

Solution Manual For Algorithms by Das Gupta
Papadimitriou and Vazirani

Sidharth Arya

October 5, 2018

Contents

Prologue	iii
1 Algorithms with numbers	1
Code	3

Prologue

0.1

- $f = \Theta(g)$

Since $n-100$ and $n-200$ have the same power of n .

- $f = O(g)$

Since $n^{1/2}$ is smaller than $n^{2/3}$

- $f = \Theta(g)$

Since $\log n$ can always be overcome by n above a particular n , and so can it be less than $\log n$ below a particular n .

- $f = \Theta(g)$

Since $10n \log 10n = 10n(\log 10 + \log n) = 10n \log 10 + 10n \log n = \theta(n \log n)$

- $f = \Theta(g)$

Since $\log 2n = \log 2 + \log n$ and $\log 3n = \log 3 + \log n$. which makes $\log 2$ and $\log 3$, just constants.

- $f = \Theta(g)$

Since $\log n^2 = 2 \log n$. and 2 is just a constant that can be dropped.

- $f = \Omega(g)$

Since power greater than 0 can always overtake log at some point

- $f = \Omega(g)$

On comparing n^2 is greater than n , and log's are not that significant in comparison.

- $f = \Omega(g)$

Since power greater than 0 can always overtake log at some point

- $f = \Omega(g)$

Since $(\log n)^{(\log n)^{-1}}$ is greater than n for some value of n . Let us simplify equation for better comparison. We can multiply the equations by $\log n$

Giving

$$f'(x) = (\log n)^{(\log n) + 1}$$

$$g'(x) = n$$

I am using ' since equations have been altered and not the same as they initially were, yet they are still comparable.

now applying log

$$f''(x) = (1 + \log n) \log (\log n)$$

$$g''(x) = \log n$$

It is clear that it may not be possible to draw a direct relation. But $f''(x)$ can be written as:

$$f''(x) = (1 + g''(x)) \log (g''(x))$$

Now, if we visualize, $\log g''(x)$ will produce 1 at some point and will keep increasing after that value, and at that point it is multiplied by $1 + g''(x)$ which will clearly compound to something greater than $g''(x)$ itself.

Therefore, at some point $f(x)$ will overtake $g(x)$

- $f = \Omega(g)$

Since power greater than 0 can always overtake log at some point

- $f = O(g)$

$$5^{\log_2 n} = 5^{\log_2 n \times \log_5 5} = 5^{\log_5 n \times \log_2 5} = (5^{\log_5 n})^{\log_2 5} = n^{\log_2 5} \approx n^{2.\text{something}}$$

Therefore, at some n g will overcome f , by comparison of powers.

- $f = \Omega(g)$

Since $n2^n$ will produce a greater value for n than 3^n at some point.

- $f = \Theta(g)$

Since the two differ by a constant multiplicative factor, i.e. 2.

- $f = \Theta(g)$

Expansion of $n!$

$$n! = n(n-1)(n-2) \dots 1$$

Notice that largest possible power of n will be n . if we count unity as (n -something)

Therefore $n!$ can be dependent on n^n

and so n^n at some point will definitely overcome 2^n .

$n!$ grows atleast as fast as 2^n , maybe more, but our concern is satisfied.

- $f = O(g)$

Taking log on both equations, and comparing

$$f'(x) = \log n \times \log(\log n)$$

$$g'(x) = (\log_2 n)^2 \times \log 2 = \log 2 \times (\log_2 e)^2 \times \log n \times \log n$$

Comparing the n-dependent terms, $\log n$ is certainly greater than $\log(\log n)$. Therefore, $g'(x)$ will be greater than $f'(x)$ at some point.

0.2

$$g(n) = 1 + c + c^2 \dots + c^n$$

- if $c < 1$

The series will be decreasing. so the maximum number will be 1. Therefore, $g(n)$ be independent of n, on approximation, implying $g(n) = \Theta(1)$.

- if $c = 1$

$$g(n) = 1 + 1 + 1 + \dots + 1 = n$$

$$\text{Therefore, } g(n) = \Theta(n)$$

- if $c > 1$

$g(n)$ will be increasing. The largest term will be c^n

$$\text{Therefore, } g(n) = \Theta(c^n)$$

0.3

-

$$F_n \geq 2^{0.5n} \text{ for } n \geq 6$$

Induction

Case : $n = 6$ (Base Case)

$$F_0 = 0, F_1 = 1, F_2 = 1, F_3 = 2, F_4 = 3, F_5 = 5$$

$$\text{L.H.S : } F_6 = F_5 + F_4 = 8$$

$$\text{R.H.S : } 2^{0.5 \times 6} = 8$$

Since L.H.S = R.H.S

This case is true.

