Predicting the Future

A Lecture in the Freshman Seminar Series:
Puzzling Problems in Science and Technology

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

Edition	Released	Revised	Revised	Revised	Revised
First	Sep. 2016	Oct. 2018			

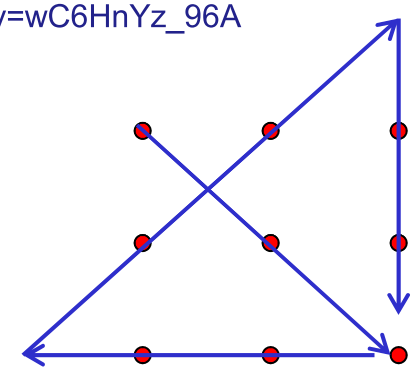
Puzzling Problems in Science and Technology

What is a puzzling problem?

☞ looks deceptively simple, but ...

☞ appears very difficult, or even impossible, but is readily tamed with the correct insight

Rotate faces until each face is single-colored
https://www.youtube.com/watch?v=wC6HnYz_96A



Connect all dots using four straight lines, without lifting your pen

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

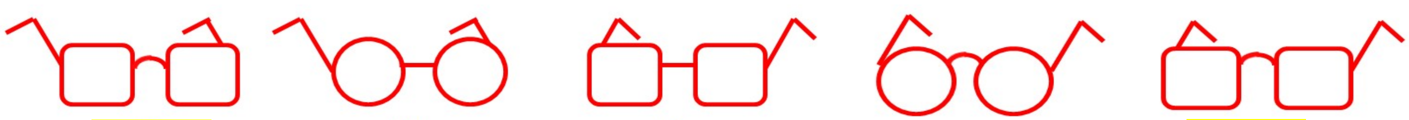
Find the Next Term in an Integer Sequence

1	2	3	4	__					
2	4	8	16	__					
1	2	2	3	3	3	4	4	__	
1	3	5	7	9	__				
3	7	11	__						
10	15	19	22	24	__				
1	1	2	3	5	8	13	__		
1	4	9	16	__					
1	3	6	10	15	21	28	__		
0	1	2	…	8	0	1	2	__	
1	2	3	4	9	27	512	__		[OEIS]

Online Encyclopedia of Integer Sequences: http://oeis.org/

Find Missing Term in an Arbitrary Sequence

Z	O	T	T	F	F	__		
J	F	M	__	M	J	J		
31	__	31	30	31	30	31	31	30
A	E	F	H	I	__			
3	3	5	4	4	3	5	__	
3	4	6	9	__	18	24		
1	3/2	__	7/8	9/16				
1	11	21	1211	111221	312211	__		



