

**Lecture 20:  
Sex,  
Religion,  
and Politics**

CS150: Computer Science  
University of Virginia  
Computer Science

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*Science's Endless Golden Age*




<http://www.pbs.org/wgbh/nova/sciencenow/3313/nn-video-toda-w-220.html>

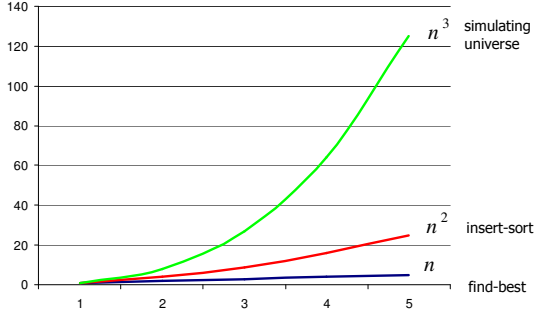
**Astrophysics**

- "If you're going to use your computer to simulate some phenomenon in the universe, then it only becomes interesting if you change the scale of that phenomenon by at least a factor of 10. ... For a 3D simulation, an increase by a factor of 10 in each of the three dimensions increases your volume by a factor of 1000."
- How much work is astrophysics simulation (in  $\Theta$  notation)?


$\Theta(n^3)$  When we double the size of the simulation, the work octuples! (Just like oceanography octopi simulations)

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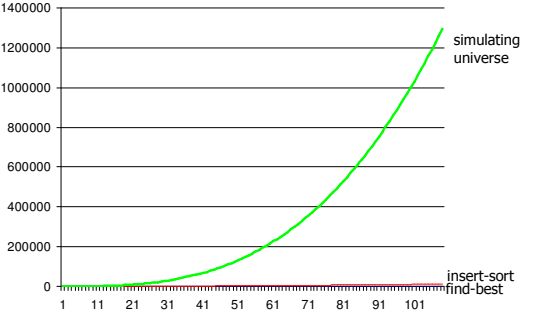
**Orders of Growth**




n	n (find-best)	n <sup>2</sup> (insert-sort)	n <sup>3</sup> (simulating universe)
1	1	1	1
2	2	4	8
3	3	9	27
4	4	16	64
5	5	25	125

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**Orders of Growth**




n	n (find-best)	n <sup>2</sup> (insert-sort)	n <sup>3</sup> (simulating universe)
1	1	1	1
11	11	121	1331
21	21	441	9261
31	31	961	29791
41	41	1681	68921
51	51	2601	132651
61	61	3721	226981
71	71	5041	357911
81	81	6561	531441
91	91	8281	753571
101	101	10201	1030301

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**Astrophysics and Moore's Law**

- Simulating universe is  $\Theta(n^3)$
- Moore's law: computing power doubles every 18 months
- Dr. Tyson: to understand something new about the universe, need to scale by 10x
- How long does it take to know twice as much about the universe?

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## Knowledge of the Universe

```

;;; doubling every 18 months = ~1.587 * every 12 months
(define (computing-power nyears)
  (if (= nyears 0) 1
      (* 1.587 (computing-power (- nyears 1)))))

;;; Simulation is  $\Theta(n^3)$  work
(define (simulation-work scale)
  (* scale scale scale))

(define (log10 x) (/ (log x) (log 10))) ;;; log is base e
;;; knowledge of the universe is  $\log_{10}$  the scale of universe
;;; we can simulate
(define (knowledge-of-universe scale) (log10 scale))

```

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## Knowledge of the Universe

```

(define (computing-power nyears)
  (if (= nyears 0) 1 (* 1.587 (computing-power (- nyears 1)))))
;;; doubling every 18 months = ~1.587 * every 12 months
(define (simulation-work scale) (* scale scale scale))
;;; Simulation is  $\Theta(n^3)$  work
(define (log10 x) (/ (log x) (log 10)))
;;; primitive log is natural (base e)
(define (knowledge-of-universe scale) (log10 scale))
;;; knowledge of the universe is log10 the scale of universe we can simulate
(define (find-knowledge-of-universe nyears)
  (define (find-biggest-scale scale)
    ;;; today, can simulate size 10 universe = 1000 work
    (if (> (/ (simulation-work scale) 1000)
        (computing-power nyears))
        (- scale 1)
        (find-biggest-scale (+ scale 1)))))
  (knowledge-of-universe (find-biggest-scale 1)))

