

*Errata and Updates*  
*for*  
Algorithms Sequential  
and Parallel: A Unified  
Approach

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**Prentice-Hall, Inc., New Jersey, 2000**  
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## Overview

This document contains errata, corrections, improvements, and updates to *Algorithms Sequential & Parallel: A Unified Approach*, Prentice Hall, Inc., New Jersey, 2000. Creating this document (*i.e.*, typing this document into MS Word) took approximately 1 staff day by one of the authors. Therefore, while this document is somewhat extensive, we anticipate that the changes to the text will require no more than 0.5 staff days of effort by the publisher, excluding figures. There are some revisions required to several figures, which we anticipate should take an additional 0.5 staff days of effort by the publisher. Therefore, we anticipate that with minimal effort on the part of the publisher, a significantly enhanced version of the text will be available.

This document was prepared using fairly standard professional notation. In most cases, we give the page and line number (positive numbers count from the top of the page and negative numbers count from the bottom of the page). Since this document should only be available for a relatively short period (until a new version of the text is released that incorporates these changes), this document has not been prepared to conform to a high standard, but rather to disseminate critical information in a timely fashion.

We apologize for the large number of relatively minor errors/fixes. Many of the errors were caused by the typesetters choosing to work from our hardcopy instead of from the electronic version supplied to them. The book is essentially in beta form, though the bibliography and index should be considered as an alpha release. Since this book is rich in mathematics, and mathematics is particularly susceptible to problems when being entered by a 3<sup>rd</sup> party, do not hesitate to contact us if you believe there is an error that we have not yet detected in the mathematical typesetting.

Please feel free to forward any comments, questions, criticism to the authors via [www.prenhall.com/millerboxer/](http://www.prenhall.com/millerboxer/)

Russ Miller & Laurence Boxer, January 2000

**General Comments:**

- Algorithms need to be typeset in a consistent fashion. For any text statement, the 2<sup>nd</sup> and subsequent lines of any individual statement should be indented so as to improve readability.
- Variable declarations should be lined up.
- Comments should be formatted and typeset in a consistent fashion. All statements should either have or not have a capitalized first word and period.
- Nil pointers in diagrams should be presented in a consistent fashion. They should either all use the ground symbol or all use the T symbol.
- Chapter Notes at the end of every chapter should start on a new page so as to improve accessibility.
- The Exercises at the end of every chapter should start on a new page so as to improve readability and presentation for students.

**Preface:**

- Pg vi: change to “**Prerequisites:** We assume that the reader has a basic knowledge of data structures. That is, the reader should be comfortable with the notion of a stack, queue, list, and binary tree.”
- Pg vi, -12: change “Divide-and-Conquer” to “divide-and-conquer”
- Pg vii, 13: change to “mathematically-based” (add hyphen)

**Contents:**

- Pg xi, -3: change to “Hausdorff Metric ...” (remove hyphen)

**Chapter 1:**

- Pg 5, 9, change to “latter, which has a much slower growth...”
- Pg 5, change to “ $f(n) = \Theta(g(n))$  (read “ $f$  of  $n$  is **theta** of  $g$  of  $n$ ”) *if and only if* there exist positive constants  $c_1$ ,  $c_2$ , and  $n_0$  such that  $c_1g(n) \leq f(n) \leq c_2g(n)$  whenever  $n \geq n_0$ .” (remove comma after constants and reverse inequality at the end from  $\leq$  to  $\geq$ )
- Pg 5, Figure 1-1. Place the  $n_0$  under the vertical line. Make the vertical line a dashed line, as in Figs 1-2 – 1-6, and move the vertical line so that it intersects with the intersection of curves  $f(n)$  and  $g(n)$ .
- Pg 6, Figure 1-2.  $f(n)$  and  $g(n)$  should appear to grow together (at the same rate) near the right side of the figure (and forever after). That is, you should be able to physically cut out the last inch or so of one curve and lay it on top of the last inch or so of the other curve.
- Pg 6, Figures 1-3 and 1-4.  $f(n)$  and  $g(n)$  should be redrawn on the rightside of the figures so that it appears that they will never intersect. That is,  $f(n)$  and  $g(n)$  should turn slightly away from each other on the rightside of the figure, but both should still appear to be increasing.
- Pgs 6-7, Figures 1-5 and 1-6. The 3 straight lines should intersect and originate at a point near the origin.
- Pg 6, Figure 1-5 caption. Change to “An illustration of  $o$ -notation:  $f(n) = o(g(n))$ .”
- Pg 7, Figure 1-6 caption. Change to “An illustration of  $w$ -notation:  $f(n) = w(g(n))$ .”
- Pg 8, Example. Midway down the page, change the floors and ceilings to be correct as

.....Notice that

$$\sum_{k=1}^n k^p = \sum_{k=1}^{\lfloor n/2 \rfloor} k^p + \sum_{k=\lfloor n/2 \rfloor + 1}^n k^p .$$

Using this result, we know that

$$\sum_{k=1}^n k^p \geq \sum_{k=\lfloor n/2 \rfloor + 1}^n k^p .$$

Notice that in

$$\sum_{k=\lfloor n/2 \rfloor + 1}^n k^p$$

there are  $n - \lfloor n/2 \rfloor$  terms, where  $(\lfloor n/2 \rfloor + 1)^p$  is the smallest term. ....

