

Asymptotic  
 Big O:  $T(n) \leq c \cdot f(n)$   
 Copper:  $T(n) \geq c \cdot f(n)$   
 (Lower)  
 Big  $\Theta$ : both  $O$  &  $\Omega$   
 (Tight)

Proof by induction

1. Base Case
2. Induction hypothesis - true for  $(n-1)$  Assume
3. Prove to be true for  $(n)$  or  $(n+1)$ , if  $n$  in prev step.

Distance problems

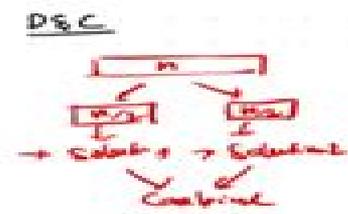
$S_L$  = left subproblem  
 $S_R$  = right subproblem  
 $S_M$  = smallest distance between points in 2 of 3 sides

Master Theorem

Let  $T(n) = O(n^c)$   
 $T(n) \leq a \cdot T(n/b) + c \cdot n^d$   
 for  $n > 1$ ,  $a, b, c, d$  = constants  
 $T(n) = O(n^d) \rightarrow a < b^d$   
 $O(n^{\log_b a}) \rightarrow a > b^d$   
 $O(n^d \log(n)) \rightarrow a = b^d$

log c linear & quad & poly  
 $\log n \leq \frac{1}{2} \leq n \cdot \log n < \frac{1}{2} \log n^2$   
 Bring them all to same bound.

**RULE:**  
 $n^{1/2} = 2 \log(n^2)$   
 $\log n = \frac{1}{2} \log(n^2)$   
 $\log \log n = \frac{1}{2} \log(\log n^2)$



Matrix Mult

$\begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{pmatrix} \cdot \begin{pmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{pmatrix} = \begin{pmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{pmatrix}$   
 $C_{11} = A_{11}B_{11} + A_{12}B_{21}$      $C_{12} = A_{11}B_{12} + A_{12}B_{22}$   
 $C_{21} = A_{21}B_{11} + A_{22}B_{21}$      $C_{22} = A_{21}B_{12} + A_{22}B_{22}$

naive:  $O(n^3)$

Strassen's Algorithm

$\begin{pmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{pmatrix} \cdot \begin{pmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{pmatrix} = \begin{pmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{pmatrix}$   
 $M_1 = (A_{11} + A_{22})(B_{11} + B_{22})$      $M_2 = A_{11}B_{21} + A_{22}B_{12}$   
 $M_3 = (A_{21} + A_{12})B_{11}$      $M_4 = A_{21}B_{12} + A_{12}B_{21}$   
 $M_5 = A_{11}(A_{22} - A_{21})$      $M_6 = (A_{11} + A_{21})B_{22}$   
 $M_7 = (A_{22} - A_{12})A_{21}$      $M_8 = (A_{22} - A_{12})(B_{21} + B_{12})$   
 $C_{11} = M_1 - M_5 - M_8$   
 $C_{12} = M_3 + M_4$   
 $C_{21} = M_2 + M_5$   
 $C_{22} = M_1 - M_4 - M_7$   
 Only 7 multiplications  
 $T(n) = 7 \cdot T(n/2) + O(n^2)$

Max Gap

MAXGAP(A[1...n])  
 1. if  $n = 1$ , return -1  
 2.  $m = \lfloor n/2 \rfloor$   
 3.  $A_L = \text{MAXGAP}(A[1...m])$   
 4.  $A_R = \text{MAXGAP}(A[m+1...n])$   
 5.  $Lowest = \text{MIN}(A[m], A[m+1])$   
 6.  $MaxGap = \text{MAX}(A[m], A[m+1]) - Lowest$   
 7.  $Gap = \text{MAX}(A_L, A_R, MaxGap)$   
 8. return  $\text{MAX}(Gap, A[m], A[m+1])$   
 Total  $2T(n/2) + O(1)$

Counting inversions

```

SORTANDCOUNT(A[1...n])
1. if  $n > 1$ 
2.  $m = \lfloor n/2 \rfloor$ 
3.  $C_L = \text{SORTANDCOUNT}(A[1...m])$ 
4.  $C_R = \text{SORTANDCOUNT}(A[m+1...n])$ 
5.  $C_M = \text{COUNTINVERSIONS}(A[1...n], m)$ 
6.  $\text{MERGE}(A[1...n], m)$ 
7. return  $C_L + C_R + C_M$ 
  
```

```

COUNTINVERSIONS(A[1...n], m)
1.  $i = 1, j = m + 1, k = 1$ 
2. while  $i \leq m$  and  $j \leq n$ 
3. if  $A[i] < A[j]$ 
4.  $i = i + 1, k = k + 1$ 
5. else
6.  $A[k] = A[j], j = j + 1$ 
7.  $A[k] = A[i], i = i + 1, k = k + 1$ 
8. return  $\sum_{i=1}^n \text{inv}(i)$ 
  