```

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```

> (find-knowledge-of-universe 0)
1.0
> (find-knowledge-of-universe 1)
1.041392685158225
> (find-knowledge-of-universe 2)
1.1139433523068367
> (find-knowledge-of-universe 5)
1.322219294733919
> (find-knowledge-of-universe 10)
1.6627578316815739
> (find-knowledge-of-universe 15)
2.0
> (find-knowledge-of-universe 30)
3.00560944536028
> (find-knowledge-of-universe 60)
5.0115366121349325
> (find-knowledge-of-universe 80)
6.348717927935257

```

*Only two things are  
infinite, the  
universe and  
human stupidity,  
and I'm not sure  
about the former.*  
Albert Einstein

Will there be any mystery  
left in the Universe when  
you die?

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## The Endless Golden Age

- Golden Age – period in which knowledge/quality of something doubles quickly
- At any point in history, half of what is known about astrophysics was discovered in the previous 15 years!
  - Moore's law today, but other advances previously: telescopes, photocopiers, clocks, agriculture, etc.

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## Endless/Short Golden Ages

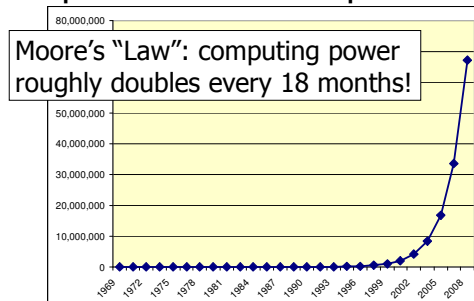
- **Endless golden age:** at any point in history, the amount known is twice what was known 15 years ago
  - Always exponential growth:  $\Theta(k^n)$   
 $k$  is some constant,  $n$  is number of years
- **Short golden age:** knowledge doubles during a short, "golden" period, but only improves linearly most of the time
  - Usually linear growth:  $\Theta(n)$   
 $n$  is number of years

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## Computing Power 1969-2008 (in Apollo Control Computer Units)

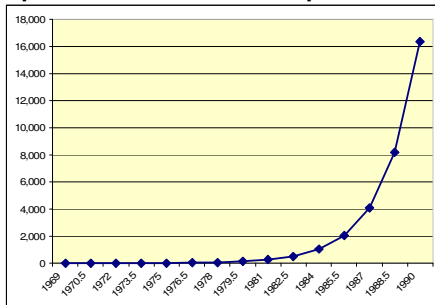


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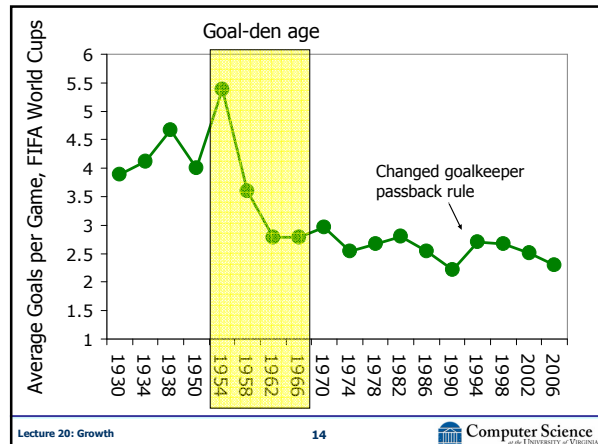


## Computing Power 1969-1990 (in Apollo Control Computer Units)



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## Endless Golden Age and "Grade Inflation"

- Average student gets twice as smart and well-prepared every 15 years
  - You had grade school teachers (maybe even parents) who went to college!
- If average GPA in 1977 is 2.00 what should it be today (if grading standards didn't change)?

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## Grade Inflation or Deflation?

- 2.00 average GPA in 1977 ("gentleman's C"?)
  - \* 2 better students 1977-1992
  - \* 2 better students 1992-2007
  - \* 1.49 population increase Virginia 1976: ~5.1M  
Virginia 2006: ~7.6M
  - \* 0.74 increase in enrollment Students 1976: 10,330  
Students 2006: 13,900
- Average GPA today should be: 8.82  
(but our expectations should also increase)

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## The Real Golden Rule?

Why do fields like astrophysics, medicine, biology and computer science have "endless golden ages", but fields like

- music (1775-1825)
- rock n' roll (1962-1973, or whatever was popular when you were 16)
- philosophy (400BC-350BC?)
- art (1875-1925?)
- soccer (1950-1966)
- baseball (1925-1950?)
- movies (1920-1940?)

have short golden ages?

Thanks to Leah Nylen for correcting this (previously I had only 1930-1940, but that is only true for Hollywood movies).

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## Golden Ages or Golden Catastrophes?

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## PS4, Question 1e

**Question 1:** For each  $f$  and  $g$  pair below, argue convincingly whether or not  $g$  is (1)  $O(f)$ , (2)  $\Omega(f)$ , and (3)  $\Theta(g)$  ...

- (e)  $g$ : the federal debt  $n$  years from today,  
 $f$ : the US population  $n$  years from today

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## Malthusian Catastrophe

Reverend Thomas Robert Malthus, *Essay on the Principle of Population*, 1798

"The great and unlooked for discoveries that have taken place of late years in natural philosophy, the increasing diffusion of general knowledge from the extension of the art of printing, the ardent and unshackled spirit of inquiry that prevails throughout the lettered and even unlettered world, ... have all concurred to lead many able men into the opinion that we were touching on a period big with the most important changes, changes that would in some measure be decisive of the future fate of mankind."



Source: The Walter J. Sarnoff Portrait Collection at Duke University

