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THE STATE OF THE ART OF COMPUTER PROGRAMMING

by

D. E. Knuth

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School of Humanities and Sciences
STANFORD UNIVERSITY

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The State of The Art of Computer Programming

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This report lists all corrections and changes to volumes 1 and 3 of The Art of Computer Programming, as of May 14, 1976. The changes apply to the most recent printings of both volumes (February and March, 1975); if you have an earlier printing there have been many other changes not indicated here. Volume 2 has been completely rewritten and its second edition will be published early in 1977. For a summary of the changes made to volume 2, see SIGSAM Bulletin 9, 4 (November 1975), p. 10f -- the changes are too numerous to list except in the forthcoming book itself.

On any given day the author likes to feel that the last bug has finally disappeared, yet it appears likely that further amendments will be made as time goes by. Therefore a family of computer programs has been written to maintain a collection of errata, in the form printed here, but encoded as an ad-hoc sequence of ASCII characters. The author wishes to thank Juan Ludlow-Saldivar for the enormous amount of help he provided in order to get this system rolling. (Some readers who have access to the Stanford A.I.-Lab computer may wish to consult the change file before they report a "new" error; the file name is ACP.MAS [ART,DEK]. Entries for page nnn of volume k begin with $\beta k01nnn$ (but change the 01 to 00 if nnn is the Arabic equivalent of a Roman numeral); since " β " is the control character " $\backslash C$ ", you may rather search for simply the string " $k01nnn$ ". The text of the correction usually includes special codes following the symbol " $\backslash$ ", for things like font changes, etc.)

The author thanks all the bounty hunters who have reported difficulties they spotted. The reward to first finder of each error is still \$1 for the first edition and \$2 for the second, gratefully paid. Volume 1 remains rather far from completion, so there is plenty of time to work all the exercises in volumes 1-3 and to catch all the remaining errors therein.

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The Art of Computer Programming

Errata et Addenda May 14 1976

1.XVII line 5

1

forcing himself $\rightsquigarrow$ being encouraged

1.XVIII line 10

2

answer $\rightsquigarrow$ answers

1.XVIII new quote for bottom of page

3

*We can face our problem.
We can arrange such facts as we have
with order and method.*

--HERCULE POIROT, in *Murder on the Orient Express* (1934)

1.41 line 23

4

E0. $\rightsquigarrow$ E0. (boldface)

1.16 line 3

5

prove $\Lambda 6 \rightsquigarrow$ prove that $\Lambda 6$

1.29 line -1

6

$3n_0 \rightsquigarrow 3n$

1.29 lines -3 and -2

$T < 3n_0$, where n_0 is the original value of n , $\rightsquigarrow T \leq n$

Active Section	☒
Static Section	☐
Other Section	☐
JANUARY 1976	
1976. 100-100-100	

21.26 ex 25 8

delete step L5 and move the 1 to the end of step L4

21.26 ex 25, change step L3 to: 9

L3. [Shift.] If $x-z < 1$, set $z \leftarrow z$ shifted right 1, $k \leftarrow k+1$, and repeat this step.

21.26 line 15, new sentence 10

hardware. $\rightsquigarrow$ hardware. The idea goes back in essence to Henry Briggs, who used it (in decimal rather than binary form) to compute logarithm tables, published in 1624.

21.27 line 23 11

example, $\rightsquigarrow$ example

21.26 exercise 40 12

a period (.) should appear after the displayed equation

21.29 line 2 two changes 13

(i) the (q/p) and (p/q) don't match each other. (ii) the next two lines of p44 should be moved back to p43, otherwise the reader will think exercise 47 is complete without turning the page.

21.26 line 20 14

$1/12n \rightsquigarrow 1/(12n)$

21.28 ex 15 15

put spaces in the first matrix, i.e.