- Pg 9, item 9, change to: “ $f(n)$  is bounded above and below by positive constants *if and only if*  $f(n) = \Theta(1)$ .”
- Pg 12, -3, the integral needs to be formatted better by moving the  $h(t)dt$  slightly to the left, as in the identical equation in the line above.
- Pg 13, 3, change to “...the curve of  $h(t)$ , where ...” (add comma)
- Pg 13, 10, change “(left)” to “(left figure)” and “(right side)” to “(right figure)”
- Pg 17, Figure 1-10 caption. Remove last sentence “So, given ...”
- Pg 18, 20, change to “of  $|q|$ , a loop ...” (add comma)
- Pg 19, -11, change to “total *search* time is” (add italics)
- Pg 19 -7, add the following sentence after “are used.”: “Notice that  $O$ -notation is used, as both results represent upper bounds on the search time.”
- Pg 19, -4, change the last two sentences to: “However, in the worst case, the insert step always requires  $X[*current*]$  to be moved to position 1, requiring *current* data items to be moved, while in the best case,  $X[*current*]$  is always in the proper position (*i.e.*, the initial data is sorted). Therefore, the number of data movement operations is given by ...”
- Pg 20, change the first real sent and the remainder of the paragraph to: “Hence the running time of InsertionSort is  $\Theta(n)$  in the best case (when data is already sorted and a sequential search from (*current* – 1) downto 1 is used),  $\Theta(n^2)$  in the average (or expected) case, and  $\Theta(n^2)$  in the worst case. The reader should verify these results by substituting the appropriate values into the summation and simplifying the equation. Notice that the average- and worst-case running times are dominated by the data movement operations.”
- Pg 20, change last sent of 2<sup>nd</sup> par to “An insertion routine is presented below.”

- Pg 20, at the end of the gray box, add the following:

For completeness, we present an efficient implementation of InsertionSort based on the analysis we have presented.

**Subprogram InsertionSort** ( $x, n$ )

{Simple version of InsertionSort with sequential search.}

```

For  $i = 2$  to  $n$ , do
     $hold = x[i]$ 
     $position = 1$ 
    While ( $hold > x[position]$ ), do
         $position = position + 1$ 
    end While
    If  $position < i$ , then
        For  $j = i$  downto  $position$ , do
             $x[j] = x[j - 1]$ 
        End For
         $x[position] = hold$ 
    End If
End For
End InsertionSort

```

- Pg 21, 9, change to "...as InsertionSort, but is typically faster in practice."
- Pg 21-22, **Subprogram BinSort** should have the four major statements numbered as
  1. For  $j = 1 \dots$
  2. For  $j = 1 \dots$
  3.  $s = 1$
  4. For  $j = 1 \dots$
- Pg 22, Figure 1-2, consistency of ground vs. T for nil pointer.
- Pg 26, 8, change "must also be correct." to "be in the correct position."
- Pg 27, 3, indent line so *startIndex* lines up with *List* from the line above (see general comments on page 3 of this document)

**Chapter 2:**

- Pg 30, 17, change “induce” to “*induce*” (italics)
- Pg 32, 1<sup>st</sup> par, last sent, change to “The induction proof follows.”
- Pg 32, enumerated item 1, change to “We must show the assertion to be true for the base case, which is  $n = 4$ . Notice that since  $4! = 24 > 16 = 2^4$ , the assertion is true for our base case of  $n = 4$ .”
- Pg 42, Figure 2-5, global consistency of ground vs. T for nil pointer.
- Pg 43, **Subprogram Split**, make changes of *false* to 0, *true* to 1, *flag* to *current\_list*, and the line *flag* = not *flag* to *current\_list* = 1 – *current\_list*, as follows:

**Subprogram Split(*headIn*, *headOut*)**

**Algorithm:** Split an input list indexed by *headIn* (a pointer to the first element) into two output lists by alternating the output list to which an input element is assigned.

The output lists are indexed by *headOut*[0...1]

Local variables: *current\_list*, a switch used to alternate between output lists

*temp*, a temporary pointer to current link of input list

Action:

```
{Initialize output lists as empty.}
headOut[0] = null;
headOut[1] = null;
flag = 0;
While headIn ≠ null do
    temp = headIn;
    headIn = headIn.next;
    temp.next = headOut[current_list];
    headOut[current_list] = temp;
    current_list = 1 – current_list
end While
return headOut
```

end *Split*

- Pg 43, **Subprogram MergeSort**, similarly change all occurrences of *false* to 0 and all occurrences of *true* to 1.

**Subprogram MergeSort(*head*)**

**Algorithm:** Sort a linked list via Mergesort algorithm

**Input:** A linked list indexed by *head*, a pointer to the first element

**Output:** An ordered list

Local variables:  $temp[0 \dots 1]$ , an array of two pointers

Action:

```

    If  $head \neq null$  then {input list is nonempty}
      If  $head.next \neq null$  then
        {There's work to do, as the list has at least two
         elements.}
         $Split(head, temp)$ ;
         $MergeSort(temp[0])$ ;
         $MergeSort(temp[1])$ ;
         $Merge(temp[0], temp[1], head)$ 
      End If
    End If
    Return  $head$ 
  End Sort

```

- Pg 46, problem 5a) change “used” to “associated”
- Pg 46, recurrence indentation. Indent lines 11-12, 15-16, and 24-25 the same amount as the other recurrences are indented on that page.
- Pg 47, 1, add a space after *numbers*, and before the *f*s.