221 111 212 122 __

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

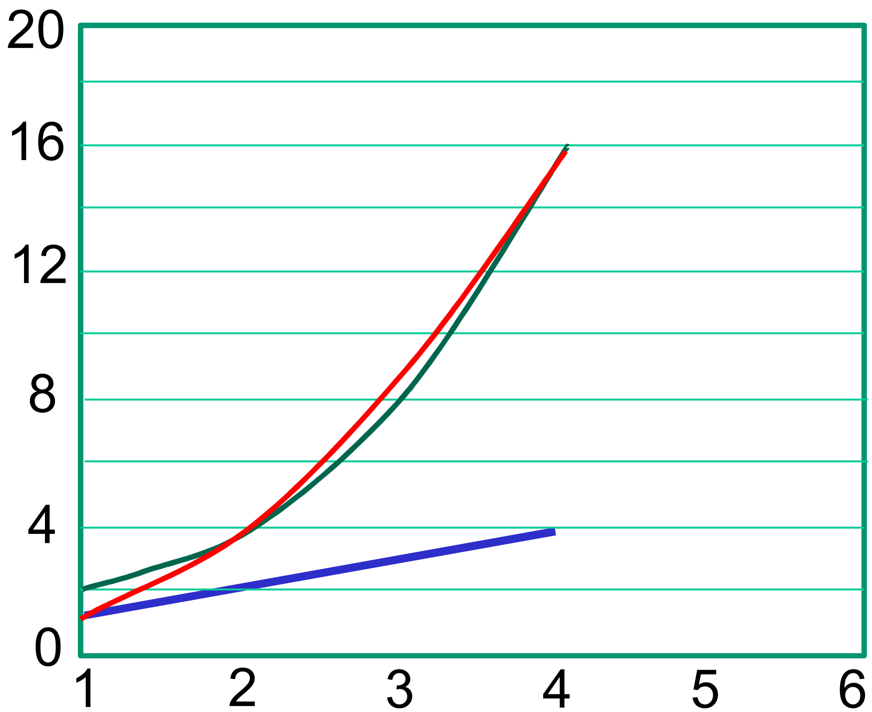
Parrot Pigeon Robin Sparrow ___

Choose from: Cardinal Oriole Lovebird Thrush Wren

A Solution Method for Numerical Series

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



1 2 3 4 __

1 4 9 16 __

$f(n) = an^3 + bn^2 + cn + d$

$n = 1$: $a + b + c + d = 1$

$n = 2$: $8a + 4b + 2c + d = 4$

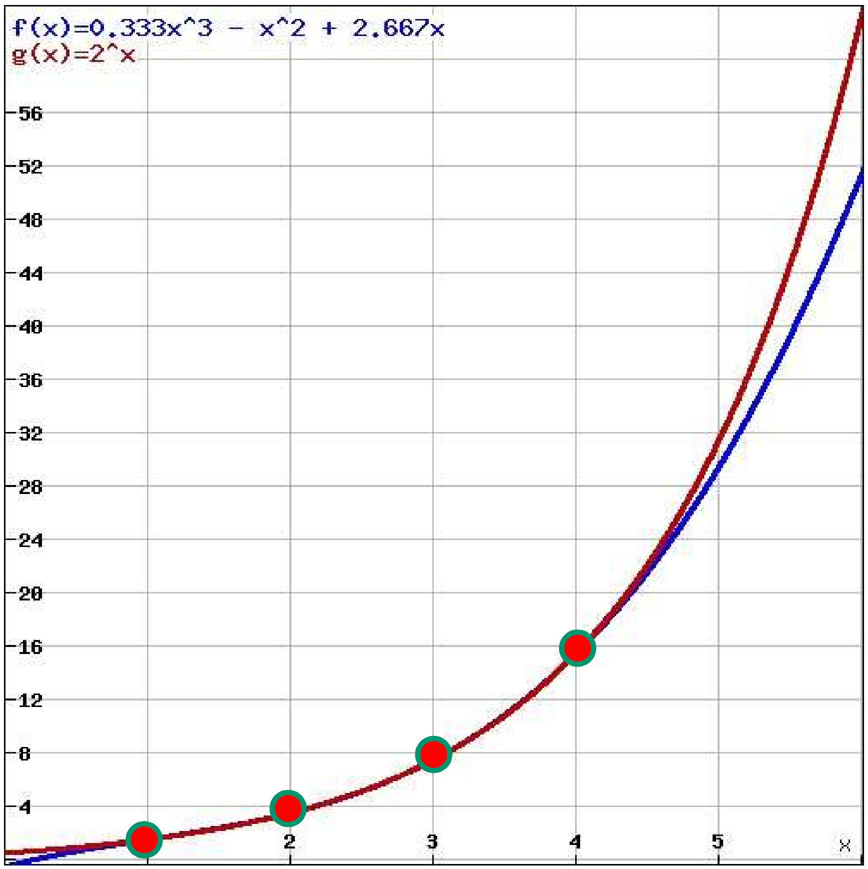
$n = 3$: $27a + 9b + 3c + d = 9$

$n = 4$: $64a + 16b + 4c + d = 16$

$b = 1$; $a = c = d = 0$; $f(n) = n^2$

2 4 8 16 __

When Several Answers Are Possible



2 4 8 16 __

Answer 1:

2 4 8 16 <u>32</u>

Reason: $f(n) = 2^n$

Answer 2:

2 4 8 16 <u>30</u>

Reason:

$f(n) = (1/3)n^3 – n^2 + (8/3)n$

Which is the correct answer?

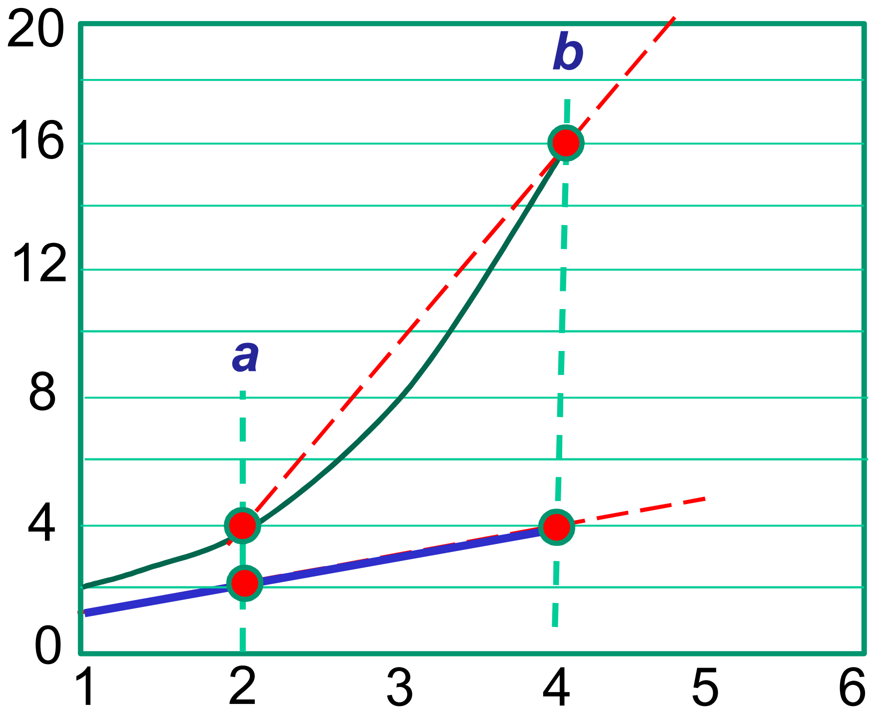
Challenge:

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



1 (2) 3 (4) __

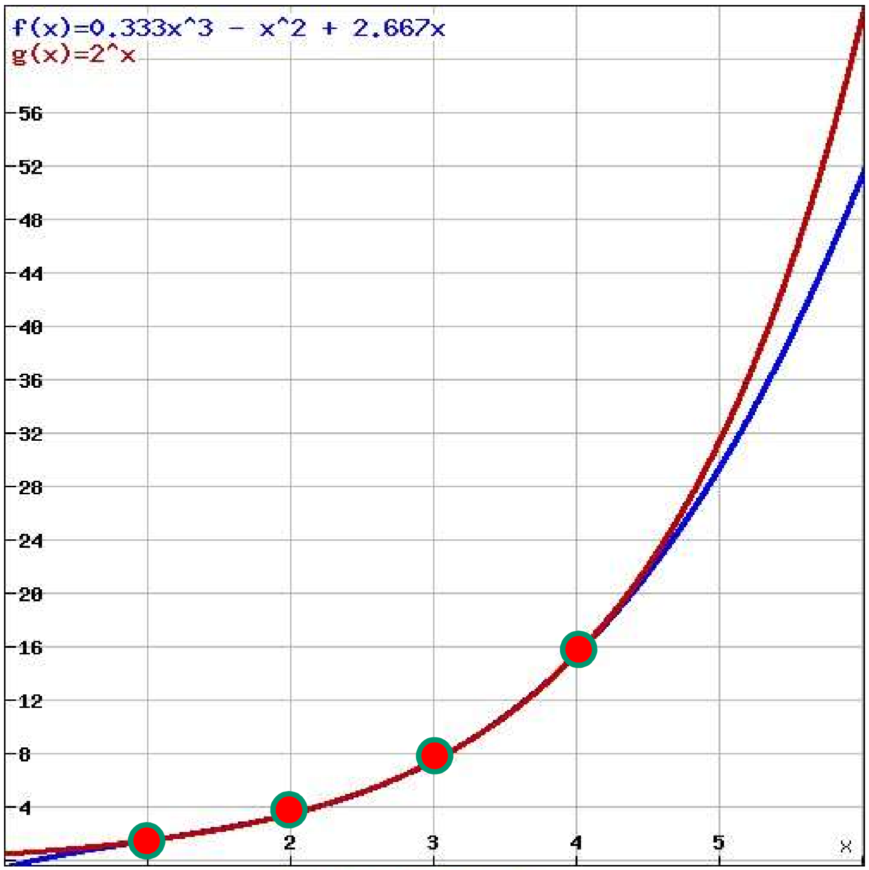
2 (4) 8 (16) __

Khan-Academy/Pixar video illustrating the use of interpolation for animation:

https://www.khanacademy.org/partner-content/pixar/animate/ball/v/a2-quick

Polynomial Extrapolation Example

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



2 4 8 16 __

$f(n) = an^3 + bn^2 + cn + d$

$n = 1$: $a + b + c + d = 2$

$n = 2$: $8a + 4b + 2c + d = 4$

$n = 3$: $27a + 9b + 3c + d = 8$

$n = 4$: $64a + 16b + 4c + d = 16$

$a = 1/3$; $b = –1$; $c = 8/3$; $d = 0$;