$abc \rightsquigarrow a\ b\ c$

$def \rightsquigarrow d\ e\ f$

$ghi \rightsquigarrow g\ h\ i$

2.52	line 7 after Table 1	16
	Shih-chieh $\rightsquigarrow$ Shih-Chieh	
2.56	left side of eq. (17)	17
	move the k a little left, to center it	
2.58	line 7 after (26)	18
	Shih-chieh $\rightsquigarrow$ Shih-Chieh	
2.58	line 8 after (26)	19
	the boldface 3 appears to be in wrong font (too small)	
2.72	14 places	20
	change B to B (Roman type) in the notation for Beta function, namely in line 1, line 2, line 3 (twice), line 4 (thrice), line 5 (twice), line 7, line 10 (twice), line 12, line 15.	
2.72	exercise 47	21
	in displayed formula: change upper indices from $n, n+1/2, 2n+1, 2n+1-k$ to $r, r-1/2, 2r, 2r-k$ respectively	
	line 3: $n = -1$. $\rightsquigarrow$ $r = -1/2$	
2.78	lines -3 and -2	22
	before the Renaissance. $\rightsquigarrow$ during the Middle Ages.	
2.81	line 2	23
	1963-) $\rightsquigarrow$ 1963-),	
2.96	between (23) and (24)	24
	series $\rightsquigarrow$ series (cf. (17))	

21.910 insert new sentence just after (26): 25

See D. A. Zave, *Inf. Proc. Letters* 5 (1976), to appear, for a further generalization.

21.910 replace (25) by new equation (25): 26

$$(1/(1-z)^{m+1}) \ln(1/(1-z)) = \sum_{k \geq 0} (H_{m+k} - H_m) \binom{m+k}{m} z^k, \quad m \geq 0.$$

21.915 lines 4-8 27

move the copy for each step to the left next to the step numbers (standard format, see e.g. Algorithm E on p2)

21.918 line -4 28

$$\Sigma \rightsquigarrow \Sigma_k$$

21.1012 lines 3 and 4 after Fig. 11 29

X; that $\rightsquigarrow$ X — that
values, we $\rightsquigarrow$ values — we

21.1115 line 5 30

distribution, the $\rightsquigarrow$ distribution, we can improve significantly on Chebyshev's inequality: The

21.1110 line after (13) 31

$$f^{(2k+1)}(x) \text{ tends } \rightsquigarrow f^{(2k+1)}(x) \text{ and } f^{(2k+3)}(x) \text{ tend}$$

21.1110 line 11 32

$$C \rightsquigarrow C \text{ (Roman, not italics)}$$

21.1110 line 20 33

$$\text{records } \rightsquigarrow \text{blocks}$$

21,233	line 5 (two places)	34
record	↪ block	
21,236	row 5 column 4 of the table	35
1+T	↪ 1+T	
21,244	Fig. 14 in both steps P7 and P6	36
PRIME [K]	↪ PRIME[K]	
21,244	line 4	37
fix broken type in the [	of PRIME[1]	
21,250	line 9	38
delete the exclamation point (!)		
21,252	ex 3, first line of program	39
X+1	↪ X+1 (0)	
21,257	last line of ex 18	40
assume	↪ assume that	
21,264	line 5	41
insert more space after the period, this line's too narrow		
21,272	line no. 21 of the program	42
PERM+1 ...	↪ PERM+1,...	

1.1810	line 8	43
itself " ~ itself."		
1.1810	top of page	44
the "1" is broken in "1.3.3"		
1.2118	line 14	45
the 0 is broken		
1.2226	line 16	46
O. J. ~ O.-J.		
1.2237	line -10	47
print) ~ print),		
1.2337	Fig. 3(a)	48
delete the funny little box which appears between "third from top" and "fourth from top"		
1.2338	just after (1)	49
remove black speck		
1.2339	lines -3 and -2	50
delete the sentence "Is there ... obtainable?"		
1.2423	bottom line	51
TOP ~ TOP (twice)		

2.244 line 3 52

<L < ~ <L <

2.245 after step names G1 and G2 53

broken type T for [

2.246 line -1 54

BASE, BASE+1, BASE+2, ~ BASE+1, BASE+2, BASE+3,

2.247 in (10) 55

move the heavy bar to the right so that it is aligned vertically with the heavy bar in (11)

2.248 comment for line 18 of the program 56

T3 ~ T4

2.249 new paragraph before the exercises 57

In spite of the fact that Algorithm T is so efficient, we will see an even better algorithm for topological sorting in Section 7.4.

2.275 changes to Program A 58

line 04: 6H ~ 1H

line 05: becomes line 06

line 06: becomes line 07

line 07: becomes line 05, and delete the "1H" and change x ~ 1+m

line 12: becomes the following two lines

12 LD2 1:3(LINK)

q' Q-LINK(Q1).