```

→ Easy to check  
 we simply divide into 2 arrays  
 we check within array to count from  
 we check that half & repeat steps  
 → comparison  $\Rightarrow O(n^2)$   
 $\sqrt{2n} \rightarrow n = 10, n^2 \log(n), n^2, 10n^2, 10n^2 \log(n)$

```

DOMINATE(A[1...n])
1.  $D = 0$ 
2. if  $n \leq 1$ 
3. return  $D$ 
4.  $m = \lfloor n/2 \rfloor$ 
5. if  $\text{COUNTDOMINATIONS}(m, A) = 1$ 
6.  $D = D + 1$ 
7.  $D_L = \text{DOMINATE}(A[1...m])$ 
8.  $D_R = \text{DOMINATE}(A[m+1...n])$ 
9. for each  $i \in D_L \cup D_R$ 
10. if  $\text{COUNTDOMINATIONS}(i, A) = 1$ 
11.  $D = D + 1$ 
12. return  $D$ 
  
```

```

COUNTDOMINATIONS(A[1...n])
1. count = 0
2. for  $i = 1$  to  $n$ 
3. if  $\text{COUNTEQ}(i, A) = 1$ 
4. count = count + 1
5. if count >  $n/2$ 
6. return 1
7. return -1
  
```

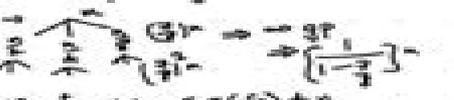
Stack concept useful to traverse a path once  
 & compare  $\Rightarrow O(n)$  instead of  $O(n^2)$

$A[1...n]$   
 create stack  
 o/p array result  
 for  $i = 1$  reverse  
 while stack not empty  
 tall = stack.pop()  
 if  $A[i] < tall$   
 we append (tall)  
 break  
 else stack.pop()

if stack empty  
 result.append(-1)  
 stack.push(A[i])  
 return result.reverse

Recurrence Trees

→ tree depth: log n ends when  $T(1)$



→ get  $T(n) \leq T(n/2) + n$   
 let  $n = 2^k$   
 → get into master theorem form  
 $\sum_{i=0}^{k-1} \sqrt{n} \Rightarrow f(n) \leq n\sqrt{n}$   
 $\leq \text{form} = \frac{1}{2} \sqrt{2n}$   
 $O(n\sqrt{n}) \Rightarrow O(n^2)$

→  $\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \dots = \frac{1}{2} \Rightarrow \sum_{i=1}^{\infty} \frac{1}{2^i} = 1$   
 log split with val  
 sum of  $n$  w's:  $\frac{n \cdot \log(n)}{2}$   
 $\rightarrow n \cdot \frac{1}{2} = n \cdot \frac{1}{2} = n/2$   
 $\rightarrow \log(n) \leq \sqrt{n}$

# Data Structures Lecture Notes Doc

**Simone Marinai**



## **Data Structures Lecture Notes Doc:**

Principles of Document Processing Charles Nicholas, Derick Wood, 1997-09-17 This book constitutes the thoroughly refereed post workshop proceedings of the Third International Workshop on Principles of Document Processing PODP 96 held in Palo Alto California USA in September 1996 The book contains 13 revised full papers presented as chapters of a coherent monograph like book The papers focus equally on the theory and the practice of document processing Among the topics covered are theory of media cross media publishing and multi modal documents SGML content models grammar compatible stylesheets multimedia documents temporal constraints in multimedia hypertext representation contextual knowledge structured documents for IR Web publishing virtual documents etc

**Document Analysis Systems: Theory and Practice** Seong-Whan Lee, Yasuaki Nakano, 2003-07-31 Recently there has been an increased interest in the research and development of techniques for components of complete document analysis systems In recognition of this trend a series of workshops on Document Analysis Systems commenced in 1994 under the leadership of Henry Baird The first workshop held in Kaiserslautern Germany in October 1994 was chaired by Andreas Dengel and Larry Spitz The second workshop on Document Analysis Systems was held in Malvern PA USA in October 1996 chaired by Jonathan J Hull and Suzanne Liebowitz Taylor The DAS workshop has been one of the most prestigious technical meetings bringing together a large number of scientists and engineers from all over the world to express their innovative ideas and report on their latest achievements in the area of document analysis systems The papers in this special book edition were rigorously selected from the Third IAPR Workshop on Document Analysis Systems DAS 98 held in Nagano Japan on 4 6 November 1998 It is worth mentioning that the papers were chosen for their original and substantial contributions to the workshop theme and this special book edition From among the 53 papers that were presented by authors from 11 countries at the DAS 98 after critical reviews by at least three experts we carefully selected 29 papers for this special book edition Most of the contributions in this edition have been expanded or extensively revised to include helpful discussions suggestions or comments made during the workshop