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## Malthus' Postulates

"I think I may fairly make two postulata.

- First, that food is necessary to the existence of man.
- Secondly, that the passion between the sexes is necessary and will remain nearly in its present state.

These two laws, ever since we have had any knowledge of mankind, appear to have been fixed laws of our nature, and, as we have not hitherto seen any alteration in them, we have no right to conclude that they will ever cease to be what they now are..."

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## Malthus' Conclusion

"Assuming then my postulata as granted, I say, that the power of population is indefinitely greater than the power in the earth to produce subsistence for man.

Population, when unchecked, increases in a geometrical ratio. Subsistence increases only in an arithmetical ratio. A slight acquaintance with numbers will show the immensity of the first power in comparison of the second."

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## Malthusian Catastrophe

- Population growth is geometric:  $\Theta(k^n)$  ( $k > 1$ )
- Food supply growth is linear:  $\Theta(n)$

What does this mean as  $n \rightarrow \infty$ ?

Food per person = food supply / population  
=  $\Theta(n) / \Theta(k^n)$

As  $n$  approaches infinity, food per person approaches zero!

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## Malthus' Fallacy



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## Malthus' Fallacy

He forgot how he started:  
 "The great and unlooked for discoveries that have taken place of late years in natural philosophy, the increasing diffusion of general knowledge from the extension of the art of printing, the ardent and unshackled spirit of inquiry that prevails throughout the lettered and even unlettered world..."

## Golden Age of Food Production

- Agriculture **is** an "endless golden age" field: production from the same land increases as  $\sim \Theta(1.02^n)$
- Increasing knowledge of farming, weather forecasting, plant domestication, genetic engineering, pest repellants, distribution channels, etc.

## Growing Corn

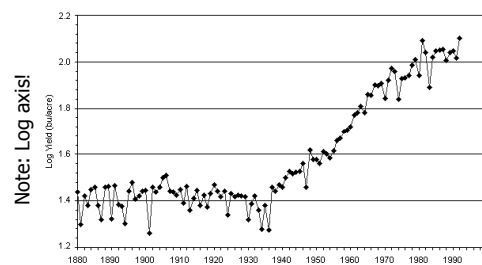


1906: < 1,000  
pounds per acre

2006: 10,000  
pounds per acre

Michael Pollan's *The Omnivore's Dilemma*

## Corn Yield

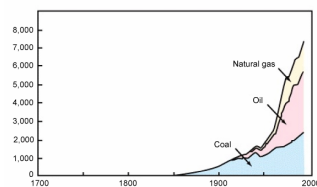


<http://www.agbioforum.org/v2n1/v2n1a10-ruttan.htm>

## Upcoming Malthusian Catastrophes?

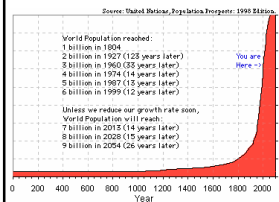
- Human consumption of fossil fuels grows as  $\Theta(k^n)$  (fairly large  $k$  like 1.08?)
- Available fuel is constant (?)

Fig. 3: Trends in World Fossil Fuel Consumption  
 (Million tons oil equivalent)

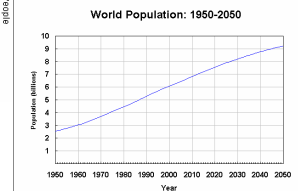


Source: Environment Agency's "White Paper on the Environment" (1998)  
[http://www.wpp.mest.go.jp/hakusyo/book/hpap200001/hpap200001\\_2\\_006.html](http://www.wpp.mest.go.jp/hakusyo/book/hpap200001/hpap200001_2_006.html)

## Malthus was wrong about #2 Also



Advances in science (birth control), medicine (higher life expectancy), education, and societal and political changes (e.g., regulation in China) have reduced  $k$  (it is  $< 1$  in many countries now!)



Source: U.S. Census Bureau, International Data Base, April 2005 version.

## PS4, Question 1e

$g$ : the federal debt  $n$  years from today,  
 $f$ : the US population  $n$  years from today

Debt increases:

Spending – Revenues  
this varies, but usually positive  
+ Interest on the previous debt (exponential)  
=  $\Theta(k^n)$

Population increase is not exponential:  
rate continues to decrease

=> as  $n$  increases, debt per person approaches infinity!

This will *eventually* be a problem, but growth analysis doesn't say *when*.

## "Cornucopian View"

- Few resources are really finite
- All scientific things seem to have endless golden ages
- (We hope) Human ingenuity and economics and politics will solve problems before they become catastrophes
  - No one will sell the last gallon of gas for \$2.35

## "Kay"-sian View

The best way to predict  
the future is to invent it.  
— Alan Kay

## Charge

- When picking majors, pick a short golden age field that is about to enter its short golden age
  - This requires vision and luck!
- Play it safe by picking an endless golden age field (CS is a good choice for this!)
- Enjoy your break!
  - PS5 is due Wednesday after break
  - Read GEB chapters (by Monday week after)