Reminder

Section 20 is the “systems track.”
Course Content

• **Machine model**
  ◦ Machine code
  ◦ C

• **Data structures**
  ◦ Balanced binary trees, hash tables, ...

• **Algorithms**
  ◦ Binary search, dynamic programming, ...
CS 1410-20 Machine

\[(+ (* 3 4) 8)\]
\[\rightarrow (+ 12 8)\]
\[\rightarrow 20\]
CS 2420-20 Machine

Diagram showing the flow of data between Disk, Memory, CPU, and Screen, with values in Memory and Registers.
The Jam2000 Machine

Memory

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>17</th>
<th>96</th>
<th>3</th>
<th>4</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>17</td>
<td>1</td>
<td>88</td>
<td>77</td>
<td>11</td>
<td>19</td>
</tr>
<tr>
<td>4</td>
<td>21</td>
<td>11</td>
<td>26</td>
<td>2</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>81</td>
<td>5</td>
<td>97</td>
<td>31</td>
<td>45</td>
<td>90</td>
</tr>
</tbody>
</table>

Disk

Screen

CPU

[13]: +0019 (Id R1 0) %

Registers

| 40 | 8  | 37 | 9  | 13 | 44 | 9 |

Shell
Everything is a Number

The number 1490: 1490
The “copy register 4 to 1” instruction: 1490
The name of the 1491st memory cell: 1490
A greenish-blue pixel: 1490

In fact, everything is represented by a number between -99999999 and 999999999

• but memory addresses are 0 to 9999
• only some numbers are sensible instructions
• the screen ignores some digits
Pixels

- Screen memory starts at 8000
- Digits encode red, green, and blue intensities:

\[
\begin{array}{cccccc}
? & ? & d_r & d_r & d_g & d_g \\
\end{array}
\]

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>990000</th>
<th>9900</th>
<th>99</th>
<th>888888</th>
<th>999900</th>
</tr>
</thead>
</table>

[Diagram showing color encoding]
Instructions

Numbers encode actions like “put the number $d_7d_6d_5d_4d_3d_2$ in register $x$”:

$$(\text{ldi R}x\ d_7d_6d_5d_4d_3d_2)$$

$d_7$ $d_6$ $d_5$ $d_4$ $d_3$ $d_2$ $x$ 9

“Put the number 77 in register 6”:

$$(\text{ldi R}6\ 77)$$

0 0 0 0 7 7 6 9