Babbage Machines

Chris Gregg, based on slides by Eric Roberts
CS 208E
September 24, 2018
<table>
<thead>
<tr>
<th>Week 1</th>
<th>Introductions; course overview; Babbage machines; Ada Lovelace</th>
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<tbody>
<tr>
<td>Week 2</td>
<td>Karel the Robot; beginning JavaScript; algorithms</td>
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<td>Week 3</td>
<td>Binary arithmetic; digital logic</td>
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<td>Week 4</td>
<td>Stored-program machines; the Toddler machine</td>
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<td>Week 5</td>
<td>Guest Lecture: Dr. Enigma, Turing machines; the Busy Beaver problem; undecidability</td>
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<td>Week 6</td>
<td>Computational complexity; the P = NP question</td>
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<td>Week 7</td>
<td>Cryptography; public-key cryptography; digital signatures</td>
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<td>Week 8</td>
<td>Networking; networking algorithms; Artificial Intelligence</td>
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<td>Week 9</td>
<td>Early Programming Languages / Reflections on Trusting Trust</td>
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<td>Week 10</td>
<td>Historiography of Computing</td>
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</tbody>
</table>
Who is Chris Gregg?

• Career:
  • Johns Hopkins University Bachelor’s of Science in Electrical and Computer Engineering
  • Seven years active duty, U.S. Navy (14+ years reserves)
  • Harvard University, Master’s of Education
  • Seven years teaching high school physics (Brookline, MA and Santa Cruz, CA)
  • University of Virginia, Ph.D. in Computer Engineering
  • Three years teaching computer science at Tufts University
  • Stanford! (arrived, Fall 2016)
• Personal website: http://ecosimulation.com/chrisgregg
Web page: https://web.stanford.edu/class/cs208e/

Textbook: Eric Roberts’s *Great Ideas in Computer Science Reader* (available in the bookstore in hard copy, or online (see website) as a PDF)
## CS 208E—Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class participation</td>
<td>20%</td>
</tr>
<tr>
<td>Weekly assignments</td>
<td>30%</td>
</tr>
<tr>
<td>Class presentation</td>
<td>10%</td>
</tr>
<tr>
<td>Final project</td>
<td>40%</td>
</tr>
</tbody>
</table>
Let’s Play a Game

Question 1

Q: Who invented the idea of the “difference engine,” in 1822?
Let’s Play a Game

Question 1

Q: Who invented the idea of the “difference engine,” in 1822?
A: Charles Babbage

Charles Babbage
(1791-1871)
Let’s Play a Game

Question 2

Q: Who is often described as “the first computer programmer?”
Let’s Play a Game

Question 2

Q: Who is often described as “the first computer programmer?”
A: Ada Lovelace, who was friends with Charles Babbage
Let’s Play a Game

Question 3

Q: What does this symbol represent?
Let’s Play a Game

Question 2

Q: What does this symbol represent?
A: Karel the Robot, used in CS 106A to introduce programming
Let’s Play a Game

Question 4

Q: What British Mathematician worked at Bletchley Park during World War II, is a giant in theoretical computer science, and has the “Nobel Prize for computing” named after him?
Let’s Play a Game

Question 4

Q: What British Mathematician worked at Bletchley Park during World War II, is a giant in theoretical computer science, and has the “Nobel Prize for computing” named after him?

A: Alan Turing

Just kidding on the picture (that is Benedict Cumberbatch, who played Turing in the 2014 film, *The Imitation Game*)
Let’s Play a Game

Question 4

Q: What British Mathematician worked at Bletchley Park during World War II, is a giant in theoretical computer science, and has the “Nobel Prize for computing” named after him?

A: Alan Turing
Let’s Play a Game

Question 5

Q: Whose master's thesis, on digital circuit theory, has been called "possibly the most important, and also the most noted, master's thesis of the century"?
Let’s Play a Game

Question 5
Q: Whose master's thesis, on digital circuit theory, has been called "possibly the most important, and also the most noted, master's thesis of the 20th century"?
Q: Claude Shannon, who also invented information theory.
Let’s Play a Game

Question 6

Q: Who is known as "the grandmother of COBOL" by popularizing the idea of machine-independent programming languages?
Let’s Play a Game

Question 6

Q: Who is known as "the grandmother of COBOL" by popularizing the idea of machine-independent programming languages?

A: Grace Hopper, who was also a Rear Admiral in the U.S. Navy
Let’s Play a Game

Question 7

Q: In what decade were each of the following programming languages created?

1. Pascal
2. Python
3. BASIC
4. ALGOL
5. FORTRAN
6. Javascript
7. C
8. C++
9. Java
10. COBOL

11. LISP
12. Swift
13. Scratch
14. C#
15. Perl
16. Assembly Language
17. Ruby
18. PHP
## Let’s Play a Game

### Question 7

Q: In what decade were each of the following programming languages created?