**Chapter 3:**

- Pg 49, -11, change “solutions to obtain” to “solutions in order to obtain”
- Pg 50, Figure 3-1, caption. Add after the current sentence: “The number of problems to be solved at each (horizontal) level of recursion is listed along with the size of each problem at that level. Time is used to represent the time per problem, not counting recursion, at each level.” Also, the vertical columns should be rearranged so that “No. of Problems” is moved to the left side of the figure and “Each Problem Size” (centered over its entries) is moved to the first column on the right side of the figure.
- Pg 50, -3, change “following page” to “following pages”.
- Pg 54, *Proof*, remove “that” so as to read “First, we observe by Lemma 1 ...”
- Pg 56, last paragraph, change “In the following ...; use – otherwise.” to “Without loss of generality, we have  $\log_b a - e \geq 0$ .”
- Pg 56-57, last couple of mathematical lines of 56 and first mathematical line of 57 should be changed to replace the  $\pm$  symbol with a + symbol.

**Chapter 4:**

- Pg 63, 5, change “two algorithms,” to “two sorting algorithms,”
- Pg 63, 7, change “are given” to “were presented”
- Pg 63, 8, change “makes” to “made”
- Pg 63, 10, change “Bitonic Sort.” To “Batcher’s BitonicSort.”
- Pg 63, 15-16, change “flows from” to “flows along the lines from”
- Pg 63, -8, change “ $\Theta(1)$  (constant) time.” to “constant time.”
- Pg 63, -3, change “These units” to “Further, these functional units”
- Pg 65, 3, change “then we have plateaus in our list,” to “then there are plateaus in the list,”
- Pg 65, Figure 4-2, the curve should end (intersect) at the last vertical line segment.
- Pg 66, Figure 4-3, the vertical line associated with point  $j$  should intersect the curve at the peak of the curve, not just off to the right of the peak.
- Pg 66-67. Relabel Figure 4-3 to Figure 4-3a and add a Figure 4-3b that is identical to the current Figure 4-3 but with  $d$  and  $e$  appropriately denoted with heavy or dashed lines.  $\langle d \rangle$  goes from points 1 to  $k - n$  **and** from points  $k + 1$  to  $2n$ .  $\langle e \rangle$  is the remainder (middle) of the curves, from points  $k - n + 1$  to point  $k$ .
- Pg 67, **Subprogram BitonicMerge**, the word “Procedure” should be in **bold**. In the statement “If *direction*...”, the subscript on the first  $A$  should be in italics.
- Pg 67, Figure 4-4, change “a bitonic sequence” to “a **bitonic** sequence” and “a monotonic (ordered) sequence” to “a **monotonic** (ordered) sequence” – *i.e.*, add bold.
- Pg 68, -16, change  $a$  to  $\langle a \rangle$  and  $c$  to  $\langle c \rangle$ , so as to read, “the input sequence,  $\langle a \rangle$ , is bitonic and that the output sequence,  $\langle c \rangle$ , is sorted.
- Pg 68, -14, change “low” to “lower” and “high” to “higher”
- Pg 71, add the base of the logarithm into both log’s on the right side of the equal sign at the top of the page, as follows

$$\sum_{i=1}^{\log_2 2n} i = \frac{(\log_2 2n)(\log_2 2n + 1)}{2} = \frac{(\log_2 2n)^2}{2} + \frac{\log_2 2n}{2}$$

### Chapter 5:

- Pg 75, -12, change “location (address)” to “address”
- Pg 77, 10-11, remove the sentence/paragraph “On a parallel computer, ... affect running time.”
- Pg 77, -8 to -7, skip a line between paragraphs since the line ending on -8 ends the Memory Access unit section and the line beginning on -7 continues the section.
- Pg 80, 19, change “appealing model.” to “appealing machine.”
- Pg 83, 4, remove extra space between “variables:” and the “*i, min\_so\_far*”.
- Pg 84, -2, change “defined as  $n \times T_{par}(n)$ ,” to “defined as  $cost = n \times T_{par}(n)$ ,”
- Pg 85, 4-5, change “is performing.” to “performs.”
- Pg 85, 15, change “value  $P$ ,” to “value of  $P$ ,”
- Pg 93, 3, change “of size  $n^{1/2}$ ,” to “of size  $n^{1/2}$ ,” (add comma)
- Pg 95, Figure 5-13, on the rightmost cell of the Initial Data, Step 1, Step 2, Step 3, Step 4, and Step 5 figures, move the value and left arrow down vertically so as to appear as the first element of the bottom row of values (of the tractor-tread) which is moving from right to left. In the first cells of Step 5 and 6, the value and left arrow need to move up to the top line. In general, this figure should be redrawn, especially the Initial Data and Step 5, so that the reader sees a top line of the tractor-tread going from left to right and the bottom line of the tractor-tread going from right to left.
- Pg 99, -15, change “(viewed as the bottom of the tractor tread)” to “(viewed as the top of the tractor tread)”
- Pg 99, -14, change “(viewed as the top of the tractor tread)” to “(viewed as the bottom of the tractor tread)”
- Pg 100, 4-5, change “operation (here, generically denoted  $\otimes$ ) to all” to “operation  $\otimes$  to all”
- Pg 103, 13, change “children)” to “children),” (add comma)
- Pg 103, -4, change “So, the pyramid” to “Therefore, the pyramid”
- Pg 106, -9, change “mesh-of-trees such that” to “mesh-of-trees of base size  $n$  such that”
- Pg 108, Figure 5-22, on (c) and (d), change the diagonal elements from single valued entries to duplicate entries per node. So, reading from top-left to bottom-right on (c), we should have 5,5 then 9,9 then 4,4 and finally 2,2. In (d), we should have 5,5 then 9,9 then 4,4 and finally 2,2.

