CS 31: Introduction to Computer Systems

August 30th 2016
Course Staff

Professor: Bryce Wiedenbeck (call me Bryce)
• I’m a Swattie (class of ‘08).
• My research is on algorithmic game theory.
• My primary hobby is ultimate Frisbee.

Ninjas:

Lu Min  Rachel  Jeff  Emily  Douglass
Meeting times

Lecture: Tue/Thu 1:15-2:30 SCI 199

Lab: Wed
- A: 10:30-12 Clothier 016 (bookstore lab)
- B: 1:15-2:45 SCI 240
- C: 2:30-4 SCI 240

Ninja Session: Sun 7-11pm SCI 240

Office Hours: M 11-1:30, Tu 2:30-4:30, Th 2:30-4
Ninja Sessions and Office Hours

• Lecture + Lab = 2 * 1:15 + 1:30 = 4 hours of class

• Ninja session: 4 additional hours every week

• Office hours: 6 additional hours every week

Take advantage of this time!

If all you do is come to lecture and lab, you are not getting the most out of this class.
Resources

Course web page:  
[cs.swarthmore.edu/~bryce/cs31/f16](cs.swarthmore.edu/~bryce/cs31/f16)

Piazza forum:  
[piazza.com/swarthmore/fall2016/cs31](piazza.com/swarthmore/fall2016/cs31)

Supplemental textbook (on reserve in Cornell)
Grading

35%  Lab assignments (two late days total)
25%  Midterm exam
25%  Final exam
25%  Written homework
5%   Reading quizzes (lowest three dropped)
5%   Class participation
Reading Quizzes

• Readings from online sources

• Target low difficulty: did you read?

• Goal: incentivize / reward preparation
  • Can be an easy 5%!

• You may bring handwritten notes.
Class Participation

General format:

• I will pose a question or problem.

• You will first answer on your own.

• You will then compare answers with your neighbors and discuss until you agree.

• You will then answer again (everyone in the group must submit the same answer).
Class Participation

Why are we using this format?

Research shows that people learn better this way!

If I spent the entire class lecturing, I might be able to present more information, but you would retain less of it.
Clickers!

• Record which one you took.
  • Write it down.
  • Take a picture.
  • Email yourself.

• Register your clicker: clickers.cs.swarthmore.edu

• Return it to the correct bin after class.

• Use the same clicker every time.
Things you need to do this week

**TODAY**

- Register your clicker
- Complete Lab 0
- Attend *Using Unix* session (7-8 pm SCI 256)

**TOMORROW**

- Attend lab
- Reading for Thursday
Let’s get started!
How does a computer run your program?

1. Compiler translates C code into an executable.
2. Shell forks a new process.
3. Operating systems allocates resources to the process.
4. CPU loads instructions and data from memory.
5. Instructions specify calculations to perform on the data.
6. Current passing through circuits carries out calculations.
7. Circuits are composed of gates, which are built from wires and transistors.
This class builds from the bottom up

Order of systems topics:
• Binary representation of data
• Building simple circuits from gates
• Building a CPU from simple circuits
• Assembly language
• Memory
• Operating systems
• Processes
• Parallel Programming

We’ll also learn lots of C programming along the way.
Binary numbers

• How computers represent all data.

• Strings are represented as a sequence of characters, and each character is represented by a number.

• The screen is a collection of pixels, and each pixel’s color is represented by several numbers.

• All numbers are in binary: they’re made up of ones and zeros.
Let’s start with what we know...

• Decimal number system (Base 10)

• Sequence of digits in range [0, 9]

64025

Digit #4  Digit #0
What is the significance of the $N^{th}$ digit in this number system? What does it contribute to the overall value?

A. $d_N \times 1$
B. $d_N \times 10$
C. $d_N \times 10^N$
D. $d_N \times 10^N$
E. $d_N \times 10^{d_N}$

Consider the meaning of $d_3$ (the value 4) above. What is it contributing to the total value?
Positional Notation

• The meaning of a digit depends on its position in a number.