<table>
<thead>
<tr>
<th>Language</th>
<th>Decade</th>
<th>Language</th>
<th>Decade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pascal</td>
<td>1960s</td>
<td>FORTRAN</td>
<td>1950s</td>
</tr>
<tr>
<td>Python</td>
<td>1990s</td>
<td>Swift</td>
<td>2010s</td>
</tr>
<tr>
<td>BASIC</td>
<td>1960s</td>
<td>Scratch</td>
<td>2000s</td>
</tr>
<tr>
<td>ALGOL</td>
<td>1950s</td>
<td>C#</td>
<td>2000s</td>
</tr>
<tr>
<td>Javascript</td>
<td>1990s</td>
<td>Perl</td>
<td>1980s</td>
</tr>
<tr>
<td>C</td>
<td>1970s</td>
<td>Assembly Language</td>
<td>1940s</td>
</tr>
<tr>
<td>C++</td>
<td>1980s</td>
<td>Ruby</td>
<td>1990s</td>
</tr>
<tr>
<td>Java</td>
<td>1990s</td>
<td>PHP</td>
<td>1990s</td>
</tr>
<tr>
<td>COBOL</td>
<td>1950s</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Let’s Play a Game

Question 8a

Q: Name the following computers:
Let’s Play a Game

Question 8a

Q: Name the following computers:

Babbage Difference Engine

Bombe from Bletchley Park

ENIAC

IBM System/360
Let’s Play a Game

Question 8b

Q: Name the following computers:
Let’s Play a Game

Question 8b

Q: Name the following computers:

Xerox
PARC Alto
Altair 8800
Apple II
IBM PC
Osborne 1
Let’s Play a Game

Question 9

Q: Who is this?
Let’s Play a Game

Question 9

Q: Who is this?
A: Donald Knuth -- Turing Award winner, author of *The Art of Computer Programming*, creator of the TEx typesetting system, office in Gates.

Knuth is a giant in computer science, and you'll probably see him around campus!
As part of this class, we will take a field trip (date TBD) to the museum, which is located in Mountain View.
Charles Babbage is one of the most fascinating figures in the history of computing.

Captivated by the idea that he could produce mathematical tables “by steam,” Babbage designed two early computing machines—the *Difference Engine* and the vastly more powerful *Analytical Engine*—that anticipated many of the features found in modern computers.

Neither machine was completed within Babbage’s lifetime. The Science Museum in London made a full-scale replica of the Difference Engine for the bicentennial of Babbage’s birth in 1991.
Babbage completed a working model of his Difference Engine, which he had on display at his popular soirées in London.

The model on the left was given to the London Science Museum by Babbage’s son.
Difference Engine #2

WIRED
Calculating with Differences

Suppose that you want to produce a table of squares:

\[
\begin{array}{cccccccccc}
0^2 & 1^2 & 2^2 & 3^2 & 4^2 & 5^2 & 6^2 & 7^2 & 8^2 & 9^2 \\
0 & 1 & 4 & 9 & 16 & 25 & 36 & 49 & 64 & 81 \\
\end{array}
\]

**first differences**

\[
\begin{array}{cccccccccc}
1 & 3 & 5 & 7 & 9 & 11 & 13 & 15 & 17 \\
\end{array}
\]

**second differences**

\[
\begin{array}{cccccccccc}
2 & 2 & 2 & 2 & 2 & 2 & 2 & 2 & 2 \\
\end{array}
\]

Note that the second differences are constant.
Exercise: Do the Same for a Table of Cubes

<table>
<thead>
<tr>
<th></th>
<th>$0^3$</th>
<th>$1^3$</th>
<th>$2^3$</th>
<th>$3^3$</th>
<th>$4^3$</th>
<th>$5^3$</th>
<th>$6^3$</th>
<th>$7^3$</th>
<th>$8^3$</th>
<th>$9^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>8</td>
<td>27</td>
<td>64</td>
<td>125</td>
<td>216</td>
<td>343</td>
<td>512</td>
<td>729</td>
</tr>
</tbody>
</table>

| first differences | 1 | 7 | 19 | 37 | 61 | 91 | 127 | 169 | 217 |
| second differences | 6 | 12 | 18 | 24 | 30 | 36 | 42 | 48 |
| third differences | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |

(first differences, second differences, third differences)
Exercise: Polynomial Calculation

How would you program the Difference Engine to calculate the terms in the sequence generated by the following polynomial:

\[ f(x) = x^2 - 5x + 10 \]
Exercise: A Table of Trigonometric Sines

Consider the following table, which shows the value of \( \sin(\theta) \) for values of \( \theta \) between 30 degrees and 31 degrees in increments of 0.1 degree:

<table>
<thead>
<tr>
<th>( \theta )</th>
<th>( \sin(\theta) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.0</td>
<td>0.5000000000</td>
</tr>
<tr>
<td>30.1</td>
<td>0.501510737</td>
</tr>
<tr>
<td>30.2</td>
<td>0.503019947</td>
</tr>
<tr>
<td>30.3</td>
<td>0.504527624</td>
</tr>
<tr>
<td>30.4</td>
<td>0.506033764</td>
</tr>
<tr>
<td>30.5</td>
<td>0.507538363</td>
</tr>
<tr>
<td>30.6</td>
<td>0.509041416</td>
</tr>
<tr>
<td>30.7</td>
<td>0.510542918</td>
</tr>
<tr>
<td>30.8</td>
<td>0.512042865</td>
</tr>
<tr>
<td>30.9</td>
<td>0.513541252</td>
</tr>
<tr>
<td>31.0</td>
<td>0.515038075</td>
</tr>
</tbody>
</table>

How would you code this calculation on the Difference Engine?
Augusta Ada Byron, the daughter of the English poet Lord Byron and his wife Anne, was encouraged to pursue her interests in science and mathematics at a time when few women were allowed to study those subjects. At the age of 17, Ada met Charles Babbage and became fascinated by his machines. Ada was convinced of the potential of Babbage’s Analytical Engine and wrote extensive notes on its design, along with several complex mathematical programs that have led many people to characterize her as the first programmer. In 1980, the U.S. Department of Defense named the programming language Ada in her honor.
The End