Algorithmic Problem Solving

Mohan Paturi

University of California, San Diego

SPIS 2014

Today's Plan

1. World of algorithms
2. Divide-and-conquer method
3. Tromino puzzle
4. Counterfeit among 8 coins
5. Course logistics
6. Homework

What is APS?

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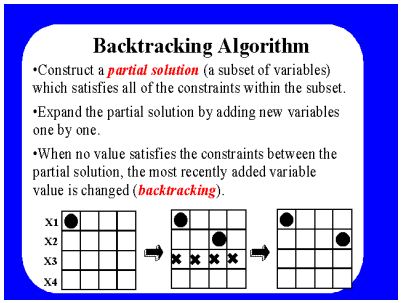
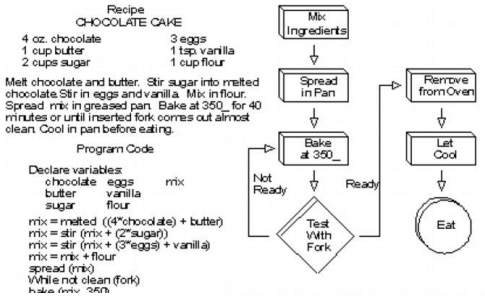
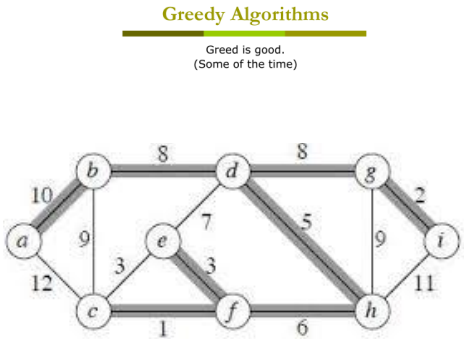
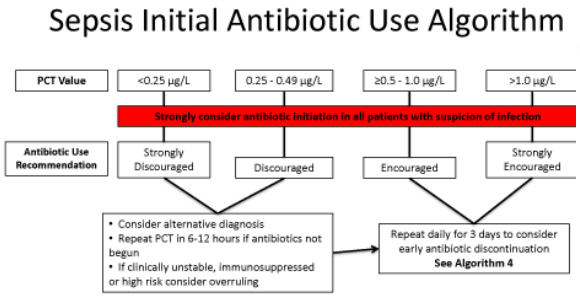
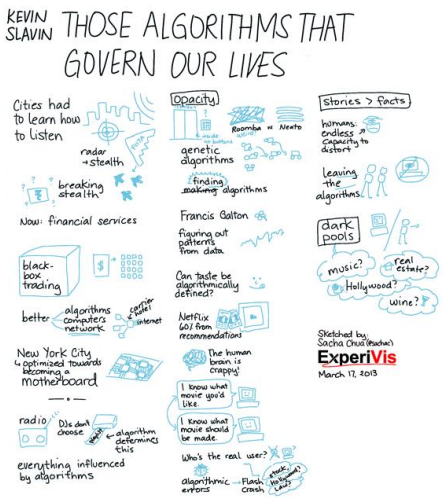
- Emphasis on writing solutions precisely and coherently.
- Practice discovering algorithms and describing them.
- Analyze algorithms











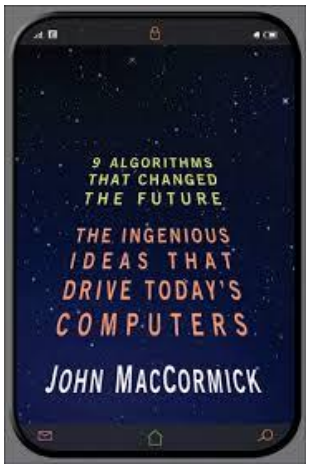


Figure: World of Algorithms

Divide-and-conquer method

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- Combine the solutions to the subproblems to arrive at the solution to the problem.
- Balance the sizes of the subproblems as much as possible.

Tromino Puzzle

- Cover a $2^n \times 2^n$ ($n \geq 1$) board missing one square with right tromnioes, which are L-shaped tiles formed by three adjacent squares.

A Protocol for Solving Problems

- Analyze the problem

Tromino Puzzle: Problem Analysis

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- The missing square can be any of the board squares.
- Trominoes should cover all the squares except the missing ones with no overlaps.
- A right tromino can also be viewed as a 2×2 board with exactly one missing square.

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- Work out concrete examples; make note of boundary cases

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- Brainstorm about the problem
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- Write the solution
- Revise
- Reflect
- Generalize
- Learn about the history and applications

Divide-and-conquer Algorithm for the Tromino Puzzle

- If $n = 1$, we have a 2×2 square with a missing square, which can be covered with one tromino.