Document Analysis Systems VI Simone Marinai, Andreas Dengel, 2004-08-26

This volume contains papers selected for presentation at the 6th IAPR Workshop on Document Analysis Systems DAS 2004 held during September 8 10 2004 at the University of Florence Italy Several papers represent the state of the art in a broad range of traditional topics such as layout analysis applications to graphics recognition and handwritten documents Other contributions address the description of complete working systems which is one of the strengths of this workshop Some papers extend the application domains to other media like the processing of Internet documents The peculiarity of this 6th workshop was the large number of papers related to digital libraries and to the processing of historical documents a taste which frequently requires the analysis of color documents A total of 17 papers are associated with these topics whereas two years ago in DAS 2002 only a couple of papers dealt with these problems In our view there are three main reasons for this

new wave in the DAS community From the scientific point of view several research fields reached a thorough knowledge of techniques and problems that can be effectively solved and this expertise can now be applied to new domains Another incentive has been provided by several research projects funded by the EC and the NSF on topics related to digital libraries

**Symbol Spotting in Digital Libraries** Marçal Rusiñol, Josep Lladós, 2010-05-25 Pattern recognition basically deals with the recognition of patterns shapes objects things in images Document image analysis was one of the very first applications of pattern recognition and even of computing But until the 1980s research in this field was mainly dealing with text based documents including OCR Optical Character Recognition and page layout analysis Only a few people were looking at more specific documents such as music sheet bank cheques or forms The community of graphics recognition became visible in the late 1980s Their specific interest was to recognize high level objects represented by line drawings and graphics The specific pattern recognition problems they had to deal with was raster to graphics conversion i.e recognizing graphical primitives in a cluttered pixel image text graphics separation and symbol recognition The specific problem of symbol recognition in graphical documents has received a lot of attention The symbols to be recognized can be musical notation electrical symbols architectural objects pictograms in maps etc At first glance the symbol recognition problems seems to be very similar to that of character recognition after all characters are basically a subset of symbols Therefore the large know how in OCR has been extensively used in graphical symbol recognition starting with segmenting the document to extract the symbols extracting features from the symbols and then recognizing them through classification or matching with respect to a training learning set

Machine Learning in Document Analysis and Recognition Simone Marinai, 2008-01-10 The objective of Document Analysis and Recognition DAR is to recognize the text and graphical components of a document and to extract information This book is a collection of research papers and state of the art reviews by leading researchers all over the world It includes pointers to challenges and opportunities for future research directions The main goal of the book is to identify good practices for the use of learning strategies in DAR

**Graph Data-Models and Semantic Web Technologies in Scholarly Digital Editing** Elena Spadini, Francesca Tomasi, Georg Vogeler, 2021-10-06 In scholarly digital editing the established practice for semantically enriching digital texts is to add markup to a linear string of characters Graph data models provide an alternative approach which is increasingly being given serious consideration Labelled property graph databases and the W3c's semantic web recommendation and associated standards RDF and OWL are powerful and flexible solutions to many of the problems that come with embedded markup This volume explores the combination of scholarly digital editions the graph data model and the semantic web from three perspectives infrastructures and technologies formal models and projects and editions

**Data Structures and Target Classification** Vibeke Libby, 1991 *Document Recognition and Retrieval*, 2004

**Course Notes**, 1992 *Proceedings of the 2006 ACM Symposium on Document Engineering* David F. Brailsford, 2006

**Database and Expert Systems Applications**, 2001 **Proceedings**, 1999 *Proceedings of the Fifth International*

*Conference on Document Analysis and Recognition : September 20-22, 1999, Bangalore, India ,1999* Proceedings of the September 1999 conference on various aspects of document analysis and recognition Following the keynote address on character and document research in the open mind initiative 195 oral and poster contributions discuss topics including multimedia document processing character recognition document image processing applications checks forms and music DAS electronic documents and document segmentation character recognition and classification information retrieval postal automation document analysis systems performance evaluation and handwriting font graphics word Oriental character and Indian languages recognition Lacks a subject index Annotation copyrighted by Book News Inc Portland OR **A Model for Document Databases** Airi Salminen,1989 Seloste Information Modelling and Knowledge Bases ,1996 **Document Analysis Systems** ,1998 Algorithm Engineering ,2001 *Bulletin - Institute of Mathematical Statistics* Institute of Mathematical Statistics,1979 **Data Documentation** Wilhelm Gaus,Rolf Henzler,1977 **Principles of Document Processing** ,1996

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