$f(n) = (1/3)n^3 – n^2 + (8/3)n$

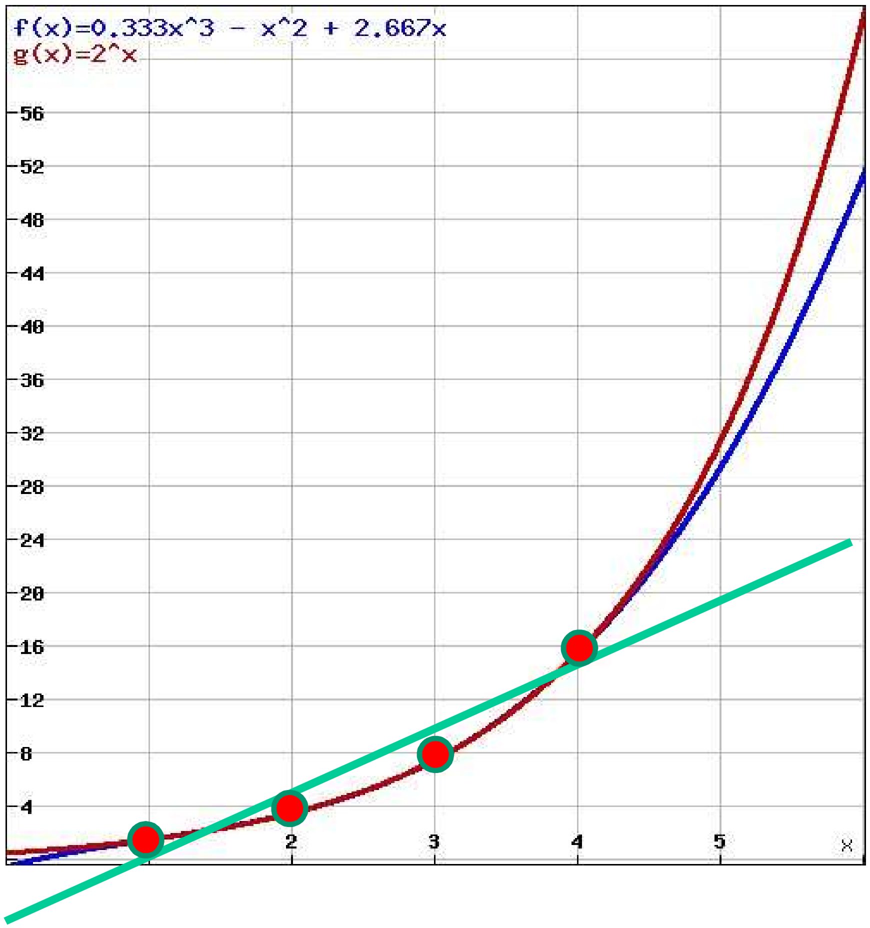
$f(5) = (1/3)125–25+(8/3)5 = 30$

$f(6) = (1/3)216–36+(8/3)6 = 52$

$f(30) =$ 8,180

2^{30} = 1,073,741,824

Polynomial Curve-Fitting Example



2 4 8 16 __

$f(x) = ax + b$

$x = 1$: $a + b$ vs. 2

$x = 2$: $2a + b$ vs. 4

$x = 3$: $3a + b$ vs. 8

$x = 4$: $4a + b$ vs.16

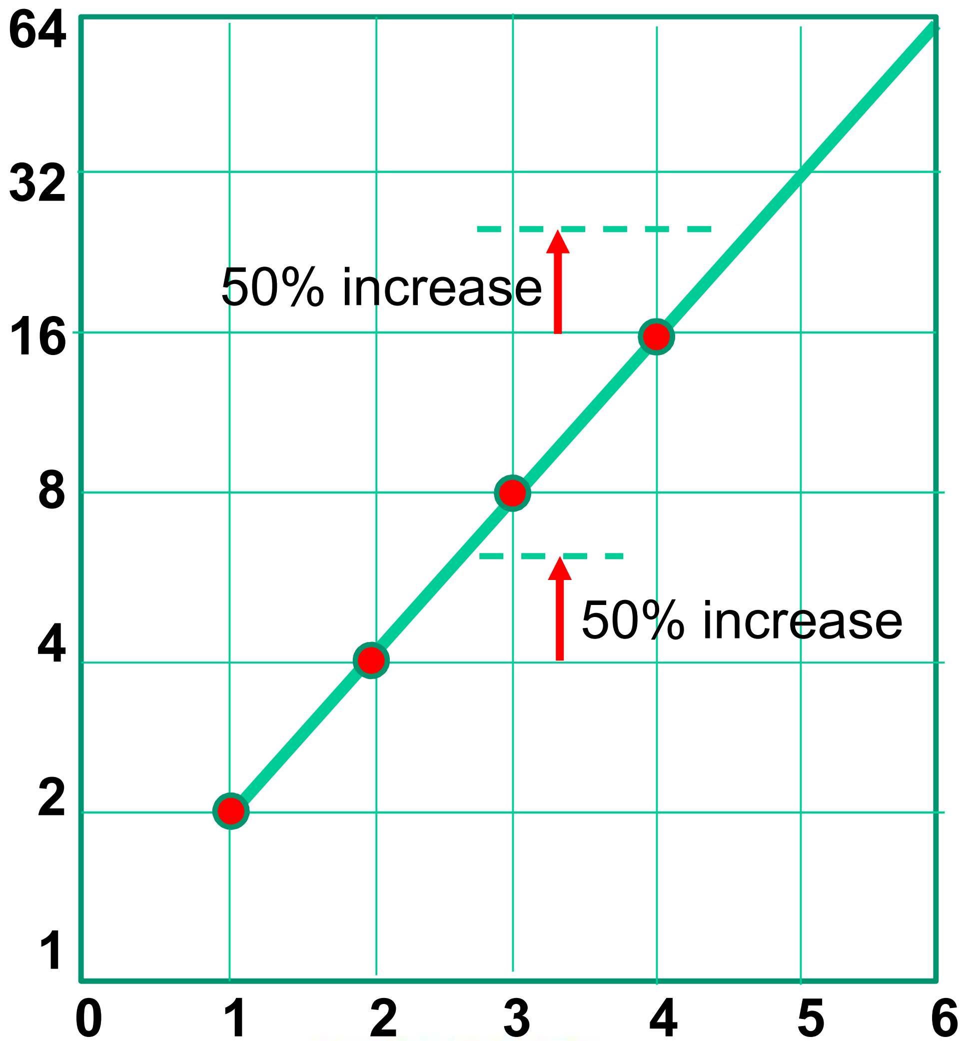
$$D(a, b) = (a + b - 2)^2 + (2a + b - 4)^2 + (3a + b - 8)^2 + (4a + b - 16)^2 = 30a^2 + 4b^2 + 20ab - 196a - 60b + 340$$