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- We use an appropriately oriented tromino to cover the three corner squares (which meet at the center of the board) of the three smaller boards.

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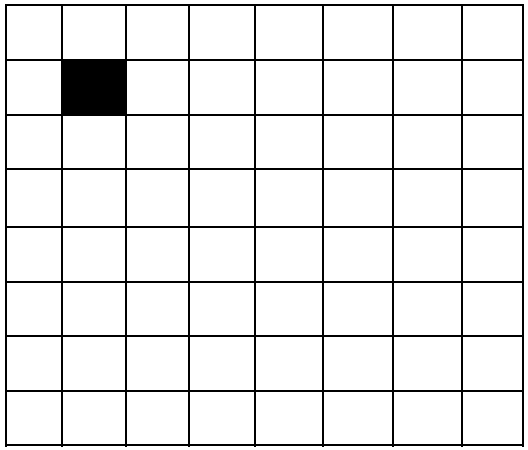
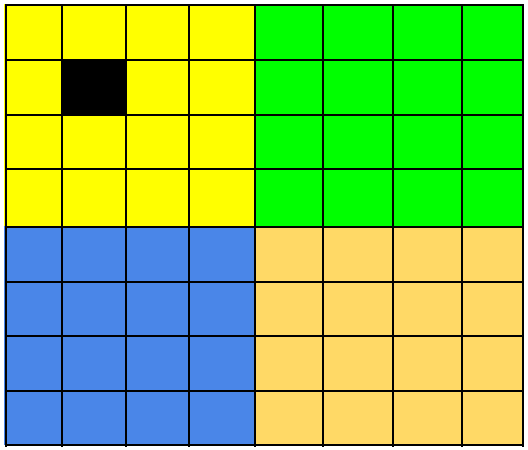
- We use an appropriately oriented tromino to cover the three corner squares (which meet at the center of the board) of the three smaller boards.
- We now have four smaller boards, each with exactly one missing square.
- We cover them recursively with L-shaped trominoes.



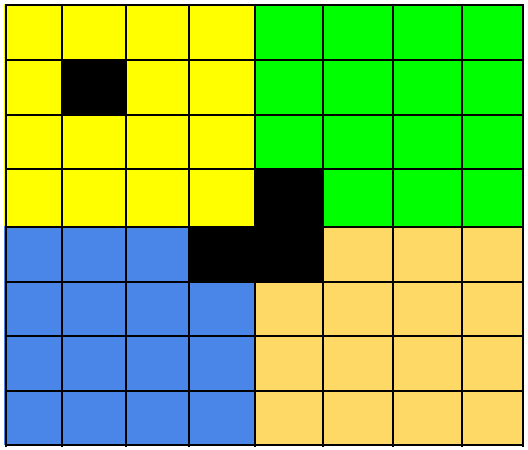
8 x 8 Board with one missing square



8 x 8 Board with one missing square

Division into 4 equal quadrants (4 x 4 boards)

The subproblems of covering the quadrants are not exactly the same type as the original problem

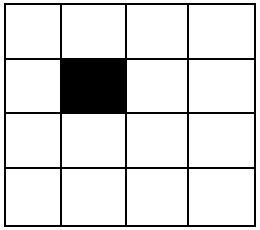


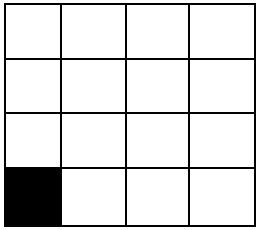
8 x 8 Board with one missing square

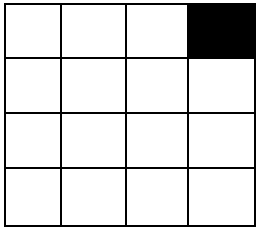
Division into 4 equal smaller size boards (4 x 4 boards)

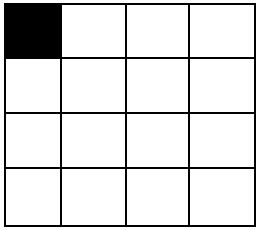
The subproblems of covering the smaller boards are not exactly the same type as the original problem since three of them do not have a missing square

Use a tromino to cover the three corner squares of the three smaller boards which do not have a missing square. The three corner squares meet at the center of the board.









4 subproblems: 4 4x4 boards each with one missing square

Goals

- Apply basic algorithmic paradigms to solve problems

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Instructors and Mentors

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- Tutors: Russell Impagliazzo, Nathan Ng, Marco Carmosino, Daniel Moeller

Topics

- Divide-and-conquer and searching (Mohan Paturi)
  Lecture: August 20th, 2014; Homework due Saturday August 23rd, 11:59 PM
  Workshop: Monday, August 25th

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  Workshop: Tuesday, September 2, 3-4 PM (Section 1) and 4-5 PM (Section 2), CSE 4140

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  Lecture: September 3rd, 2014; Homework due Saturday August 6th, 11:59 PM
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  Workshop: Monday, September 8th
- Backtracking and dynamic programming (Giorgio Quer)
  Lecture: September 10th, 2014; Homework due Saturday August 13th, 11:59 PM
  Workshop: Monday, September 15th

Topics

- Final lecture: Each group will make a 15-minute presentation about their model.