A number, written as the sequence of digits $d_n d_{n-1} \ldots d_2 d_1 d_0$ in base $b$ represents the value

$$d_n \times b^n + d_{n-1} \times b^{n-1} + \ldots + d_2 \times b^2 + d_1 \times b^1 + d_0 \times b^0$$
Decimal: Base 10

• Used by humans

A number, written as the sequence of digits \(d_n d_{n-1} \ldots d_2 d_1 d_0\) where \(d\) is in \(\{0,1,2,3,4,5,6,7,8,9\}\) represents the value:

\[
d_n \times 10^n + d_{n-1} \times 10^{n-1} + \ldots + d_2 \times 10^2 + d_1 \times 10^1 + d_0 \times 10^0
\]

64025 =
6 \times 10^4 + 4 \times 10^3 + 0 \times 10^2 + 2 \times 10^1 + 5 \times 10^0

60000+ 4000 + 0 + 20 + 5
Binary: Base 2

• Used by computers

A number, written as the sequence of digits $d_n d_{n-1} \ldots d_2 d_1 d_0$ where $d$ is in $\{0, 1\}$, represents the value

$$d_n \times 2^n + d_{n-1} \times 2^{n-1} + \ldots + d_2 \times 2^2 + d_1 \times 2^1 + d_0 \times 2^0$$
What is the value of 110101 in decimal?

A number, written as the sequence of digits \(d_n d_{n-1} \ldots d_2 d_1 d_0\) where \(d\) is in \(\{0, 1\}\), represents the value

\[d_n \times 2^n + d_{n-1} \times 2^{n-1} + \ldots + d_2 \times 2^2 + d_1 \times 2^1 + d_0 \times 2^0\]

A. 26
B. 53
C. 61
D. 106
E. 128
Converting Decimal ➔ Binary

• Two methods:
  • division by two remainder
  • powers of two and subtraction
Method 1: decimal value $D$, binary result $b$ ($b_i$ is $i$th digit):

\[
\begin{align*}
i &= 0 \\
\text{while } (D > 0) &
\begin{align*}
&\quad \text{if } D \text{ is odd} \\
&\quad \quad \text{set } b_i \text{ to 1} \\
&\quad \text{if } D \text{ is even} \\
&\quad \quad \text{set } b_i \text{ to 0} \\
&\quad i++ \\
&\quad D = D/2
\end{align*}
\end{align*}
\]

idea: $D = b$  
example: $D = 105$  
a0 = 1

Example: Converting 105
Method 1: decimal value $D$, binary result $b$ ($b_i$ is $i$th digit):

\[ i = 0 \]

while $(D > 0)$

if $D$ is odd

set $b_i$ to 1

if $D$ is even

set $b_i$ to 0

$i++$

$D = D/2$

**Example: Converting 105**

<table>
<thead>
<tr>
<th>$D$</th>
<th>$b$</th>
<th>$a_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>105</td>
<td>01101001</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>1000010</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>11010</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>1101</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

idea: $D = b$

element: $D = 105$

$D = b/2$

$D = 52$

$D = 26$

$D = 13$

$D = 6$

$D = 3$

$D = 1$

$D = 0$

105 = 01101001
Method 2

$2^0 = 1, \ 2^1 = 2, \ 2^2 = 4, \ 2^3 = 8, \ 2^4 = 16, \ 2^5 = 32, \ 2^6 = 64, \ 2^7 = 128$

• To convert 105:
  • Find largest power of two that’s less than 105 (64)
  • Subtract 64 ($105 - 64 = 41$), put a 1 in $d_6$
  • Subtract 32 ($41 - 32 = 9$), put a 1 in $d_5$
  • Skip 16, it’s larger than 9, put a 0 in $d_4$
  • Subtract 8 ($9 - 8 = 1$), put a 1 in $d_3$
  • Skip 4 and 2, put a 0 in $d_2$ and $d_1$
  • Subtract 1 ($1 - 1 = 0$), put a 1 in $d_0$ (Done)

\[ \begin{array}{cccccccc} 1 & 1 & 0 & 1 & 0 & 0 & 0 & 1 \end{array} \]
What is the value of 357 in binary?

A. 101100011
B. 101100101
C. 101101001
D. 101110101
E. 110100101

\[2^0 = 1, \ 2^1 = 2, \ 2^2 = 4, \ 2^3 = 8, \ 2^4 = 16, \ 2^5 = 32, \ 2^6 = 64, \ 2^7 = 128\]
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