$dD/da = 0$ and $dD/db = 0$ yield

$a = 23/5$ and $b = -4$

$f(x) = 4.6x - 4$

Log-Scale Linearizes Exponential Trends



2 4 8 16 __

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."

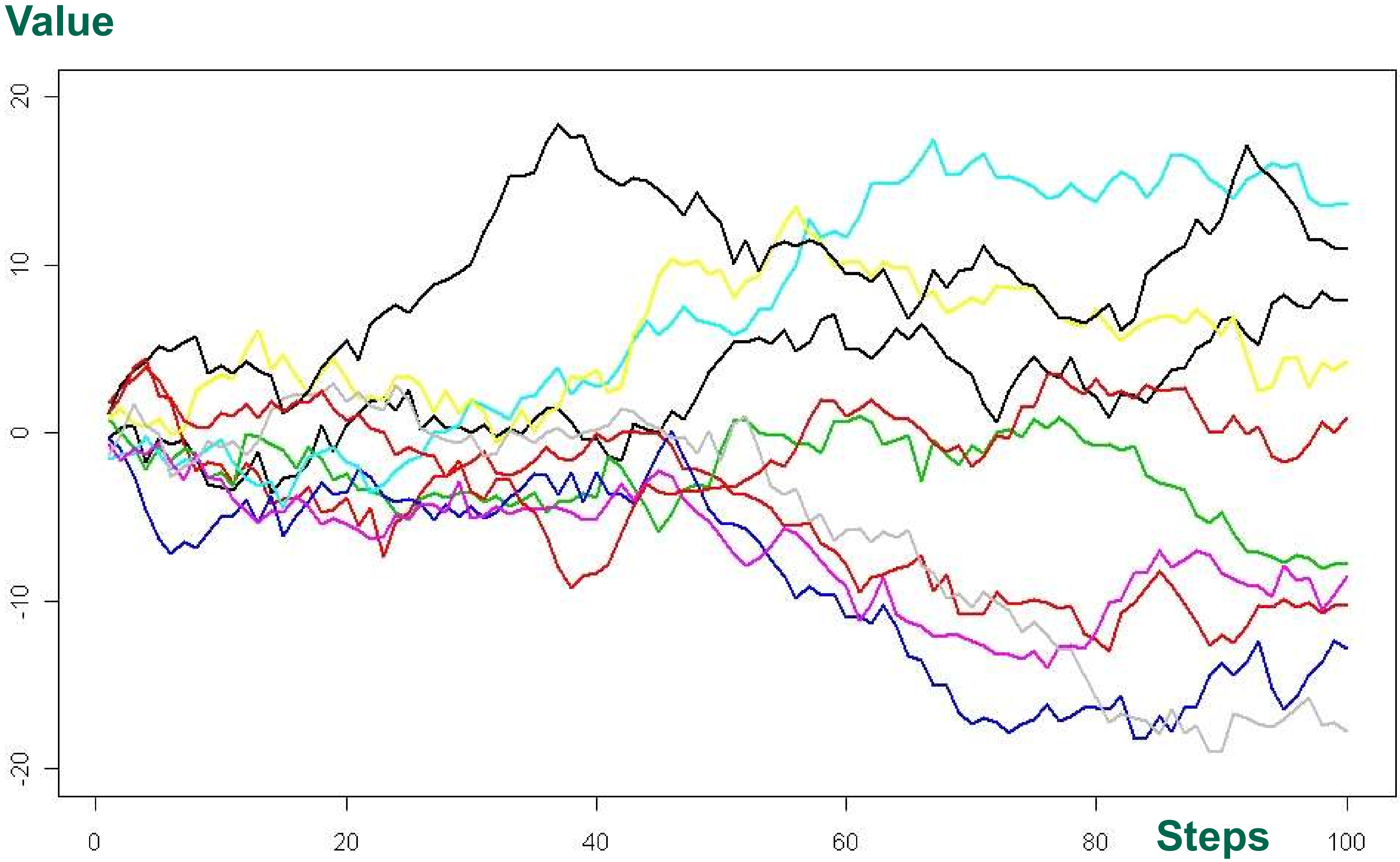
"There are two kinds of forecasts: lucky and wrong."

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

Henri Poincare was more positive on prediction:

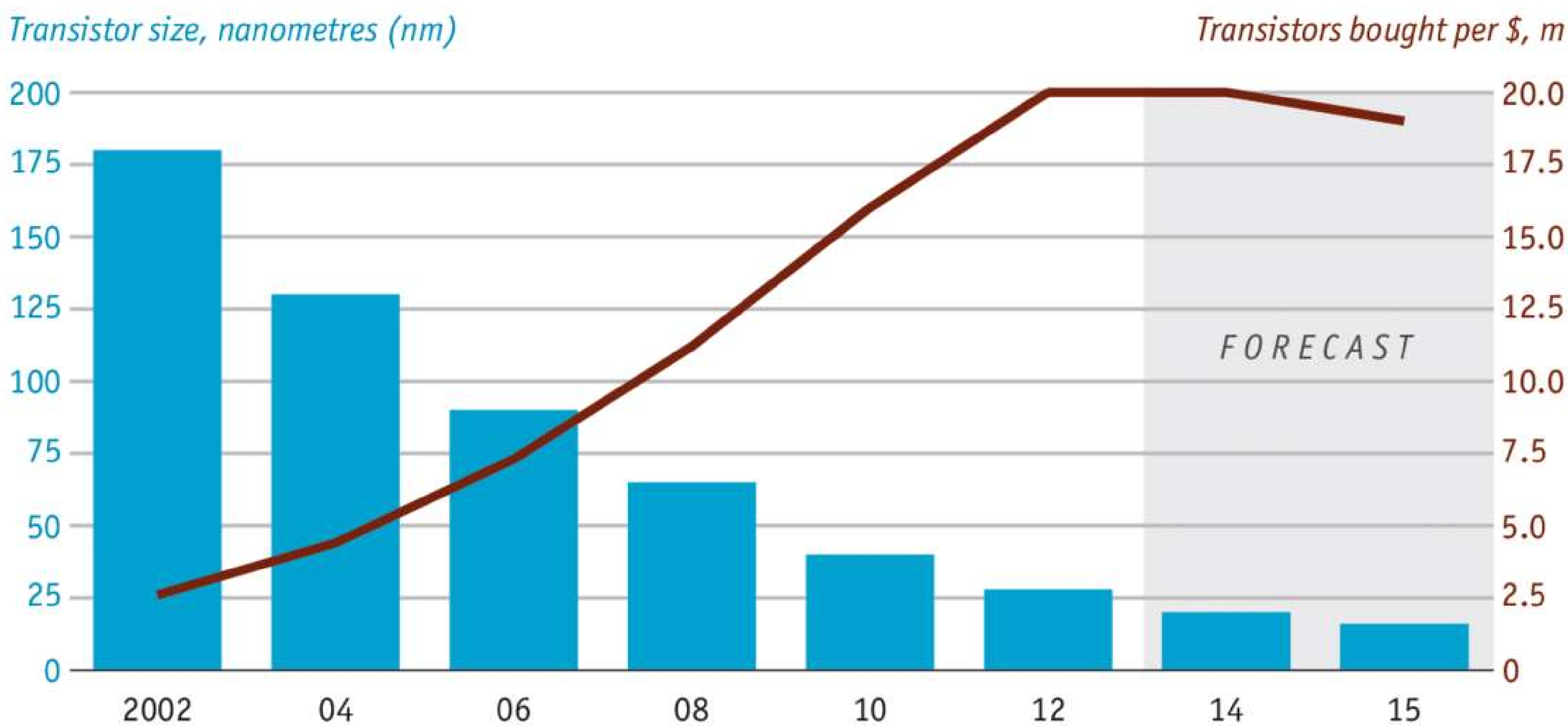
"It is far better to foresee even without certainty than not to foresee at all."

The Notion of Random Walk

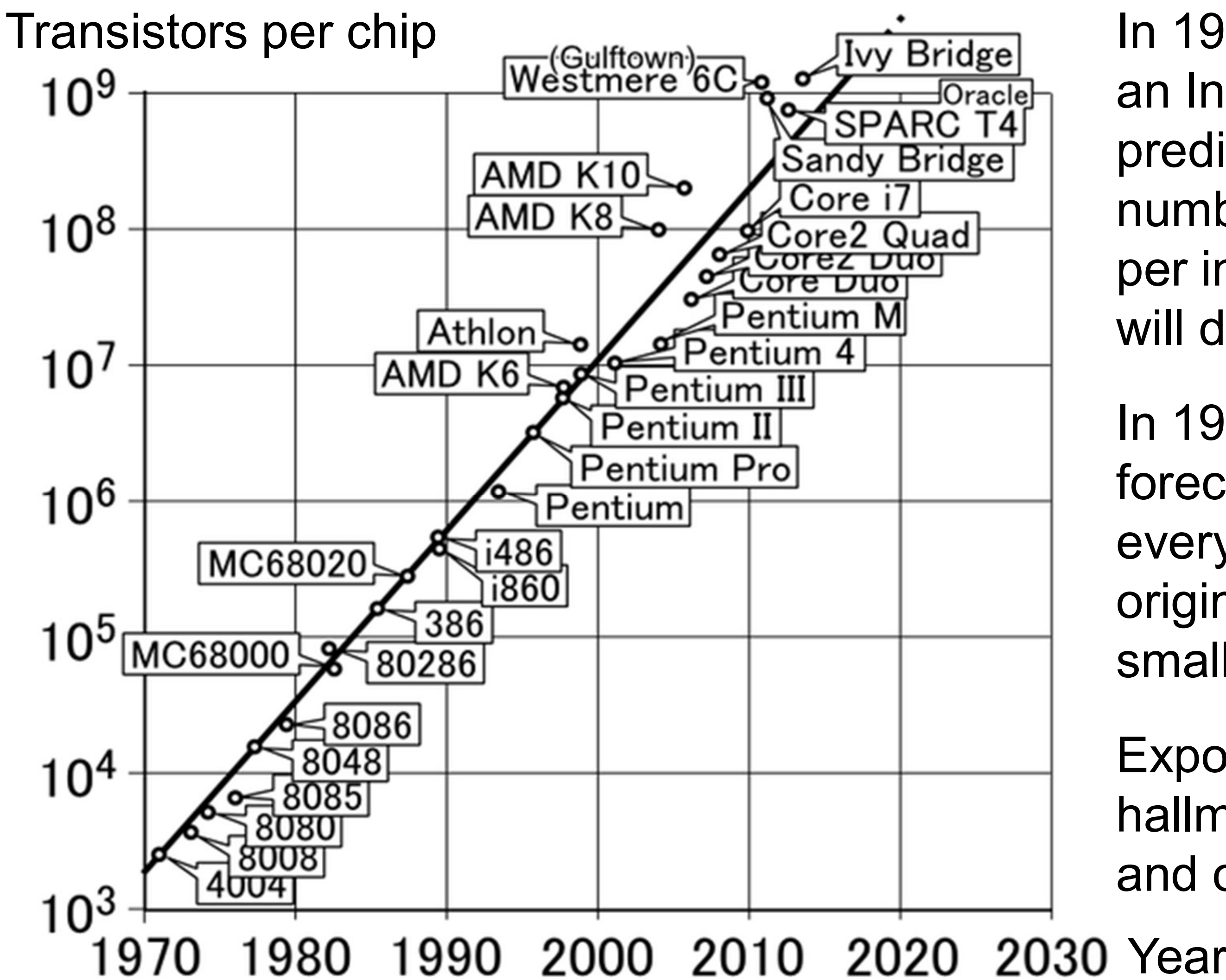


Technology Forecasting: Introduction

Reasons for technology forecasting:
Prioritize R&D programs
Plan new product development
Make strategic decisions on tech licensing, joint ventures, etc.