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- You are encouraged to brainstorm with your colleagues about the problems
- However, write your solutions entirely by yourself without any help from others.

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- Homework will only be graded to provide feedback. There are no points for the homework.
- APS course requires minimal mathematical background. No calculus is required. Knowledge of logarithms will be useful.

Last Name	First Names	Section	Gender	Partner	Mentor	Model	Workshop Mentor
Au-yeung	Nathan	1	M	Rochelle M	AY	Alan Turing	Marco Carmosino
Bennett	Zhaira	1	F	Cody P.	AY	Alan Turing	Marco Carmosino
Gozum	Khelsey	1	F	Karen M.	AY	Alan Turing	Marco Carmosino
Ma	Karen	1	F	Khelsey G.	AY	Alan Turing	Marco Carmosino
Manongdo	Rochelle	1	F	Nathan A.	AY	Alan Turing	Marco Carmosino
Pham	Cody	1	M	Zhaira B.	AY	Alan Turing	Marco Carmosino
Llobrera	Luis	1	M	Martin S.	JC	Hypatia	Daniel Moeller
Mach	Vivian	1	F	Eric X.	JC	Hypatia	Daniel Moeller
Peng	Bruce	1	M	Tiffany W.	JC	Hypatia	Daniel Moeller
Shung	Martin	1	M	Luis L.	JC	Hypatia	Daniel Moeller
Wang	Tiffany	1	F	Bruce P.	JC	Hypatia	Daniel Moeller
Xue	Eric	1	M	Vivian M.	JC	Hypatia	Daniel Moeller
Eldred	Trenten	1	M	Isaac S.	JW	al-Khowarizmi	Nathan Ng
Gobulukoglu	Mustafa	1	M	Arjun S.	JW	al-Khowarizmi	Nathan Ng
Lala	Karan	1	M	Jim L.	JW	al-Khowarizmi	Nathan Ng
Lee	Jim	1	M	Karan L.	JW	al-Khowarizmi	Nathan Ng
Shanley	Isaac	1	M	Trenten E.	JW	al-Khowarizmi	Nathan Ng
Srinivasan	Arjun	1	M	Mustafa G.	JW	al-Khowarizmi	Nathan Ng
Agcaoili	Kristin	1	F	Arvind K.	KL	Ada Lovelace	Mohan Paturi
Crofts	Marian	1	F	Jeremy S.	KL	Ada Lovelace	Mohan Paturi
Kalathil	Arvind	1	M	Kristin A.	KL	Ada Lovelace	Mohan Paturi
Ly	Tyler	1	M	Reese W.	KL	Ada Lovelace	Mohan Paturi
Siocon	Jeremy	1	M	Marian C.	KL	Ada Lovelace	Mohan Paturi
Wahlin	Reese	1	M	Tyler L.	KL	Ada Lovelace	Mohan Paturi
Bayoud	Sinan	1	M	Maya B.	NDS	John von Neumann	Russell Impagliazzo
Bello	Maya	1	F	Sinan B.	NDS	John von Neumann	Russell Impagliazzo
Chen	Warren	1	M	Vachan V.,	NDS	John von Neumann	Russell Impagliazzo
Crow	Nicholas	1	M	Warren C.,	NDS	John von Neumann	Russell Impagliazzo
Diaz-reyes	Kelvin	1	M	Andrew T.	NDS	John von Neumann	Russell Impagliazzo
Lau	Katie	1	F	Nhat N.	NDS	John von Neumann	Russell Impagliazzo
Nguyen	Nhat Quang Hai	1	M	Katie L.	NDS	John von Neumann	Russell Impagliazzo
Tonascia	Andrew	1	M	Kelvin D.	NDS	John von Neumann	Russell Impagliazzo
Vadmal	Vachan	1	M	Warren C.,	NDS	John von Neumann	Russell Impagliazzo