13 JMP 2B

q' Repeat.

lines 13-35 become lines 14-36

change 6B ~ 1B in what was line 17 (now line 18)

2,576 line -1 59

$h^3 \rightsquigarrow h^3-1$

2,576 line -4 60

exceed $h \rightsquigarrow$ exceed $h-1$

2,576 line 12 61

29 $\rightsquigarrow$ 27 (twice)

2,584 Table 1, left column 62

the line for time 0200 is out of place, it belongs just before the line for time 0256

2,584 Fig. 12 63

the shading in this figure mysteriously disappeared from the 3rd column of nodes, in the second edition. (First edition was OK!)

2,597 line 7 64

2419200 $\rightsquigarrow$ 2,119,200

2,599 two lines before (11) 65

is the lowest value $\rightsquigarrow$ points to the bottom-most value

2,604 exercise 20 line 3 66

$A(I,J) \rightsquigarrow A[I,J]$

2.314 new exercise 67

21. [20] Suggest a storage allocation function for $n \times n$ matrices where n is variable. The elements $A[i, j]$ for $1 \leq i, j \leq n$ should occupy n^2 consecutive locations, regardless of the value of n .

2.322 tree illustration near bottom of page 68

the number "(9)" must be inserted at the right of this diagram

2.325 line -13 69

$p^* \rightsquigarrow p^*$

2.333 between (2) and (3) 70

tilt the diagram $\rightsquigarrow$ and we have $\rightsquigarrow$
tilt the diagram and bend it slightly, obtaining

2.336 Fig. 17 71

the photocopier has lined up the two parts of this figure improperly in this edition; the left-hand half of the illustration should be lowered so that the trees are flush at the bottom -- this means that corresponding letters will be on the same line in both left and right parts of the illustration

2.336 line -9 72

of (7) $\rightsquigarrow$ of the left-hand tree in (7)

2.349 line 16 73

node to $\rightsquigarrow$ node with

2.353 line 9 74

only upward links are sufficient $\rightsquigarrow$ upward links are sufficient by themselves

1.357	in (17)	75
	delete "." outside the boxes (for consistency in style)	
1.360	exercise 11	76
	change script k to italic k in five places (lines 5,6,6,23,25)	
1.363	Theorem A part (a)	77
	; $\sim$.	
1.375	line 4	78
	remove hairline between "fin" and "("	
1.395	line -3	79
	or it $\sim$ or	
1.396	line -2	80
	Exercise $\sim$ exercise	
1.405	exercise 12	81
	Suppose $\sim$ [20] Suppose	
1.406	line -14	82
	partic lar $\sim$ particular	
1.427	line -4	83
	3). $\sim$ 3).	

2,429 Fig. 40

84

the shape of the box containing B6. should have rounded sides (like that of B2); on the other hand, the box that says "Error" should be rectangular

2,445 line -5

85

this displayed line should be raised half a space so that it is separated from line -4 by the same amount as it is separated from line -6

2,447 lines 4,6,7

86

audition $\rightsquigarrow$ condition
emergencies $\rightsquigarrow$ emergencies.
hence $\rightsquigarrow$ Hence

2,450 line -7

87

two level $\rightsquigarrow$ two-level

2,455 exercise 39 line 3

88

$N(n,m) \rightsquigarrow N(n,m)/n$

2,457 line 18

89

2 $\rightsquigarrow$ 2,2

2,463 first line of quote

90

me that $\rightsquigarrow$ me ... that

1.465 exercise 3

91

line 3: let r be $\sim$ let m be
 line 4: If $r = 0$, $\sim$ If $m = 0$,
 line 5: $n/r \sim n/m$
 r and let m be $\sim$ m and let n be
 lines 6 and 7 (steps F4 and F5) *deleted*
 line 8: F6. $\sim$ F4.

1.466 better answer to exercise 3

92

3. $-1/27$, but the text hasn't defined it.

1.468 exercise 13

93

first sentence should become:
 Add " $T < 3(n-d) \cdot k$ " to assertions $A3, A4, A5, A6$, where k takes the respective values
 $2, 3, 3, 1$.

1.468 line 16

94

elements a and $b \sim$ elements, $a < b$,

1.470 exercise 3

95

the value 3 is .. two n^2 . $\sim$ $n^2 = 3$ occurs for no n , and in the second place $n^2 = 4$
 occurs for two n .

1.470 line 10

96

388. $\sim$ 388; V. S. Linskii, *Zh. Vych. Mat. i Mat. Fiz.* 2 (1957), 90-119.

1.470 new answer replacing answer 10

97

9, 10. No, the applications of rule (d) assume that $n \geq 0$. (The result is correct for $n = -1$
 but the derivation isn't.)