Technology Forecasting: Moore’s Law

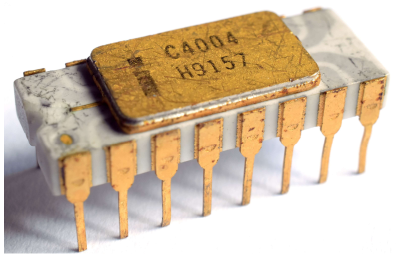


In 1965, Gordon Moore, an Intel co-founder predicted that the number of components per integrated circuits will double every year.

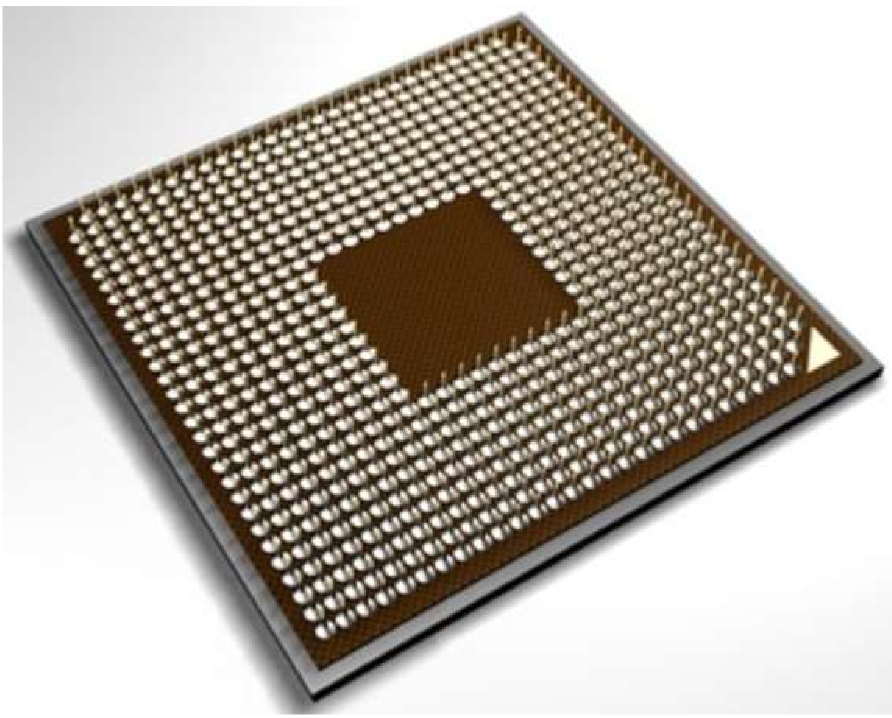
In 1975, he revised his forecast to doubling every 2 years (the original forecast had a small set of data points).

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

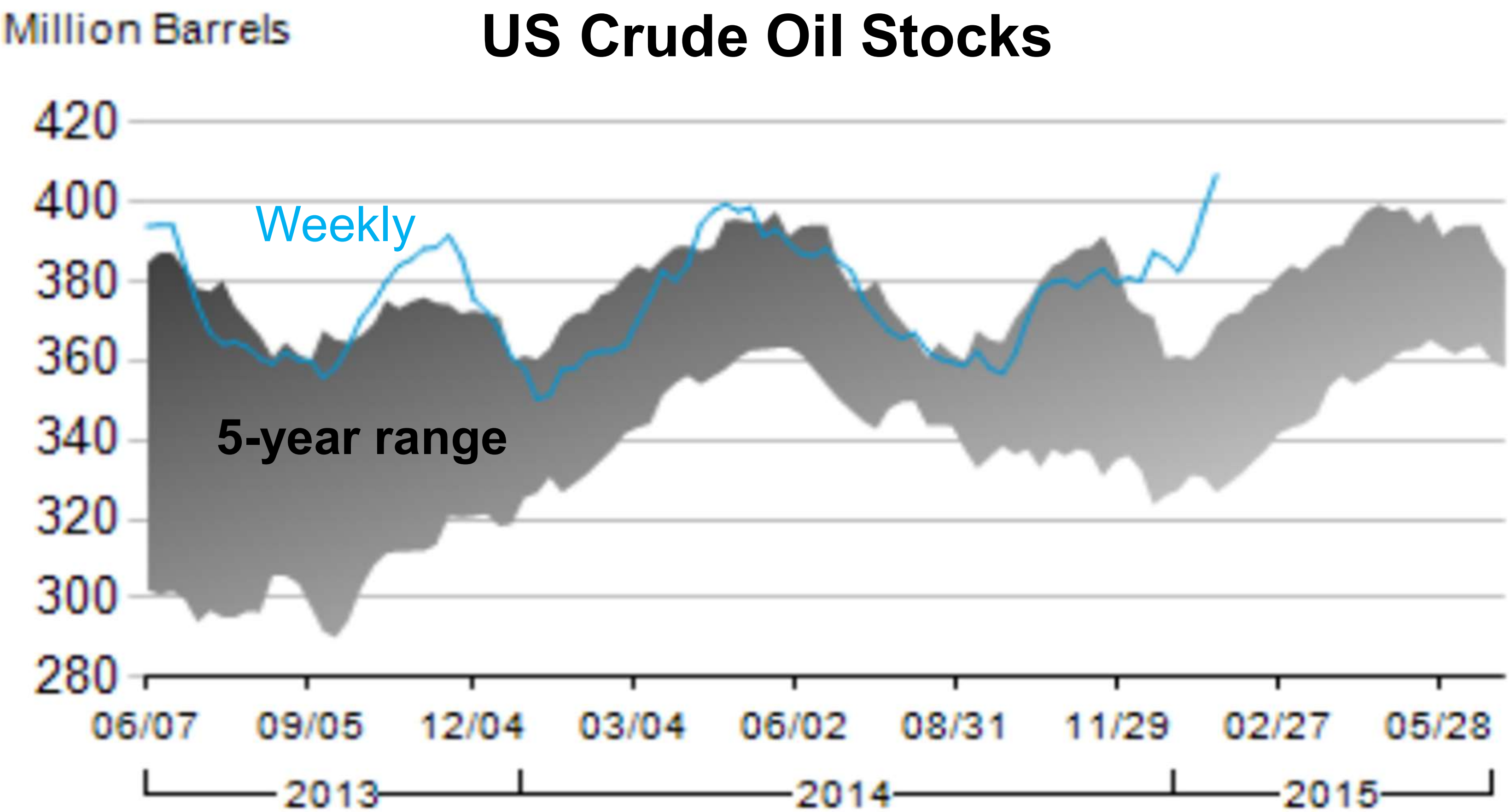
Display technology forecasting: resolution, thickness, contrast