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Kannan	Anish	2	M	Jonathan P	JL	Julia Robinson	Marco Carmosino
Okunev	Sergey Sergeye	2	M	Yacoub O.	JL	Julia Robinson	Marco Carmosino
Oulad Daoud	Yacoub	2	M	Sergey O.	JL	Julia Robinson	Marco Carmosino
Perapalanunt	Jonathan Boon	2	M	Anish K.	JL	Julia Robinson	Marco Carmosino
Shan	David	2	M	Daniel V.	JL	Julia Robinson	Marco Carmosino
Vick	Daniel Allen	2	M	David S.	JL	Julia Robinson	Marco Carmosino
Bontigao	Jacqueline Clau	2	F	Rishabh M.	RD	Leonhard Euler	Daniel Moeller
Juandy	Matthew Albert	2	M	Quoc L.	RD	Leonhard Euler	Daniel Moeller
Luong	Quoc Toan Min	2	M	Matthew J.	RD	Leonhard Euler	Daniel Moeller
Malhotra	Rishabh	2	M	Jacqueline	RD	Leonhard Euler	Daniel Moeller
Phan	Khoi Minh	2	M	June S.	RD	Leonhard Euler	Daniel Moeller
Suk	June Young	2	F	Khoi P.	RD	Leonhard Euler	Daniel Moeller
Bach	Triet Minh	2	M	Alicia C.	ST	Charles Babbage	Nathan Ng
Chen	Alicia Miao	2	F	Triet B.	ST	Charles Babbage	Nathan Ng
Lee	Pearl Jinjoo	2	F	Sherman L.	ST	Charles Babbage	Nathan Ng
Lee	Sherman Henry	2	M	Pearl L.	ST	Charles Babbage	Nathan Ng
Smith	Jeremy Seiji	2	M	Aaron Y.	ST	Charles Babbage	Nathan Ng
Yang	Aaron	2	M	Jeremy S.	ST	Charles Babbage	Nathan Ng
Chou	Vanessa	2	F	Jed T.	VC	Leelavati	Mohan Paturi
Ho	Thong Ung	2	M	Ethan V.	VC	Leelavati	Mohan Paturi
Ponce	Nancy Jacqueli	2	F	Connor S.	VC	Leelavati	Mohan Paturi
Seong	Daniel Shinyup	2	M	Christine W	VC	Leelavati	Mohan Paturi
Smith	Connor A	2	M	Nancy P.	VC	Leelavati	Mohan Paturi
Tadios	Jed Matthew	2	M	Vanessa C.	VC	Leelavati	Mohan Paturi
Vander Horn	Ethan Douglas	2	M	Thong H.	VC	Leelavati	Mohan Paturi
Wu	Christine May	2	F	Daniel S.	VC	Leelavati	Mohan Paturi
Chen	Julia	2	F	Guiseppie	YEW	Qin Jiushao	Russell Impagliazzo
Huang	Tiffany Mae	2	F	Krishi V.	YEW	Qin Jiushao	Russell Impagliazzo
Justo	David Antonio	2	M	Jenny W.	YEW	Qin Jiushao	Russell Impagliazzo
Pagliaro	Guiseppie Robe	2	M	Julia C.	YEW	Qin Jiushao	Russell Impagliazzo
Vemula	Krishi Kesav	2	M	Tiffany H.	YEW	Qin Jiushao	Russell Impagliazzo
Wong	Jenny	2	F	David J.	YEW	Qin Jiushao	Russell Impagliazzo

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- Typical search algorithm: A series of steps where in each step we
  - perform some computation, and
  - ask a question to narrow down the possibilities.

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- Explicitly identify the set of possible scenarios.
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  - perform some computation, and
  - ask a question to narrow down the possibilities.
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  - perform some computation, and
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- Each possible answer to the question reduces the problem to a subproblem where we have fewer possibilities.
- The set of possible scenarios is partitioned along the possible answers to the question.
- Design questions so that the number of possibilities in each case is as equal as it can be to the number of possibilities in other cases.

A Fake among Eight Coins

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- What is the minimum number of weighings needed to identify the fake coin with a two-pan balance scale without weights?

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- Call them L, R, and E respectively.
- Use the two-pan balance to compare the weights of the groups L and R.
- If they weigh the same, the fake coin can neither be in L nor in R, so it must be in E.
- Take the two coins in E and compare them. The lighter coin (between the two coins in E) must be the fake coin.

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- If one of them is lighter, the lighter coin must be the fake coin.

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- Take any 2 coins from this group and weigh them.
- If they weigh the same then the remaining coin in the group must be fake.
- If one of them is lighter, the lighter coin must be the fake coin.
- In all cases, we identified the counterfeit with two comparisons.