5,5	5,9	5,4	5,2
9,5	9,9	9,4	9,2
4,5	4,9	4,4	4,2
2,5	2,9	2,4	2,2

Data values that go in the nodes of both Figure 5-22 (c) and (d)

- Pg 108, Figure 5-22 caption. Remove the sentence “Note that the ... singleton item.”
- Pg 109, Figure 5-23, fix node 0011 so that the arc from 1011 does not enter the circle
- Pg 109, Figure 5-24, add shading to the leftmost (0) node of the 1-cube, to the topmost 2 nodes of the 2-cube, and to the leftmost 4 nodes of the 3-cube.
- Pg 109, Figure 5-24, caption, add a sentence that says “Subcube  $A$  is shaded in all diagrams for ease of presentation.”
- Pg 109, -5, change “*fixed degree network*” to “fixed degree network” (no italics)
- Pg 110, 22-23, remove “design and” so that it reads “...hard to produce a...”
- Pg 111, 13, change both occurrences of “ $i$ -th bit” to “ $(\log_2 n - i + 1)$ -th bit”
- Pg 112, Figure 5-25b, caption, change “0-dimensional edge” to “1-dimensional edge”
- Pg 112, Figure 5-25c, caption, change “1-dimensional edge” to “2-dimensional edge”
- Pg 113, Figure 5-25d, caption, change “2-dimensional edge” to “3-dimensional edge”
- Pg 113, Figure 5-25e, caption, change “3-dimensional edge” to “4-dimensional edge”
- Pg 113, Figure 5-25, caption, 3, change “most significant bit, to their” to “most significant bit to their” (remove comma)

**Chapter 6:**

- Pg 123, 18, change “contribute” to “contributes”
- Pg 127, 11, change “We say each ... matrix  $A$ .” to “Given an  $n \times n$  matrix  $A$ , each of the following is said to be an *elementary row operation*.”
- Pg 128, 2<sup>nd</sup> text line, change “the matrix.” to “the augmented matrix.”
- Pg 128, 5, change “1 on the *diagonal*” to “1 along the *diagonal*”
- Pg 129-130, Replace the algorithm (Steps 1 and 2, as well as the sentence at the end “We now come ... algorithm.” with the algorithm that is presented on the next page.
- Pg 130, -11, change “examining  $column_1$  that” to “examining the first column that”
- Pg 131, change “**Mesh of  $n^2$  processors:**” to “**Mesh with  $n^2$  processors:**” (change “of” to “with” in section title)

1. {Gaussian elimination phase: use elementary operations to transform  $A$  into an upper triangular matrix, *i.e.*, a matrix in which every diagonal entry has value 1 and every entry below the diagonal has value 0.}

For  $i = 1$  to  $n$ , do

- If  $A[i,i] = 0$  and  $A[m,i] = 0$  for all  $m > i$ , conclude that  $A^{-1}$  does not exist and halt the algorithm.
- If  $A[i,i] = 0$  and  $A[m,i] \neq 0$  for some smallest  $m > i$ , interchange rows  $i$  and  $m$  in the array  $A$  and in the array  $I$ .
- Now we assume  $A[i,i] \neq 0$ . Divide row  $i$  of  $A$  and row  $I$  of  $I$  by  $A[i,i]$ . That is, let  $scale = A[i,i]$  and then for  $j = 1$  to  $n$ , set  $A[i,j] \leftarrow A[i,j] / scale$  (actually, it suffices to do this for  $j = i$  to  $n$ , since the Gaussian elimination has caused  $A[i,j] = 0$  for  $j < i$ ). Similarly, for  $j = 1$  to  $n$ , set  $I[i,j] \leftarrow I[i,j] / scale$ . Note we now have  $A[k,k] = 1$  for  $k \leq i$ , and  $A[m,j] = 0$  if  $j < i$  and  $j < m$ .
- Now we have  $A[i,i] = 1$ . If  $i < n$ , then for  $r > i$ , subtract  $A[r,i]$  times row  $i$  from row  $r$  in both the arrays  $A$  and  $I$  (this zeroes out the entries in  $A$  of column  $i$  below the diagonal without destroying the 0s below the diagonal in columns further to the left). That is,

If  $i < n$ , then

For  $row = i + 1$  to  $n$

$factor \leftarrow A[row,i]$

For  $col = 1$  to  $n$

$A[row,col] \leftarrow A[row,col] - factor \times A[i,col]$

$I[row,col] \leftarrow I[row,col] - factor \times I[i,col]$

End for  $col$

End for  $row$

End if

Note we now have  $A[k,k] = 1$  for  $k \leq i$ , and  $A[m,j] = 0$  if  $j \leq i$  and  $j < m$ .

End for  $i$

2. (Back substitution phase: eliminate the nonzero entries above the diagonal of  $A$ .)