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



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

INDICES	CLOSE	CHANGE	CHANGE %
Nasdaq Composite	4564.29	78.36	1.75
S&P 500	1985.05	23.42	1.19
DJIA	17005.75	187.81	1.12

www.linkedin.com/company/jhunjhunwalas

Jhunjhunwala's

Market Prediction: One Particular Stock

Stock-Market Prediction: Short-Term

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

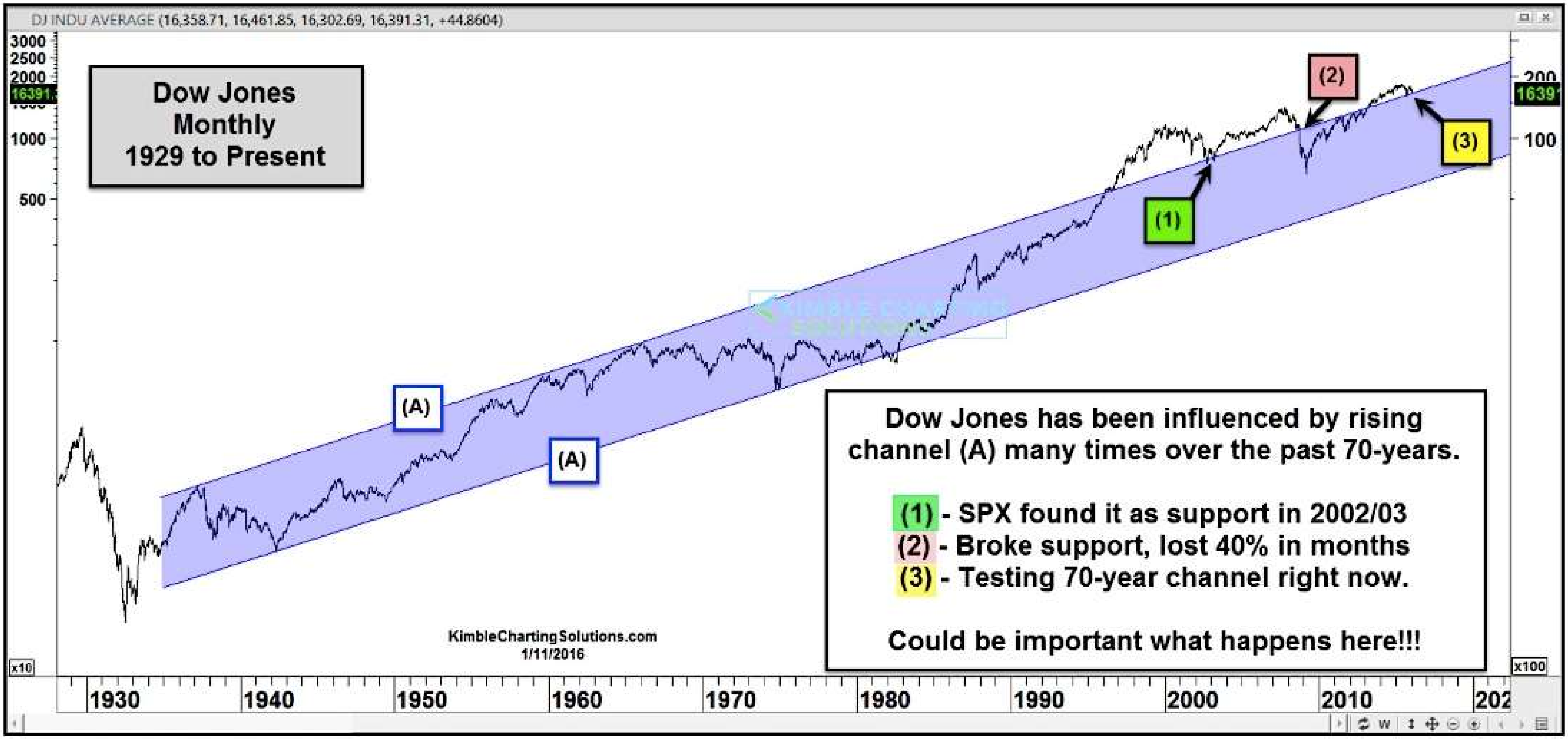
Stock-Market Prediction: Long-Term

Long-term variations: Uses logarithmic scale on the value axis