2.478 exercise 41 line 4

98

$1/4 \rightsquigarrow 1/8$ (twice)

2.485 exercise 31

99

We have $\rightsquigarrow$ [This sum was first obtained in closed form by J. F. Pfaff, *Nova acta acad. scient. Petr.* 11 (1797), 38-57.] We have

2.486 and extending to page 487

100

change B to B (Roman type) in the solutions to exercises 40, 41 (twice), 42, 48 (twice).

2.491 exercise 14

101

$n+4 \rightsquigarrow n+1$

2.494 exercise 10 line 2

102

(25) $\rightsquigarrow$ (17)

2.494 exercise 15

103

line 1: $zG_{n-2}(z), \rightsquigarrow zG_{n-2}(z) \cdot \delta_{n0}$

line 3 (the displayed formula): delete the period, then add a new line:

when $z \neq -1/4$; $G_n(-1/4) = (n+1)/2^n$ for $n \geq 0$.

2.496 bottom of page, a new answer to exercise 1.2.11.2-3:

104

3. $|R_{2k}| < (B_{2k}/(2k)) \int_1^n |f^{(2k)}(x)| dx$. [C. H. Reinsch observes that $R_{2k} = \int_1^n (B_{2k+2} - B_{2k+2}(\{x\})) f^{(2k+2)}(x) dx / (2k+2)$, and that $B_{2k+2} - B_{2k+2}(\{x\})$ always lies between 0 and $(2 - 2^{-2k-1})B_{2k+2}$. Therefore if $f^{(2k+1)}(x)$ but not $f^{(2k+3)}(x)$ tends monotonically to zero, (13) still holds for some θ with $0 < \theta < 2 - 2^{-2k-1}$.]

2.511 exercise 6

105

$O(n^{-3}) \rightsquigarrow O(n^{-3})$

1.5102 exercise 14 106

line 3: MOVE ~ MOVE
line 4: JSJ*+1 ~ JSJ *+1

1.5102 exercise 17(b) 107

(Using assembly ... section.) ~
(A slightly faster, but quite preposterous, program uses 993 STZ's: JMP 3995; STZ 1,2; STZ 2,2; ...; STZ 993,2; J2N 3999; DEC2 993; J2NN 3001; ENN1 0,2; JMP 3000,1.)

1.5102 exercise 18 add new sentence: 108

(Unless the program itself appears in locations 0000-0015.)

1.5102 exercise 20 109

Fukuoka) ~ Fukuoka.)

1.5102 exercise 16 line 1 110

(49): ~ (49);

1.5104 new line just before answer no. 23: 111

For small byte size, the entries $\pm 6^{13}$ would not appear.

1.5106 exercise 6 line 3 112

$\sqrt{n}$ ~ $\sqrt{N}$

1.5117 line -13 113

e.g. the ~ e.g., the

21.529 exercise 22(d) 114

Since the α 's are independently chosen, the $\sim$ The

21.5210 exercise 23 115

line 1: $\int_0^1 \dots (\ln t) \sim \int_0^\infty \exp(-t-E_1(t))dt$, where $E_1(x) = \int_x^\infty e^{-t} dt/t$.

line 4: $\ln n / e^\gamma \sim e^{-\gamma} \ln n$

line 6: 8310...; $\sim$ 83100 83724 -1796+ [Math. Comp. 22 (1968), 411-415];

21.5211 line 6 116

$\text{dev } \sqrt{1/m} \sim \text{dev } \sqrt{1/m}$, when $n \geq 2m$.

21.529 line 5 117

process would loop indefinitely; $\sim$
algorithm breaks down (possibly refers to buffer while I/O is in progress);

21.523 exercise 9 118

in reverse, we can get the inverse $\sim$
backwards, we can get the reverse of the inverse of the reverse

21.524 exercise 12 119

$0 < \alpha < 1 \sim |\alpha| < 1$

21.524 line 12 120

$r_2(z) \sim r_2(z)x$

21.525 exercise 4(ii) should have the following answer instead: 121

(ii) LDA X, 7: 7 (0: 2).

1.541 new answer 122

13. D. J. Kleitman has shown that $\lim_{n \rightarrow \infty} 2^{-n} \log f(n) = \lim_{n \rightarrow \infty} 2^{-n} \log \prod_{0 \leq k \leq n} \binom{n}{k}!$.
[To appear.]