For  $elim = n$  downto 2

For  $row = elim - 1$  downto 1

$factor \leftarrow A[row,elim]$

For  $col = 1$  to  $n$

$A[row,col] \leftarrow A[row,col] - factor \times A[elim,col]$

$I[row,col] \leftarrow I[row,col] - factor \times I[elim,col]$

End for  $col$

End for  $row$

End for  $elim$

We now discuss the analysis of Gaussian elimination on sequential and parallel models of computation.

**Chapter 7:**

- Pg 137, 6, change “combines pairs of” to “combines prefixes of”
- Pg 137, algorithm in middle, keep the formatting of the word For consistent between the For statement and the End For statement (make the End *For* out of italics is probably most consistent with the rest of the book). This occurs in 2 places on the page. Consistency of algorithm formatting is a major issue to be checked throughout the book.
- Pg 142, Figure 7-7, In (c), change “2-dimensional” to “3-dimensional”. In (d), change “1-dimensional” to “2-dimensional”. In (e), change “0-dimensional” to “1-dimensional”.
- Pg 143, Algorithm, check global consistency in presenting comments that start with a capitalized word vs. a lower case word and do end in periods vs. don’t end in periods.
- Pg 147, 6-7, change “are in larger” to “are associated with larger”
- Pg 149, change Figure 7-9 to the following:

Processor Index:	0	1	2	3	4	5	6	7	8	9
Leader	1	0	0	1	0	1	1	0	0	0
Data	18	22	4	36	-3	72	28	100	54	0

Processor Index:	0	1	2	3	4	5	6	7	8	9
Leader	1	0	0	1	0	1	1	0	0	0
Data	18	22	4	36	-3	72	28	100	54	0
LeaderData	18	18	18	36	36	72	28	28	28	28

Figure 7-9 An example of a segmented broadcast. The top table shows the initial state (*i.e.*, the information before the segmented broadcast). Thus, by examining the Leader field in each processor, we know that the interval leaders are processors 0, 3, 5, and 6. In the bottom table, we show the information after the segmented broadcast. Notice that information from each leader has been propagated (broadcast) to all processors to the right (higher index values) up to, but not including, the next leader.

- Pg 149, 2<sup>nd</sup> line of text, change “.leader” to “Leader” (capitalize the word leader)
- Pg 150, 19-20, remove “The algorithm follows.”
- Pg 155, quest #8, line 3, change “these points as” to “these segments as”

**Chapter 8:**

- Pg 158, change two sentences in final text paragraph to “During every step of the algorithm, each element  $L(i)$  knows that  $L(next(i))$  is at distance, say,  $current\_dist(i)$  from it. In order to determine the element at distance  $\max\{2 \times current\_dist(i), d(i)\}$ ,  $L(i)$  simply locates  $L(next(next(i)))$ , as shown in Figure 8-1.”
- Pg 158, algorithm at bottom, continue with global consistency issues regarding capitalization and punctuation of comments.
- Pg 159, 2<sup>nd</sup> line of text, change to “must traverse  $\lceil \log_2 n \rceil + 1$  links”
- Pg 159, Figure 8-1, consistency of ground vs. T symbol for nil pointer.
- Pg 159, figure 8-1, caption. In the last line, change to “with 10 elements, five iterations are required ( $\lceil \log_2 10 \rceil + 1 = 5$ ).
- Pg 160, algorithm in middle, continue with global consistency issues.
- Pg 160, -1, change to “must traverse  $\lceil \log_2 n \rceil + 1$  links in”
- Pg 161, Figure 8-2, in the 3<sup>rd</sup> line of the example, the next to last expression should be “ $x_2 \otimes x_3 \otimes x_4 \otimes x_5$ ” and the last expression of that line should be “ $x_3 \otimes x_4 \otimes x_5 \otimes x_6$ ”
- Pg 161, Figure 8-2, caption, at the end change to “procedure requires three iterations to complete the prefix computation, plus an additional iteration to determine that the process should terminate ( $\lceil \log_2 6 \rceil + 1 = 4$ ).

## Chapter 9:

- Pg 166, 9, change “recursively sorted, since” to “recursively sorted since” (remove comma)
- Pg 167, Figure 9-1, line up the time per level with the levels horizontally – the times are all below their respective lines of data.
- Pg 167, Figure 9-1, move the + symbol over to the right so that it appears that a long vertical string of values is being summed (which it is). So, the + should go much closer to the  $\Theta(n)$  that is to the right of it.
- Pg 169, 17, change to “... naive algorithm for arbitrary input data has a running time ...”
- Pg 170, Figure 9-5(a), caption, change to “Initial array of size 25”
- Pg 170, Figure 9-6, consistency of ground vs. T for nil pointers.
- Pg 171, algorithm, check for consistency of format to assess whether or not “Local variables” should be bold.
- Pg 171, 7, change to “*bigList*: linked lists used ...” (*i.e.*, insert the word “linked”)
- Pg 171, after line 7, insert a new declaration as follows:  
“*smallList\_array*, *bigList\_array*: arrays used for recursive function calls;”
- Pg 172, 2, change to “*Selection(k, smallList\_array, 1, |smallList|)*;” (*i.e.*, *smallList* changes to *smallList\_array* as the second parameter in the procedure call)
- Pg 172, 8, change to “*Selection(k - |smallList| - |equalList|, bigList\_array, 1, |bigList|)*.” That is, change *bigList* to *bigList\_array* as the second parameter in the procedure call.
- Pg 173, 11<sup>th</sup> text line, change to “*Selection(k, smallList\_array, 1, |smallList|)*;” (*i.e.*, *smallList* changes to *smallList\_array* as the second parameter in the procedure call)
- Pg 174, 18-19, bad break. Keep “ $\Theta(\log n)$ ” on the same line.
- Pg 174, -10, change to “QuickSort has a  $\Theta(n)$  ...”
- Pg 175, 3, change to “similarity of the divide step of QuickSort with the divide step...”
- Pg 175, 4, change to “note that the”
- Pg 175, 5-6, change to “its members all have the same value.”
- Pg 175, 13, change to “concatenating sublists.”
- Pg 175, Figure 9-7, consistency of ground vs. T for nil pointers.
- Pg 176, 7, change to “way as *AM* is used during”