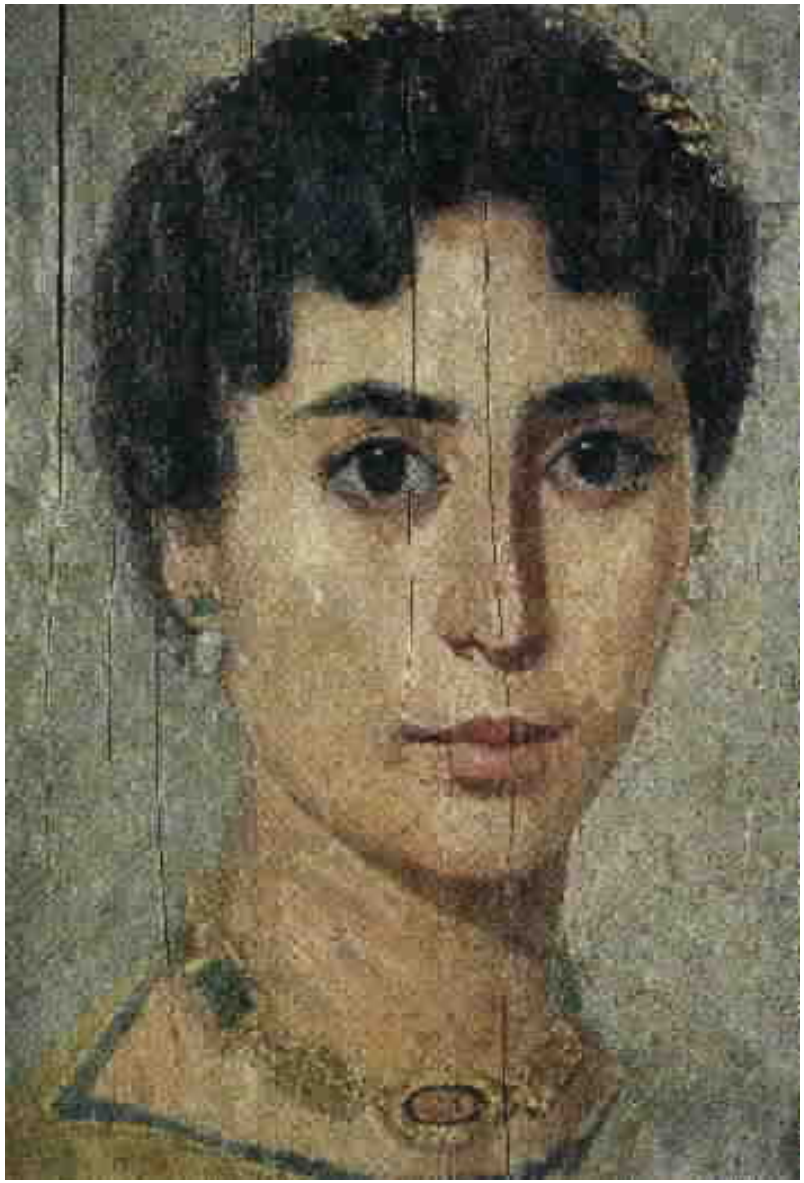

Figure: Hypatia

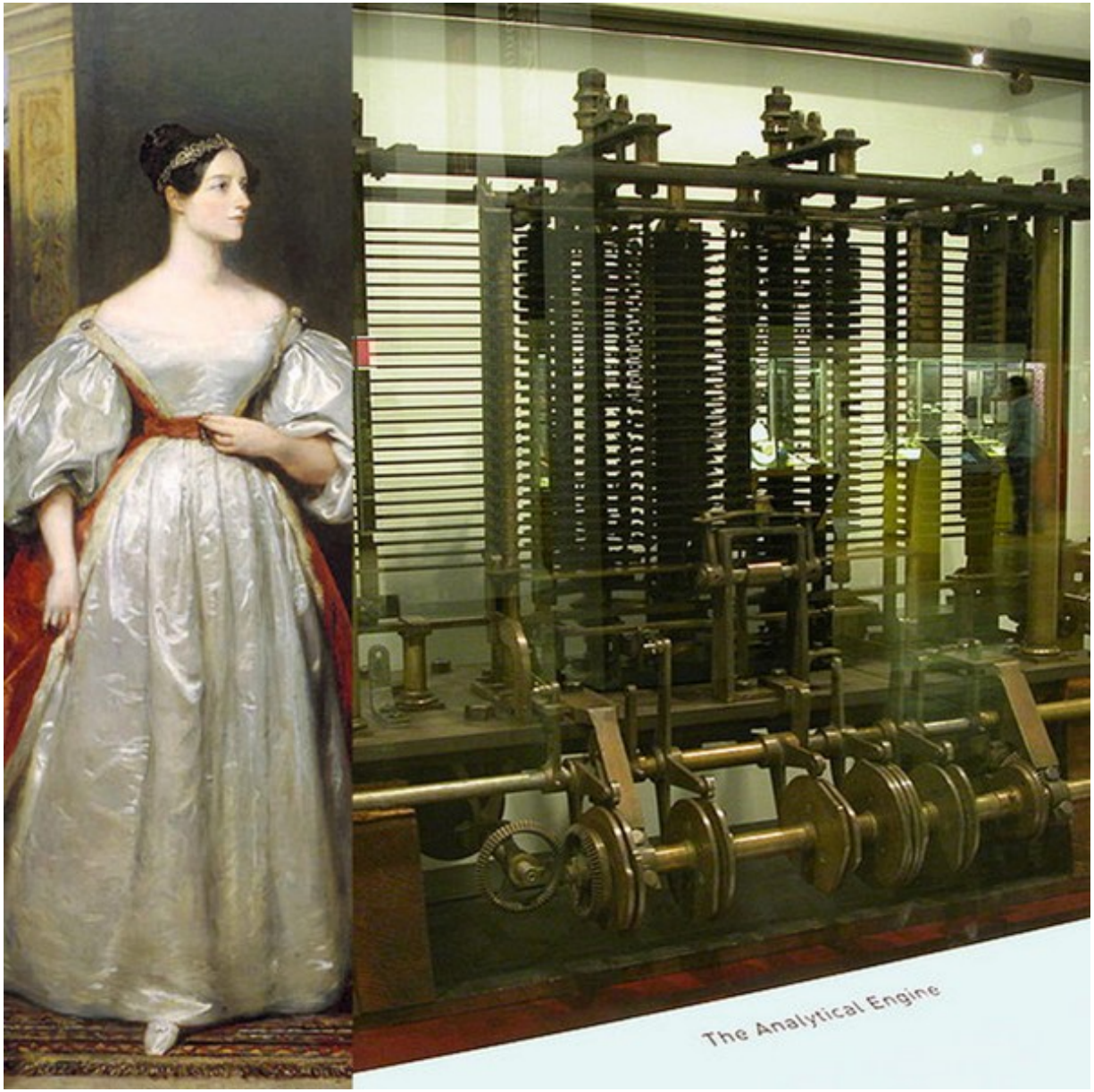

Figure: Ada Lovelace

Muhammad ibn Musa al-Khwarizmi

- Muhammad ibn Musa al-Khwarizmi (approx 800-847 CE)
- Born around 800 CE in Khwarizm, now in Uzbekistan.
- Al-Khwarizmi lived in Baghdad, where he worked at the "House of Wisdom" (*Dar al-Hikma*) under the Caliph Harun al-Rashid.
- What is the origin of the word Algorithm?