Let it be true, for $n = k$.

$$F_k = F_{k-1} + F_{k-2} \geq 2^{0.5 \times k}$$

Case: $n = k+1$

$$F_{k+1} = F_k + F_{k-1} \geq 2^{0.5 \times k} + 2^{0.5 \times k-1} = 2^{0.5 \times k} (1 + 2^{-0.5})$$

It can easily be shown that $1 + 2^{-0.5} > 2^{0.5}$

Substituting that instead $F_{k+1} \geq 2^{0.5(k+1)}$

-

We need to solve for c such that:

$$\begin{aligned}
 F_n &\leq 2^{cn} \quad \forall n \geq 6 \\
 \Rightarrow F_{n-1} + F_{n-2} &\leq 2^{cn} \\
 \Rightarrow 2^{c(n-1)} + 2^{c(n-2)} &\leq 2^{cn} \\
 \Rightarrow 2^{c(n-2)} (2^c + 1) &\leq 2^{cn} \\
 \Rightarrow 2^c + 1 &\leq 2^{2c} \\
 \text{Let } 2^c &= x \\
 \Rightarrow x + 1 &\leq x^2 \\
 \Rightarrow x^2 - x - 1 &\geq 0 \\
 2^c &\geq \frac{1 \pm \sqrt{5}}{2} \\
 \text{Taking log} \\
 \Rightarrow c &\geq \log_2 (1 \pm \sqrt{5}) - 1 \\
 c &\approx 1.694
 \end{aligned}$$

•

From previous example . $c = 1.694$

0.4

- Basic Matrix multiplication
- If we attribute all multiplicative and additive operations as $O(1)$, then, If we have to compute fibonacci of, say 9. We already know the value of matrix X . So to find value of fibonacci 9, we need to know X^9 , which can be written as $X^8 \times X$. Since we already know the value of X . All we have to do is compute $X^2 = X \times X$ and $X^4 = X^2 \times X^2$ and $X^8 = X^4 \times X^4$, which gives us a total of 3 matrix multiplication operations. for $n = 9$.

And for $n = 8$ it would be the same. Since $\log 8$ is 3, so there are 3 matrix multiplication. which concludes the answer.

- It's an obvious statement, since even the final answer will not be n bits long.

let's say we start with 0, 1, 1. The third fibonacci number in binary will be 10. compare them with $n = 0, 1, 2, 3$. Just for sake of argument let's use induction.

Induction

for $n = 1$ (Base Case)

$$F_1 = 1$$

also in binary only one bit is needed. Base Case is satisfied.

let's assume it to be true for $n=k$

then

$$F_{k+1} = F_k + F_{k-1}$$

We know that binary $F_k = O(k)$ and binary $F_{k-1} = O(k-1)$

It is already known that the maximum of n digit number on addition with itself will have $n+1$ digits.

e.g

1111111 + 1111111 = 1111110

Therefore k-digit binary number + k-1 digit binary number cannot produce more digits than k+1...

Hence the statement is true for all fibonacci numbers.

- Since log n matrix multiplications are required, each compounding to 8 matrix multiplications. Running time will be nearly $O(8M(n) \log n) = O(M(n) \log n)$
- Basically as we raise the power of the matrices, the length increases (doubles). Therefore

$M(1) + M(2) + M(4) \dots + M(n-1) = O(M(n))$ Since the terms have some dependence on n (e.g. $M(n-1)$).

0.5 Extra

0.5.1 Fibonacci 1: By Recursion

```
#include<stdio.h>

int fib(int n)
{
    if(n == 0) return 0 ;
    if(n == 1) return 1;
    else return fib(n-1) + fib(n-2);
}

int main()
{
    printf("%d", fib(40));
    return 0;
}
```

Time: 0m1.143s Note: if you have a linux machine, you can check the time on your machine by `time output-file`. but the time will be different on your machine.

0.5.2 Fibonacci 1: By Loop

```
#include<stdio.h>

int fib(int n)
{
    if(n == 0) return 0 ;
    if(n == 1) return 1;
    int Arr[n];
```

```
    Arr[0] = 0; Arr[1] = 1;
    for(int i = 2 ; i < n; i++)
        Arr[i] = Arr[i-1] + Arr[i-2];
    return Arr[n-1] + Arr[n-2];
}
int main()
{
    printf("%d", fib(40));
    return 0;
}
```

Time: 0m0.002s

0.5.3 Fibonnaci 1: By Matrices

```
#include<stdio.h>

int fib(int n)
{
    if(n == 0) return 0 ;
    if(n == 1) return 1;
    int mat[2][2] = {
        {0, 1},
        {1, 1}
    }

}

int main()
{
    printf("%d", fib(40));
    return 0;
}
```

Time: 0m0.002s

Chapter 1

Algorithms with numbers

Code

```
(add-to-list 'org-latex-classes
  '("some"
    "\\documentclass{book}"
    ("\\chapter{%s}" . "\\chapter*{%s}")
    ("\\section{%s}" . "\\section*{%s}")
    ("\\subsection{%s}" . "\\subsection*{%s}")
    ("\\subsubsection{%s}" . "\\subsubsection*{%s}")))
```