- Pg 176, 14-15, change to “of elements are either greater than or equal to *splitValue* or less than or equal to *splitValue*.”
- Pg 176, 19, change to “to be close to the median.”
- Pg 176, **Subprogram QuickSort**, consistency of capitalization and punctuation of statements/comments.
- Pg 178, -12 - -11, change to “However, an efficient static array implementation of QuickSort is important for “dusty deck” codes that must be maintained in their original style. This includes...”
- Pg 179, -8, change to “**Conquer:** Recursively sort the two subarrays,  $A[\textit{left} \dots p]$  and  $A[p + 1 \dots \textit{right}]$ .”
- Pg 181, Example, remove the first sentence “Notice that ... of the array.”
- Pg 181, Example, change the next line to “is chosen to be  $A[1]=5$ , the first element of the array,  $i$  is set to ...”
- Pg 184, -13, change “largest of the  $n$  elements in” to “largest element in”
- Pg 184, -3, change to “it takes  $k(i-1)$  and”
- Pg 185, end of line 6, add so as to read, “to partition  $n$  data items, assuming that Partition is modified in such a way as to prevent  $i$  and  $j$  from crossing,”
- Pg 185, middle, change the “.....” to “...” in both places in the middle of the bracketed matrix.
- Pg 186, first line of math, change the “c” to a “[“ and the “d” to a “]” so as to read:

So,

$$k(n) = n + 1 + \frac{2}{n} \left[ k(n-1) + \frac{n-1}{2} (k(n-1) - n) \right]$$

- Pg 186, in math near bottom, change “(a constant)” to be “{a constant}” and put into comment font style
- Pg 187, 6, change to “on the computer systems under”
- Pg 188, -16, change to “using some  $\Theta(N \log N)$  time algorithm.”
- Pg 188, -7, change to “denoted as  $L$  and  $U$ . For simplicity, let  $L$  consist of all nodes with a 0 as the most significant bit of its address and let  $R$  consist of all nodes with a 1 as the most significant bit of its address.”
- Pg 189, 5, change to “simultaneously, independently, recursively, and”
- Pg 189, at the end of step 8 add the following: “For example, during the first recursive call, work on  $L$  will involve two subcubes of size  $2^{d-1}$ , one of which has leading address bits of 00 and the other of which has leading address bits of 01. Similarly, work on  $R$  will involve two subcubes of size  $2^{d-1}$ , one with leading bits 10 and the other with leading bits 11.”

- Pg 192, Figure 9-11, add shading to the figure so that in the first matrix, every item is shaded individually, in the second matrix, 1x2 regions are shaded (9&10, 14&2, 15&4, 11&12, etc.), in the 4<sup>th</sup> matrix, 2x2 regions are shaded (4&9&10&15, 14&12&11&2, etc.), in the 7<sup>th</sup> matrix, 2x4 regions are shaded (first two rows shaded together and the last two rows shaded together), and in the last matrix, then entire set of values is shaded.
- Pg 193, 14, change “MergeCopySort” to “MergeSort”
- Pg 194, 19, change to “determined in  $O(n^{1/2})$  time,”
- Pg 195, Figure 9-12, caption for (b), change to “Sorted data with keys for re-sorting”
- Pg 195, -6, change to “receive information about, though the total number of request records generated by any processor is no more than some fixed constant. A concurrent...”
- Pg 196, 9-10, change to “(Processors making fewer than  $C_2$  requests will create dummy request records so that all ...”
- Pg 196, -12, change to “updated with, for example, the minimum...”