1.542 line -5 123

COUNT $\rightsquigarrow$ COUNT

1.543 and also page 544, answer to exercise 24 124

replace lines 85-87 of the MIX program by
 $\text{STG } X, 1 (\text{QLINK}) \quad \text{QLINK}[r11] \leftarrow k.$
 Then renumber lines 88-118 to 86-116.
 Finally delete "Note: When the ... as the loop." on p. 544.

1.544 lines 11-12 change to (with same indentation): 125

T10. If $P \neq \Lambda$, set $\text{QLINK}[\text{SUC}(P)] \leftarrow k$, $P \leftarrow \text{NEXT}(P)$, and repeat this step.

1.545 exercise 16 126

line 2: $29\text{Z} \rightsquigarrow 27\text{Z}$ (twice)
 line 8: $6 \rightsquigarrow 4$

1.546 line -4 insert new sentence (no new paragraph) 127

[See exercise 5.2.3-29 for a faster algorithm.]

1.547 exercise 1 line 4 128

AVAIL $\rightsquigarrow$ Y $\leftarrow$ INFO(P); AVAIL

1.548 line 2 129

COL(P) $\rightsquigarrow$ COL(P0)

2.556 change answer 18 (saving space for new answer 21):

130

the first part up to "after $r = 1$ " can be shortened as follows.

18. The three pivot steps on successive columns 3,1,2, yield respectively

(use the same matrices as before, squeeze onto one line)

2.556 exercise 20

131

$A(1,1) \rightsquigarrow A(1,1)$

2.556 new answer

132

21. For example, $M \leftarrow \max(I,J)$, $LOC(A(I,J)) \leftarrow LOC(A(1,1)) + M(M-1) + I - J$. (Such formulas have been proposed independently by many people. A. L. R. Seuberg and H. R. Strong have suggested the following k -dimensional generalization: $LOC(A(I_1, \dots, I_k)) = L_k$ where $L_1 = LOC(A(1, \dots, 1)) + I_1 - 1$, $L_r = L_{r-1} + (M_r - 1)^r + (M_r - 1)(M_r - 1)^{r-1} - (M_r - 1)^{r-1}$, where $M_r = \max(I_1, \dots, I_r)$. {IBM Tech. Disclosure Bull. 14 (1972), 3026-3028.})

2.556 exercise 15

133

remove brackets in first and second lines

2.556 exercise 12 line 2

134

$A[m] \rightsquigarrow A[m]$

2.556 new answer

135

13. (Solution by S. Araujo.) Let steps T1 through T4 be unchanged, except that a new variable Q is initialized to A in step T1; Q will point to the last node visited, if any. Step T5 becomes two steps: T5. [Right branch done?] If $RLINK(P) = A$ or $RLINK(P) = Q$, go on to T6; otherwise set $A \leftarrow P$, $P \leftarrow RLINK(P)$ and return to T2. T6. [Visit P.] "Visit" NODE(P), set $Q \leftarrow P$, and return to T4. A similar proof applies.

2.556 line 15

136

$LOC(T) \rightsquigarrow LOC(T)$

2.566 exercise 1 line 1 137

consist $\rightsquigarrow$ consists

2.567 exercise 12 line 2 138

INFO(P2)-1 $\rightsquigarrow$ TREE(INFO(P2)-1)

2.572 exercise 18 line 5 139

preorder $\rightsquigarrow$ postorder

2.574 exercise 7 140

the diagrams for Case 1 have two arrowheads in the wrong direction ... the arrows should lead away from α' and towards β' both Before and After

2.575 line -8 141

332 $\rightsquigarrow$ 322

2.575 exercise 12 line 5 142

$a(i)$ set $a(i) \leftarrow c(i,j)$ and $b(i) \leftarrow j$; $\rightsquigarrow$
 $a(j)$ set $a(j) \leftarrow c(i,j)$ and $b(j) \leftarrow i$;

2.577 exercise 16 143

line 2: the existence of $\rightsquigarrow$ tracing out

lines 4,5: we have an oriented subtree $\rightsquigarrow$ the stated digraph is an oriented tree

line 5: configuration $\rightsquigarrow$ digraph

line 6: subtree $\rightsquigarrow$ tree

2.578 last line 144

D. E. Knuth, $\rightsquigarrow$ R. Dawson and I. J. Good, *Ann. Math. Stat.* 28 (1957), 946-956; D. E. Knuth,

2.550 exercise 24 line 2

145

$G \rightsquigarrow G$

2.551 last line of exercise 23, add:

146

[For $m = 2$ this result is due to C. Fyfe Sainte-Marie, *l'Intermédiaire des Mathématiciens* 1 (1891), 107-110.]

2.552 exercise 3 line 3

147

upper $\rightsquigarrow$ right

2.553 exercise 10

148

height $\rightsquigarrow$ weight (three times)

2.554 second-last line before exercise 6

149

this line isn't right-justified, add space after the semicolon

2.555 bottom line

150

exhausted. $\rightsquigarrow$ exhausted. [See Guy L. Steele Jr., *CACM* 18 (1975), 495-508, and P. Wadler, *CACM* 19 (1976), to appear, for further information.]
[Note that there's no comma between Steele and Jr. in his name.]

2.556 lines 19-21 replace by

151

Several beautiful list-copying algorithms which make substantially weaker assumptions about list representation have been devised. See D. W. Clark, *CACM* 19 (1976), to appear, and J. M. Robson, *CACM* 19 (1976), to appear.

2.557 line 4

152

minuscule $\rightsquigarrow$ minuscule

1.613 line before exercise 34 153

165.] $\rightsquigarrow$ 165. See also i. Wegbreit, *Comp. J.* 15 (1972), 204-208; D. A. Zave, *Inf. Proc. Letters* 3 (1975), 167-169.]

1.618 line -7 154

$\det(A) \rightsquigarrow \det(A)$

1.619 in several places 155

change $\dots$ to $\dots$ in the definitions of x upper k , x lower k , n factorial, and Stirling numbers of both kinds

1.620 bottom line 156

give section reference 1.2.5 in right-hand column

1.620 definition of Beta function 157

$B \rightsquigarrow B$

1.624 line -20 (the entry for 1 degree of arc) 158

1154 $\rightsquigarrow$ 1155

1.625 insert new paragraph after line 7: 159

See the answer to exercise 1.3.3-23 for the 40-digit value of another fundamental constant.

1.627L last line 160

$9 \rightsquigarrow 9.$

2.6276 161

Araujo, Saulo, 560.

2.6286 162

Bendix G20, 120.

2.6296 163

Briggs, Henry, 26.

2.6296 Bolzano entry 164

delete "theorem,"

2.6296 165

Carlyle, Thomas, xvi.

2.6296 166

Christie Mallowan, Dame Agatha Mary Clarissa (Miller), xix.

2.6296 167

Chu Shih-Chieh, 52, 58.

2.6296 168

Clark, Douglas Wells, 594.

2.6296 Chebyshev's inequality entry 169

add p. 102

2.621L	170
Dawson, Reed, 578.	
2.621B	171
Doyle, Sir Arthur Conan, 463.	
2.622B	172
Even, Shimon, 239.	
2.623L	173
Flye Sainte-Marie, Camille, 580.	
2.623L	174
delete Fisher, David Allen	
2.623B	175
Hamlet, Prince of Denmark, 228.	
2.623B entry for Good, Irving John .	176
add p. 578	
2.624B line -8	177
Exercise ~ exercise	
2.625B	178
Kleitman, Daniel J., 511.	

ᐃ.ᐅᐅᐅᐅ Knopp entry	179
add p. 494	
ᐃ.ᐅᐅᐅᐅ Krogdahl entry	180
fix broken type	
ᐃ.ᐅᐅᐅᐅ line 1	181
20 ~ 20.	
ᐃ.ᐅᐅᐅᐅ	182
Linskiĭ, V. S., 470.	
ᐃ.ᐅᐅᐅᐅ	183
Path length, 399-405.	
ᐃ.ᐅᐅᐅᐅ	184
Pfaff, Johann Friedrich, 485.	
ᐃ.ᐅᐅᐅᐅ	185
Philco S2000, 120.	
ᐃ.ᐅᐅᐅᐅ	186
Poirot, Hercule, xix.	
ᐃ.ᐅᐅᐅᐅ	187
RCA 601, 120.	