Fundamentals of Software Development 1

Slide 1

Figure: al-Khowarizmi

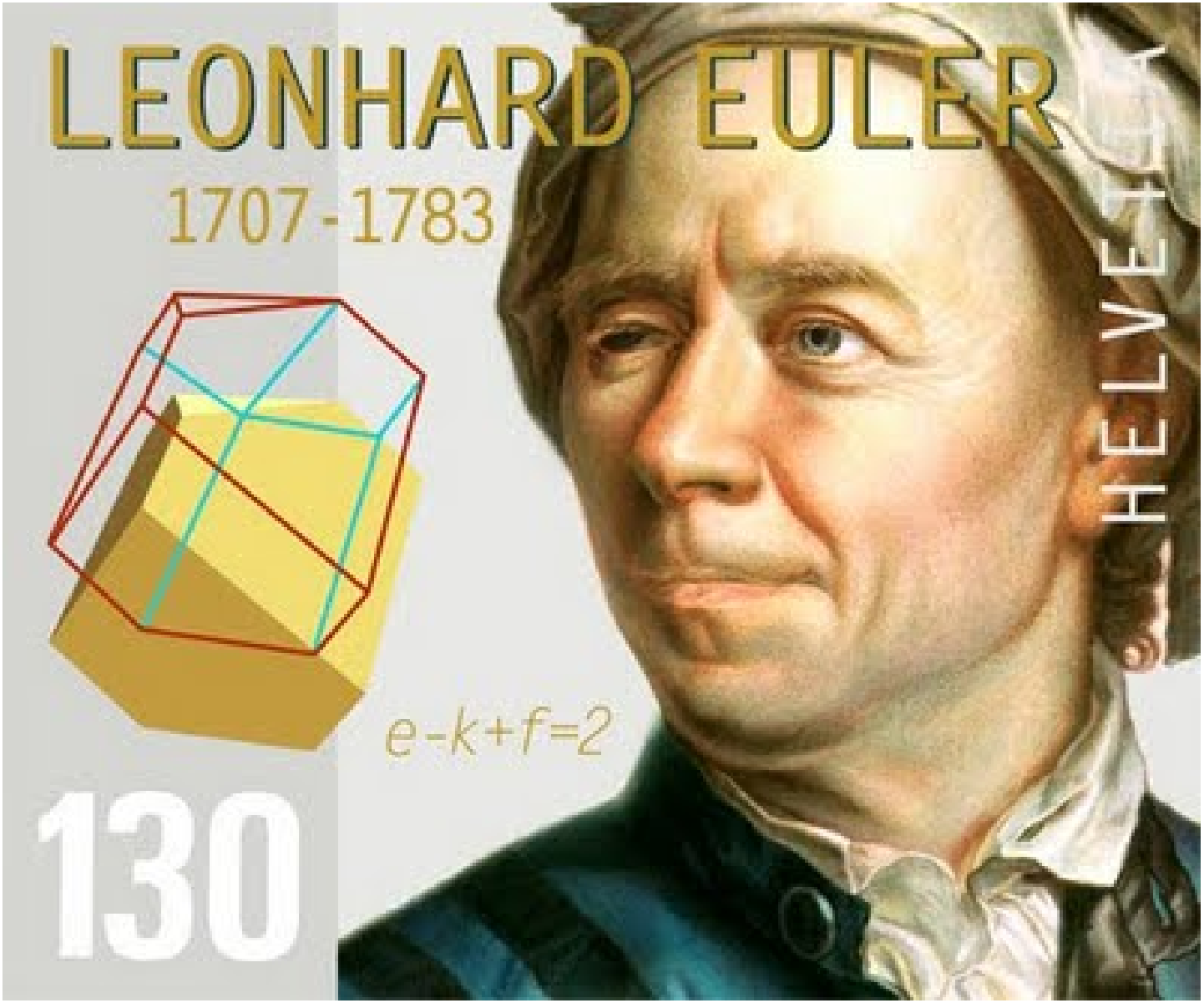

Figure: Leonhard Euler

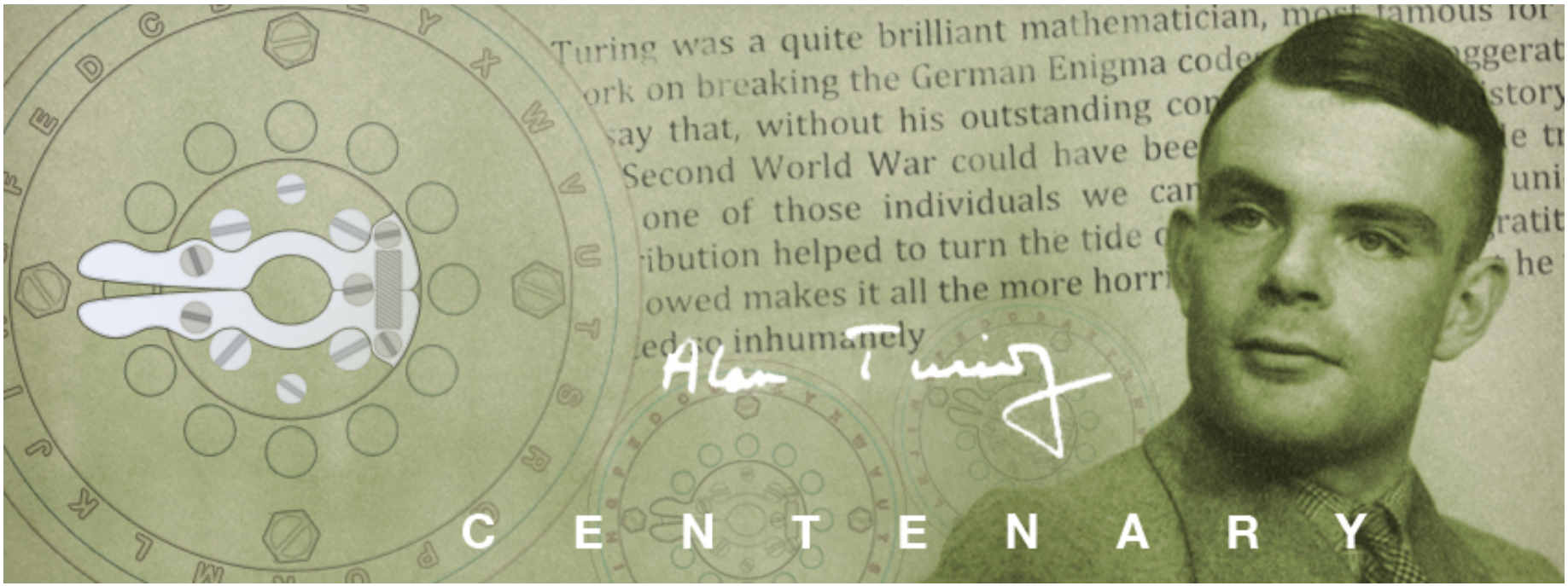

Figure: Alan Turing

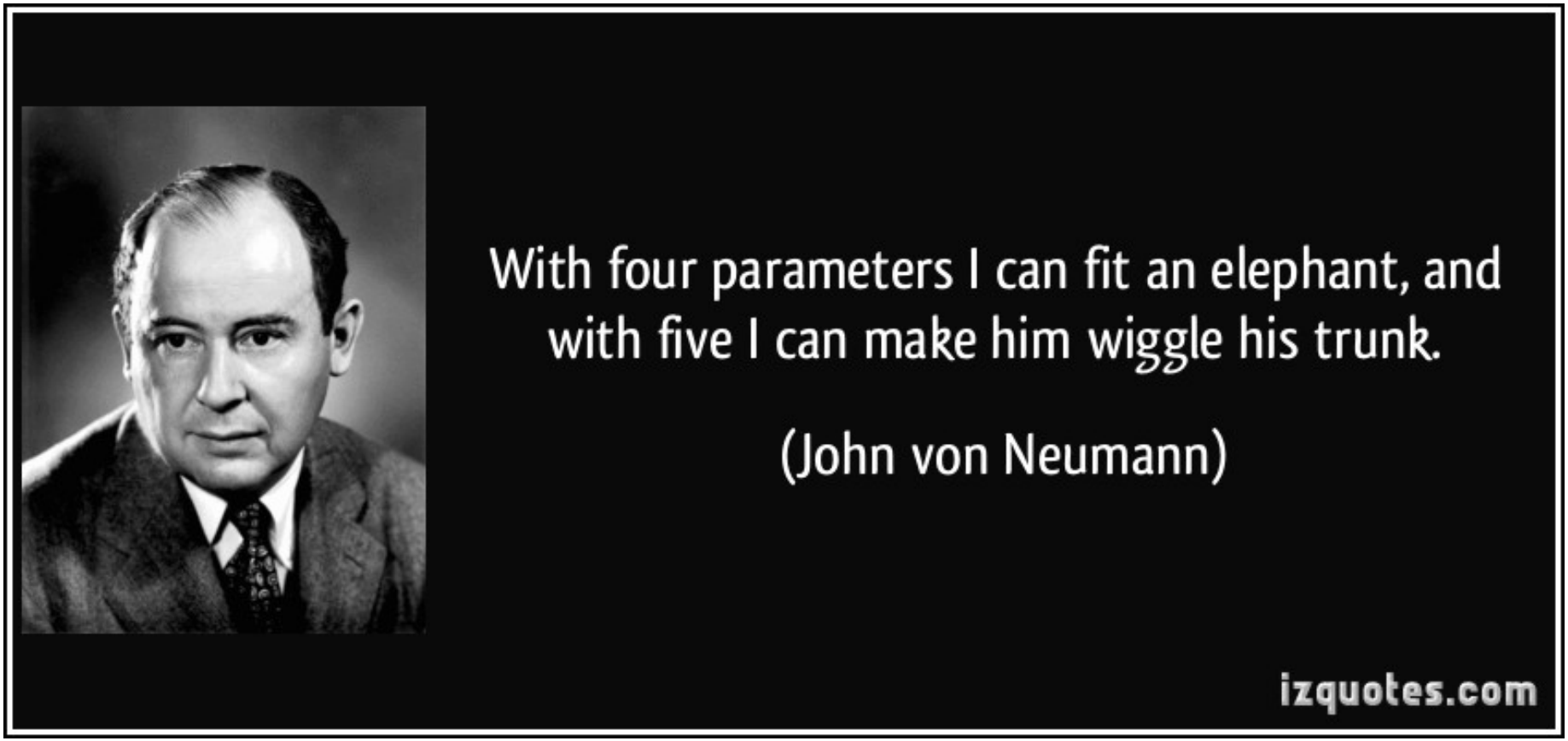

Figure: John von Neumann


Co-Sponsored by the Mathematical Sciences Research Institute and the UC Berkeley Department of Mathematics
Julia Robinson
And Hilbert's Tenth Problem
A film by
George Csicsery
Wednesday, April 30, 2008
7pm to 9pm
Room 2050 (Chan Shun Auditorium)
in the Valley Life Sciences Building
at UC Berkeley
Post-screening panel discussion
with Constance Reid (sister and
biographer of Julia Robinson),
filmmaker George Csicsery, and
mathematicians Martin Davis,
Dana Scott and Bjorn Poonen.
Moderated by Alan Weinstein,
UCB Math Dept. Chair.
The story of an American mathematician
and her passionate pursuit and triumph
over an unsolved problem.
Hilbert's 10th Problem (1900): Is there an algorithm for
deciding whether a polynomial equation with integer
coefficients has an integer solution?

Figure: Charles Babbage

Figure: Qin Jiushao

Figure: Bhaskara II (Leelavati is Bhaskara's daughter and the name of his book)

Thank You