Stock-Market Prediction: Modeling

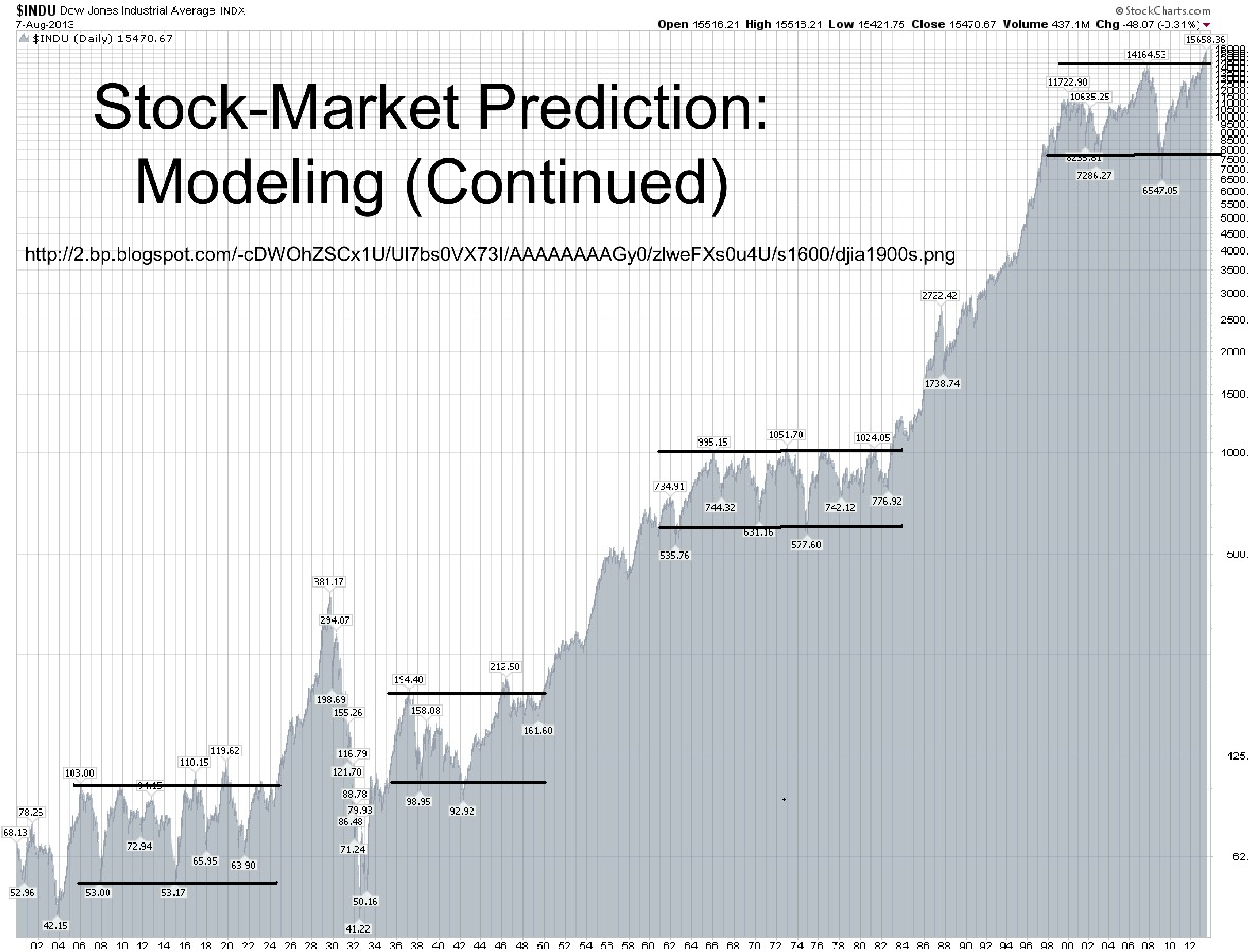
Models try to predict behavior or range of behaviors:

The so-called “black swan” effect may render most models useless



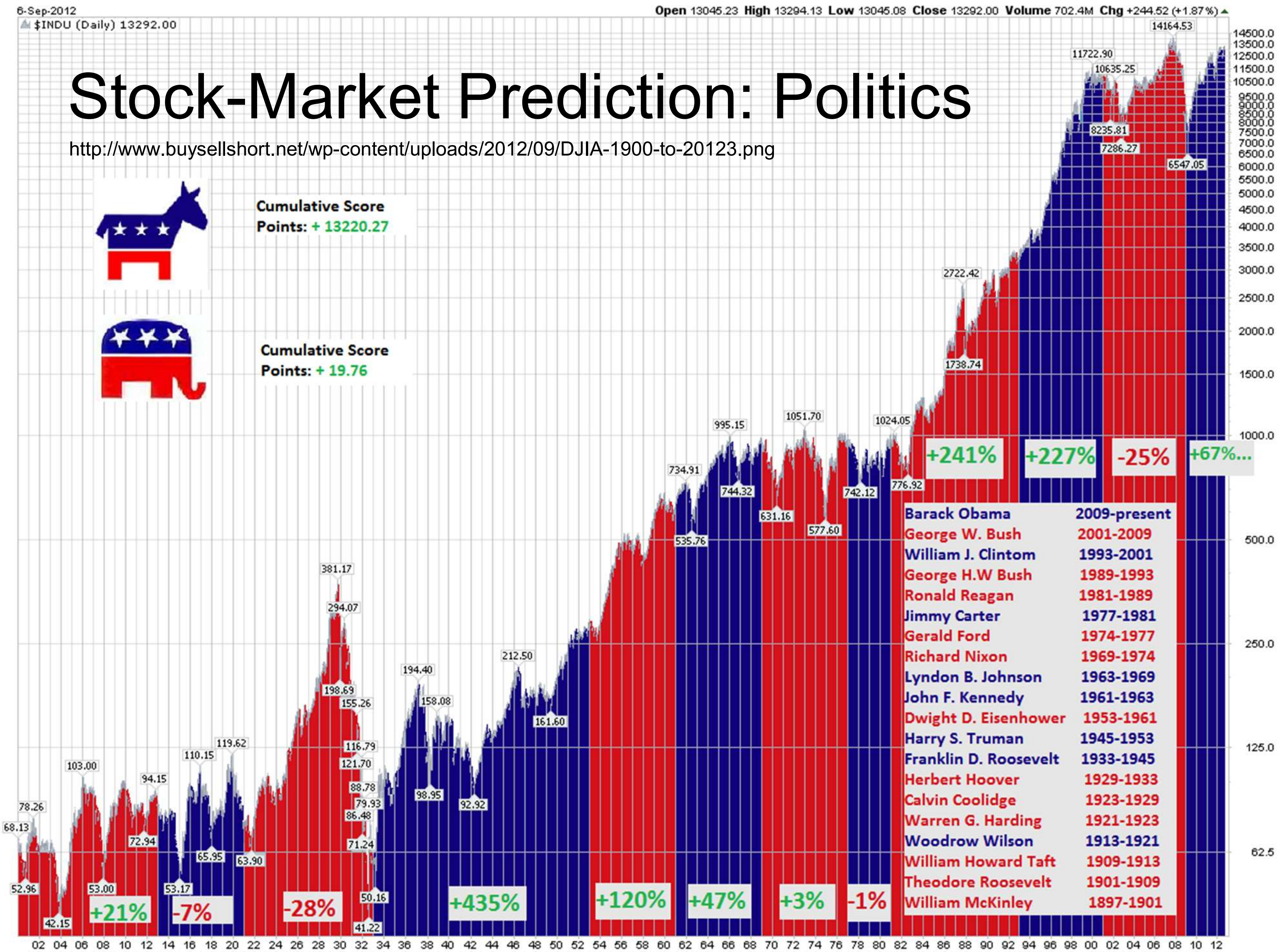
Stock-Market Prediction: Modeling (Continued)

http://2.bp.blogspot.com/-cDWOhZSCx1U/Ul7bs0VX73I/AAAAAAAAGy0/zlweFXs0u4U/s1600/djia1900s.png



Stock-Market Prediction: Politics

http://www.buysellshort.net/wp-content/uploads/2012/09/DJIA-1900-to-20123.png



Program Branch Prediction

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: