About This Presentation

This presentation belongs to the lecture series entitled “Puzzling Problems in Science and Technology,” devised for a ten-week, one-unit, freshman seminar course by Behrooz Parhami, Professor of Computer Engineering at University of California, Santa Barbara. The material can be used freely in teaching and other educational settings. Unauthorized uses, including any use for financial gain, are prohibited. © Behrooz Parhami

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Puzzling Problems in Science and Technology

What is a puzzling problem?

- Looks deceptively simple, but ...
- Appears very difficult, or even impossible, but is readily tamed with the correct insight

Many science and engineering problems are puzzle-like

Because of a long-standing interest in mathematical puzzles, I designed this course that combines my personal and professional passions

Each pair of lectures starts with one or more puzzles
We will try to solve the puzzles and discuss possible solution methods
I introduce you to sci/tech problems that are related to the puzzles
Course Expectations and Resources

**Grading:** Pass/Not-Pass, by attendance and class participation

0 absence: Automatic “Pass”

1 absence: “Pass” if you submit a written explanation for the absence; any explanation will do

2 absences: Can earn a “Pass” by taking a final oral exam covering the missed lectures

3 or more absences: Automatic “Not Pass”

Attendance is taken 10 minutes into the class session and reconfirmed just before dismissal

Course website: http://www.ece.ucsb.edu/~parhami/int_94tn.htm (Syllabus, PowerPoint and PDF presentations, links to useful sites)

Instructor’s office hours for f’16: M 12:00-2:00, W 4:30-5:30, HFH 5155
Find the Next Term in an Integer Sequence

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[OEIS]

Online Encyclopedia of Integer Sequences: http://oeis.org/
Find Missing Term in an Arbitrary Sequence

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<td>111221</td>
<td>312211</td>
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M  221
Δ  111
 ceased
∞  212
∞  122
∞  __
Which Name Should Come Next?

Mark Susan Jeff Jenny Brad Marco Jill ___
Choose from: Donald Fereshteh Robin Bill Christy Elizabeth

John Shawn Suzy Bradley Dan Barney ___
Choose from: David Elvira Tommy Robert Camelia Betty

Candy Frank Irene Lauren Oren Rose ___
Choose from: David Cyrus Angelina Jose Uma Darin

Charles Dion Stuart Kevin Joshua Sergio ___
Choose from: Jeremy Shaun Thomas Duane Rupert Ulysses

Parrot Pigeon Robin Sparrow ___
Choose from: Cardinal Oriole Lovebird Thrush Wren
Polynomial interpolation:

You can pass a line through any two points, a hyperbola through any three points, a third-degree curve through any four points, and so on.

Let's consider the function $f(n) = an^3 + bn^2 + cn + d$.

1. For $n=1$, we have $a + b + c + d = 1$.
2. For $n=2$, we have $8a + 4b + 2c + d = 4$.
3. For $n=3$, we have $27a + 9b + 3c + d = 9$.
4. For $n=4$, we have $64a + 16b + 4c + d = 16$.

Solving the system of equations, we find that $b = 1$, $a = c = d = 0$, and $f(n) = n^2$. 

In the diagram, the graph of $f(n) = n^2$ is shown, along with the points $(1, 1)$, $(2, 4)$, $(3, 9)$, and $(4, 16)$, which are solutions to the polynomial interpolation equations.
When Several Answers Are Possible

Answer 1:
\[2 \ 4 \ 8 \ 16 \ 32\]
Reason: \(f(n) = 2^n\)

Answer 2:
\[2 \ 4 \ 8 \ 16 \ 30\]
Reason:
\[f(n) = \frac{1}{3}n^3 - n^2 + \frac{8}{3}n\]

Which is the correct answer?

Challenge:
Why does \(f(n)\) always yield an integer result for an integer \(n\)?
Interpolation and Extrapolation

**Interpolation:** Given the values of the function $f(n)$ at points $a$ and $b$, find its value at some given point between $a$ and $b$

**Extrapolation:** Given the values of the function $f(n)$ at some points between $a$ and $b$, find its value at a given point before $a$ or after $b$
Polynomial Extrapolation Example

This exponential series, when solved via polynomial extrapolation, yields a different answer!

\[ f(n) = an^3 + bn^2 + cn + d \]

- \( n = 1: a + b + c + d = 2 \)
- \( n = 2: 8a + 4b + 2c + d = 4 \)
- \( n = 3: 27a + 9b + 3c + d = 8 \)
- \( n = 4: 64a + 16b + 4c + d = 16 \)

\[ a = 1/3; b = -1; c = 8/3; d = 0; \]

\[ f(5) = (1/3)125 - 25 + (8/3)5 = 30 \]
\[ f(6) = (1/3)216 - 36 + (8/3)6 = 52 \]

\[ f(30) = 8,180 \]

\[ 2^{30} = 1,073,741,824 \]
Polynomial Curve-Fitting Example

\[ f(x) = ax + b \]

\( x = 1: a + b \) vs. 2
\( x = 2: 2a + b \) vs. 4
\( x = 3: 3a + b \) vs. 8
\( x = 4: 4a + b \) vs. 16

\[ D(a, b) = (a + b - 2)^2 + (2a + b - 4)^2 + (3a + b - 8)^2 + (4a + b - 16)^2 = 30a^2 + 4b^2 + 20ab - 196a - 60b + 340 \]

\[ dD/da = 0 \] and \( dD/db = 0 \) yield
\( a = 23/5 \) and \( b = -4 \)

\( f(x) = 4.6x - 4 \)
In log-scale, one unit of distance represents not a fixed increase but multiplication by a factor.

It also allows us to focus on relative, rather than absolute, variations.

**Question 1:** Where is the place of zero on the vertical axis?

**Question 2:** Is 50% decrease represented by the same vertical distance as 50% increase?
The Perils of Forecasting

Nobel Laureate Physicist Niels Bohr said:

“Prediction is very difficult, especially if it’s about the future.”
[Paraphrased by Yogi Berra in his famous version]

Anonymous quotes about the perils of forecasting:

“Forecasting is the art of saying what will happen, and then explaining why it didn’t.”

“There are two kinds of forecasts: lucky and wrong.”

“A good forecaster is not smarter than everyone else; he merely has his ignorance better organized.”

Henri Poincare was more positive on prediction:

“It is far better to foresee even without certainty than not to foresee at all.”
The Notion of Random Walk

Value

Steps

Oct. 2018 Predicting the Future
Technology Forecasting: Introduction

**Reasons for technology forecasting:**
- Prioritize R&D programs
- Plan new product development
- Make strategic decisions on tech licensing, joint ventures, etc.
In 1965, Gordon Moore, an Intel co-founder predicted that the number of components per integrated circuits will double every year.

In 1975, he revised his forecast to doubling every 2 years (the original forecast had a small set of data points).

Exponential growth is a hallmark of computing and communications.
The Evolution of Microprocessors

Chip sizes have grown, but the bulk of increased complexity comes from higher density

Number of transistors in a processor chip:

- Intel 4004 (1971): 2.3K
- Intel 8088 (1979): 29K
- ARM 3 (1989): 300K
- Pentium (1993): 3.1M
- AMD K7 (1999): 22M
- Itanium 2 (2002): 220M
- Six-core Xeon (2008): 1.9B
- Sparc M7 (2015): 10B
Technology Forecasting for New Products

iGadget n being planned for 3 years hence:

- Processor technology forecasting: speed, energy use
- Memory technology forecasting: data capacity, cost per gigabyte
- Display technology forecasting: resolution, thickness, contrast
- Camera technology forecasting: pixels, aperture, cost, size
- Battery technology forecasting: energy capacity, size, weight
Inventory Forecasting

Inventory has seasonal variations, as well as long-term trends

US Crude Oil Stocks

Weekly

5-year range
Stock-Market Prediction

Many factors affect market performance (as measured by indices)
Some believe that prediction in order to “time” the market is infeasible
Electronic trading has made prediction more difficult
Types of analysis: Fundamental (status of underlying company), technical (time-series), data mining (using artificial neural networks)

AMERICAN STOCK MARKET INDICES
Performance as on 28th October 2014

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<th>INDICES</th>
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<td>78.36</td>
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<td>1985.05</td>
<td>23.42</td>
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<td>DJIA</td>
<td>17005.75</td>
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www.linkedin.com/company/jhunjhunwalas
Market Prediction: One Particular Stock
Stock-Market Prediction: Short-Term

Short-term variations: Uses linear scale on the value axis

Dow Stock Market Trend Forecast to Jan 2015

By Nadeem Walayat

INDU Dow Jones Industrial Average INDX

10-Oct-2014 Open 16654.88 High 16757.60 Low 16543.91 Close 16644.10 Volume 509.8M Chg -115.15 (-0.69%)

© StockCharts.com

Oct. 2018 Predicting the Future Slide 23
Stock-Market Prediction: Long-Term

Long-term variations: Uses logarithmic scale on the value axis
Stock-Market Prediction: Modeling

Models try to predict behavior or range of behaviors:
The so-called “black swan” effect may render most models useless.

Dow Jones has been influenced by rising channel (A) many times over the past 70-years.

(1) - SPX found it as support in 2002/03
(2) - Broke support, lost 40% in months
(3) - Testing 70-year channel right now.

Could be important what happens here!!!
Stock-Market Prediction: Modeling (Continued)

http://2.bp.blogspot.com/-cDWOhZSCx1U/Ui7bs0VX73I/AAAAAAAAGy0/zlweFXs0u4U/s1600/djia1900s.png
Stock-Market Prediction: Politics

Cumulative Score
Points: +13220.27

Cumulative Score
Points: +19.76

Barack Obama 2009-present
George W. Bush 2001-2009
William J. Clinton 1993-2001
George H.W Bush 1989-1993
Ronald Reagan 1981-1989
Gerald Ford 1974-1977
Richard Nixon 1969-1974
Lyndon B. Johnson 1963-1969
John F. Kennedy 1961-1963
Dwight D. Eisenhower 1953-1961
Harry S. Truman 1945-1953
Franklin D. Roosevelt 1933-1945
Herbert Hoover 1929-1933
Calvin Coolidge 1923-1929
Warren G. Harding 1921-1923
Woodrow Wilson 1913-1921
William Howard Taft 1909-1913
Theodore Roosevelt 1901-1909
William McKinley 1897-1901
Modern computers look ahead and process future work to increase speed:

When there is a conditional branch, future work to be done is uncertain

```
------
------
if A > 0
[if not, skip the then part]
then
------
------
[skip the else part]
else
------
------
```

```
------
------
while A > 0 do
------
------
endwhile
------
------
```

```
------
------
repeat n times
------
------
endrepeat
------
------
```
Analogies for Speculative Execution

Suppose you have a lot of free time early in the quarter:
You may look ahead in the textbook and try to guess which problems will be assigned as homework, and start thinking about or solving them.
If those problems are not assigned by the instructor, then your time and effort go to waste, but since you had free time, you may not mind this.

Before computers, table-makers would pre-compute functions:
Some table entries may never be used by anyone, but for those who use some of the entries, the tables save much time.
Use of tables is a modern method of speeding up computer arithmetic.

Make your own analogy: