5B	[	123	7B	{
28	1C	[FILE SEPARATOR]	60	3C	<	92	5C	\	124	7C	|
29	1D	[GROUP SEPARATOR]	61	3D	=	93	5D	]	125	7D	}
30	1E	[RECORD SEPARATOR]	62	3E	>	94	5E	^	126	7E	~
31	1F	[UNIT SEPARATOR]	63	3F	?	95	5F	_	127	7F	[DEL]

symbols & numbers

lowercase letters

Image from wikimedia.org

Comparing Strings

- The values of the ASCII characters are used when comparing strings together
  - Which can lead to some "weird" results

```
>>> "cat" < "dog"
True
>>> "cat" < "Dog"
False
>>> "DOG" < "dog"
True
```

<

 Images from publicdomainpictures.net

More on Comparing Strings

- Gets even more complex when you start adding in numbers and symbols

```
>>> "2" < "one"
True
>>> "good?" < "good!"
False
>>> "UK" < "U.K."
False
```

Rules for Comparisons

- To avoid (some) of these issues:

- Always use `.lower()` for comparing strings
- Pay attention to symbols
  - *e.g.*, spaces, hyphens, punctuation, etc.
  - Either remove them, or keep as part of the order

ASCII Characters to ASCII Values

- We can convert between ASCII characters and their values using **`ord()`** and **`chr()`**

- The **`ord()`** function takes in a single character, and returns its ASCII value
- The **`chr()`** function takes in an integer, and returns its ASCII character

Using `chr()` and `ord()`

```
>>> chr(65)
'A'
>>> chr(65+32)
'a'
>>> ord('?')
63
>>> ord("d")
100
>>> ord("e")
101
```

“Short Circuit” Evaluation

Review: Complex Expressions

- We can put multiple operators together!

```
bool4 = a and (b or c)
```

- What does Python do first?
  - Computes **`(b or c)`**
  - Computes **`a and`** the result

This isn't strictly true!

Short Circuit Evaluation

- Python tries to be efficient (*i.e.*, lazy), and so it won't do any more work than necessary
  - If the remainder of an expression won't change the outcome, Python doesn't look at it
  - This is called "short circuiting"
- "**`and`**" statements short circuit as soon as an expression evaluates to **`False`**
- "**`or`**" statements short circuit as soon as an expression evaluates to **`True`**

Short Circuiting – `and`

- Notice that in the expression:

```
bool1 = a and (b or c)
```

- If `a` is `False`
- The rest of the expression doesn't matter

- Python will realize this, and if `a` is `False` won't bother with the rest of the expression

Short Circuiting – `or`

- Notice that in the expression:

```
bool1 = a or (b or c)
```

- If `a` is `True`
- The rest of the expression doesn't matter

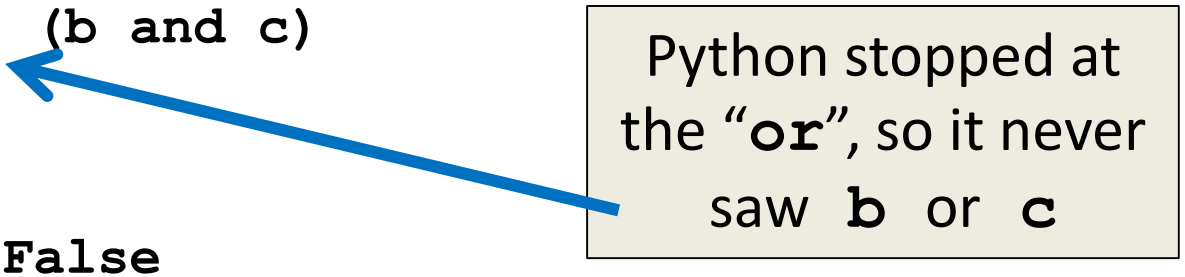
- Python will realize this, and if `a` is `True` won't bother with the rest of the expression

Causing Errors

- This can lead to "new" errors in old code

```
>>> a = True
>>> # Variables b and c not defined
>>> a or (b and c)
True

>>> a = False
>>> a or (b and c)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
NameError: name 'b' is not defined
```



Programming Languages

"Levels" of Languages

- Machine Code (lowest level)
  - Code that the computer can directly execute
  - Binary (0 or 1)
- Low Level Language
  - Interacts with the hardware of the computer
  - Assembly language
- High Level Language
  - Compiled or interpreted into machine code
  - Java, C++, Python

Compilation vs Interpretation

- Compiler
  - A complex computer program that takes another program and translates it into machine language
  - Compilation takes longer, but programs run faster
- Interpreter
  - Simulates a computer that can understand a high level language
  - Allows programming “on the fly”

Announcements

- Homework 6 out on Blackboard
  - Homework due Friday, April 28th @ 8:59:59 PM
- Project 3 will be out Saturday
  - Also going to be on recursion
- Final exam is Friday, May 19th from 6 to 8 PM