**Chapter 10:**

- Pg 202, Figure 10-1, individual captions, change all four captions from “Example of ...” to “Example of a ...”
- Pg 202, Definitions, 4, change to “determining a minimal ordered list”
- Pg 203, Figure 10-2, caption, change line 7 to “denoted as  $\text{hull}(S)$ .” (change “by” to “as”)
- Pg 204, 7, change to “(i.e., it is an ...” (add the *i.e.*)
- Pg 205, 10, change to “to this specific example, follow:”
- Pg 208, 9-11, change to “An analysis is then presented for both a RAM and a mesh implementation. At the conclusion of this section, we present a divide-and-conquer algorithm, complete with analysis, for the PRAM.”
- Pg 208, 15, change to “points is given in a”
- Pg 213, -6, the fonts on the  $R_i$  are not set consistently with the rest of such text.
- Pg 214, 5, change to “Let  $T_{i,j}$  denote the ...”
- Pg 214, 10, change “above.” to “earlier.”
- Pg 214, change item 5 to “If the angle of intersection between  $V_i$  and  $W_i$  is less than or equal to  $180^\circ$  (see Figure 10-16), or if  $w_i$  is to the left of  $v_i$  (see Figure 10-17), then none of the points representing the upper envelope of  $\text{hull}(R_i)$  belong to  $\text{hull}(S)$ ; otherwise, all points on the upper hull of  $\text{hull}(R_i)$  from  $v_i$  to  $w_i$ , inclusive, belong to  $\text{hull}(S)$  (see Figures 10-14 and 10-15). Notice that this operation is performed in  $\Theta(1)$  time.”
- Pg 216, Figure 10-18, change “ $x$ ” to “ $x'$ ” (replace the apostrophe with a prime symbol)
- Pg 220, -13, change beginning of sentence to “In  $\Theta(n)$  time, create two...”
- Pg 220, -10, change beginning of sentence to “In  $\Theta(n \log n)$  time, sort these  $2n$  records into ascending order by the  $x$ -coordinate of their ...”
- Pg 220, -8, change “allowing” to “which allows”
- Pg 222, 9, change to “members of  $S$  might represent sectors...”
- Pg 222, -3, change to “find its maximal successor, if ...”
- Pg 228, exercise 15b). Primes should all be presented as primes. The symbol masquerading as a prime in the main equation should be changed so it is actually a prime.

**Chapter 11:**

- Pg 233, 1, change to “*Warshall’s algorithm* for determining the transitive ...”
- Pg 233, 13-14, replace “Unfortunately, this algorithm ... chapter.” with “Details of this algorithm are presented in Chapter 12.”
- Pg 234, -4 - -3, change sentence “That is, every ... at most ).” to “Parallel propagation consists of every black pixel continually exchanging its current component label with each of it’s black neighbors (at most four).”
- Pg 236, change to “1. **Divide** the image into four subimages, each of size  $(n/2) \times (n/2)$ .”
- Pg 236, change to “2. **Recursively** label each of the independent subimages.”
- Pg 236, change to “3. **Stitch** the independently labeled subimages together in order to obtain a labeled image.”
- Pg 238, -7 - -6, change to “outermost points of the set.” (*i.e.*, remove the word “nonzero”)
- Pg 240, 18, change to “either  $p$  or  $r$  is a nearest distinctly ...”
- Pg 240, 21-23, change to “so that every processor  $p$  finds at most two nearest processors in its row with distinct foreground labels. Call these processors  $r_1$  and  $r_2$ , where the labels of the foreground pixels in  $r_1$  and  $r_2$  are distinct.”
- Pg 240, -2, change to “to determine a nearest distinctly ...”
- Pg 241, change to “**Running Time:** On an  $n \times n$  mesh, ...”
- Pg 241, -19, change to “will terminate immediately after information from ...”
- Pg 247, 3, add a single terminating quote after the word Continuous to match the single leading quote at the beginning of that word.
- Pg 247, Ex 8, line 2, change to “determine its Euclidean distance to...” (*i.e.*, add the word “Euclidean” before “distance”).
- Pg 248, Ex 11, at end of exercise, add the sentence “Assume  $m = O(n^2)$ .”

**Chapter 12:**

- Pg 251, 2, change to “problems including graphs. We will present efficient ...” (*i.e.*, replace “for data ... edges” with “including graphs”)
- Pg 251, 12-13, replace “The following ... used:” with “Graphs are often used in the following ways.”
- Pg 251, to start each itemized item (4 in total), replace “Represent” with “To represent” so as turn the phrases into sentences.
- Pg 252, Figures 12-1 and 12-2. Center “Kneiphof” within its oval. Add marks to make the river look like water. Make the bridges look more like bridges that you see from an aerial view (shading probably).
- Pg 253, 9, change “Usually, we do not ...” to “Typically, we do not ...”
- Pg 254, 1, change to “inside of asymptotic notation, ...” (*i.e.*, remove “an”)
- Pg 257, Figure 12-9, consistency in ground vs. T to represent nil pointers.
- Pg 257, 4, remove the comma so it reads “Notice that regardless ...”
- Pg 259, 20-21, replace “bread-first” with “breadth-first”
- Pg 261, 6-7, change to “considered at least once. Therefore, assuming ...”
- Pg 263, Figure 12-14, caption. Change reference to Figure 12-12 to 12-11 as “utilized in Figure 12-11.”
- Pg 264-265, Figure 12-15 and 12-16, change the squares to circles for consistency in representing vertices (nodes) of graphs.
- Pg 265, 4, add hyphen so that it is “minimal-weight spanning tree problem.”
- Pg 266, -8 - -7, change to “It follows that on a RAM, an Euler circuit of  $T$  can be listed in  $\Theta(E)$  time.”
- Pg 267, Figure 12-17, consistency of ground vs. T to represent nil pointers.
- Pg 267, Figure 12-17, caption, 4<sup>th</sup> line, change to “function in (c) would also change. By starting ...”
- Pg 271, Figure 12-21a-e caption, change to the following: “**Figure 12-21** An example of tree contraction. Indices of nodes in the array *Active* are shown below the nodes (these are updated following compression of *Active* as the steps are executed). The initial tree ... algorithm (after the third iteration).”
- Pg 271, 4, change to “In this section, we review both a sequential and mesh implementation of a transitive closure ...”
- Pg 272, Figure 12-22, caption, 2<sup>nd</sup> line, change to “mesh.  $A_k(k, k)$  is computed at time  $t = 3k - 2$  in processor  $P_{k,k}$ . During the ...”
- Pg 273, 3, remove comma so that it reads

“ $f_k(i, j) = g(f_{k-1}(i, j), f_{k-1}(i, k), f_{k-1}(k, j))$  or  $f_k(i, j) = g(f_{k-1}(i, j), f_k(i, k), f_k(k, j))$ .”

- Pg 273, 12, change to “all vertices that  $v$  is connected to are also ...”
- Pg 273, -8, change “for-loop” to “For-loop”
- Pg 276, Figure 12-24, move the labels of the points closer to the points so that it is easier to comprehend the figure.

- Pg 277, Figure 12-25, caption, change the last sentence to “However, Step 9 is required to change *star(e)* to *false*.”
- Pg 277, -2 - -1, change last sentence of page to “This example can be expressed in terms of a minimum-cost spanning tree.”
- Pgs 278, 279, 280, add section heading for “Kruskal’s Algorithm” before the paragraph beginning “The first algorithm we consider...”. Add section heading for “Prim’s Algorithm” before the paragraph beginning “The second algorithm we ...”. Add section heading for “Sollin’s Algorithm” before the paragraph beginning “Finally, we mention ...”
- Pg 278, add a first line to the algorithm presented near the end of the page that says “**Kruskal’s MST Algorithm**”. This line should be directly on top of “The input consists...”
- Pg 279, Figure 12-26. The figure is too congested and should be spread out some (take more space) so that the pointers are easier to follow and also so that they all point to the correct places.
- Pg 279, Figure 12-26, consistency of ground vs. T to represent nil pointers.
- Pg 280, algorithm, put title “**Prim’s MST Algorithm**” directly on top of “The input consists of”. This line must not be labeled (it would throw off the current numbers and would then require a rewriting of the text that references those lines).
- Pg 281, 10, change “repetitively” to “repeatedly”
- Pg 281, -13, add a comma after  $F = \{T_1, \dots, T_n\}$  and before the word “where”
- Pg 281, algorithm, this is a perfect example of making it difficult to read text by not having hanging indents for sentences of text that cover more than one line.
- Pg 281, -9, add comma so that it reads “ $T_j$ , where  $i \neq j$ .”
- Pg 282, 6, remove italics so that “*performing*” turns into “performing”
- Pg 282, 7, remove italics so that “*applying*” turns into “applying”

- Pg 283, Figure 12-28. The values in the matrix should be

$\infty$	98	17	36	47	58
98	$\infty$	38	89	21	39
17	38	$\infty$	97	27	73
36	89	97	$\infty$	18	9
47	21	27	18	$\infty$	47
58	39	73	9	47	$\infty$

- Pg 283, Figure 12-28. The values in the small boxes on the right column should be

17, $e_{1,3}$
21, $e_{2,5}$
17, $e_{3,1}$
9, $e_{4,6}$
18, $e_{5,4}$
9, $e_{6,4}$

- Pg 283, Figure 12-29. The values in the matrix should be

0	0	1	0	0	0
0	0	0	0	1	0
1	0	0	0	0	0
0	0	0	0	0	1
0	0	0	1	0	0
0	0	0	1	0	0

- Pg 284, Figure 12-30, spacing between “1” and “2” should be the same vertically (row labels) and horizontally (column labels).

**Chapter 13:**

- Pg 296, 4-5, change to “modern encryption techniques, such as those of importance to e-commerce, depend on factoring large integers. This is one of the many reasons why there has been a renewed interest in number theory.” (remove “so that there ... problem.”)
- Pg 296, algorithm at bottom, line up *factor* (line 4) with *nIsPrime* (line 3)
- Pg 299, 1, change to “real (*i.e.*, floating point) number ...”
- Pg 301, line 4, change to “*evaluation* = 0”
- Pg 301, change lines 16-17 (“Consider the following ...  $-8)x + 4$ ”) to “Notice that  $a_3x^3 + a_2x^2 + a_1x + a_0 = ((a_3x + a_2)x + a_1)x + a_0$ . For example  $10x^3 + 5x^2 - 8x + 4 = ((10x + 5)x - 8)x + 4$ .”
- Pg 301, -5, change to “For  $i = n$  downto 1, do”
- Pg 302, 3, change to “sequential. That is, it is difficult ...”

**Bibliography**

While there are no fatal flaws in the bibliography, there is a complete lack of consistency in its presentation. There are approximately 50 changes that need to be made to bring it into consistency. General guidelines follow:

- All books should include the city, state of the publisher.
- All publishers should be referred to in a consistent manner.
- All states should be abbreviated in a consistent manner.

**Index:**

This is an alpha-version of the Index. We have marked up approximately 350 changes that need to be made to the index. Most of these changes consist of combining entries, removing superfluous entries, correcting some spelling mistakes, correcting the presentation of some technical terms, correcting the formatting of mathematical symbols, and so on. Our deepest apologies to the user for the release of this version of the index. However, we do not anticipate that this version of the index will serve as an obstacle to using the book successfully.