1.630B	188
Rosenberg, Arnold Leonard, 556.	
1.631B Robson entry	189
add p. 594	
1.631L	190
Shakespeare, William, 228, 465.	
1.631L	191
delete Shih-chieh, Chu entry	
1.631B	192
Steele Jr., Guy Lewis (=Quux), 594.	
1.632L	193
Strong, Hovey Raymond, Jr., 556.	
1.632B	194
Tarjan, Robert Endre, 239.	
1.633B	195
Wadler, Philip Lee, 594	
1.633B last line	196
delete "theorem," (saves one line)	

1.634	197
Wegbreit, Eliot Ben, 603.	
1.634L	198
Wise, David Stephen, 434, 595.	
1.634B	199
Zave, Derek Alan, 90, 603.	
1.636 (namely the endpapers of the book)	200
delete "Table 1"	
also make the change specified for page 136	
3.V line 4 of the Preface	201
system ~ systems	
3.VII line 4	202
forcing himself ~ being encouraged	
3.IX line 10	203
answer ~ answers	
3.XIU	204
raise this illustration about 3/8 inch	

§.1 making the quotation format more consistent 205

line 5: The Prince ~ The Prince

line 10: MASON (The Case ... 1951) ~

MASON, in *The Case of the Angry Mourner* (1951)

§.22 new exercises 206

*21. [M25] (G. D. Knott.) Show that the permutation $a_1 \dots a_n$ is obtainable with a stack, in the sense of exercise 2.2.1-5 or 2.3.1-6, if and only if $C_j \leq C_{j+1} + 1$ for $1 < j < n$ in the notation of exercise 7.

22. [M28] (C. Meyer.) When m is relatively prime to n , we know that the sequence $(m \bmod n) (2m \bmod n) \dots ((n-1)m \bmod n)$ is a permutation of $\{1, 2, \dots, n-1\}$. Show that the number of inversions of this permutation can be expressed in terms of Dedekind sums (cf. Section 3.3.3).

§.23 line -9 207

45885 ~ 45855

§.24 lines 5-8 after (38) 208

Curiously ... situation to the ~ An interesting one-to-one correspondence between such permutations and binary trees, more direct than the roundabout method via Algorithm 1 that we have used here, has been found by D. Rotem [*Inf. Proc. Letters* 4 (1975), 58-61]; similarly there is a

§.27 insert new sentence after (53): 209

Actually the O terms here should have an extra 9_6 in the exponent, but our manipulations make it clear that this 9_6 would disappear if we had carried further accuracy.

§.72 exercise 28, three changes 210

the average is ~ the average l_n is

sorting" for some obscure reason, ~ sorting,"

$2\sqrt{n}; \dots 1.97\sqrt{n}.) \sim 2\sqrt{n}$. L. A. Shepp and B. F. Logan have proved that $\liminf_{n \rightarrow \infty}$

$l_n/\sqrt{n} > 2$ [to appear.]

§.7'9' figure 9 step D3 211

COUNT $[K_j]$ $\rightsquigarrow$ COUNT $[K_j]$

§.11'7' addition to step B2 212

(if BOUND = 1, this means go directly to B4.)

§.11'7' line -5 213

the underline shouldn't be broken

§.11'8' comments for lines 14 and 15 of the program 214

BOUND $\rightsquigarrow$ BOUND

§.11'10' line 9 215

(December, 1974.) $\rightsquigarrow$ (1974), 287-289.)

§.11'11' line 8 216

$\log_2$ $\rightsquigarrow$ lg

§.11'13' exercise 15 line 2 217

subscripts on superscripts are in wrong font

§.11'14' line 1 218

items; $\rightsquigarrow$ items,

§.11'15' line 3 219

r15 $\rightsquigarrow$ r15

𐎓.𐎔𐎗𐎓 line -18

220

onn ~ at least one

𐎓.𐎔𐎗𐎓 last line of Table 2

221

179 ~ 170

𐎓.𐎔𐎗𐎓 line -2

222

wise, oracle ~ dangerous, adversary

𐎓.𐎔𐎗𐎓 lines -13, -12, -9, -8

223

pronouncements ~ outcomes (four changes)

𐎓.𐎔𐎗𐎓 lines -7 thru -3

224

oracles ~ adversaries

oracle ~ adversary (five changes)

§.2.10 lines 7-23 must be replaced by new copy:

225

Constructing lower bounds. Theorem M shows that the "information theoretic" lower bound (2) can be arbitrarily far from the true lower bound; thus the technique used to prove Theorem M gives us another way to discover lower bounds. Such a proof technique is often viewed as the creation of an *adversary*, a pernicious being who tries to make algorithms run slowly. When an algorithm for merging decides to compare $A_i : B_j$, the adversary determines the fate of the comparison so as to force the algorithm down the more difficult path. If we can invent a suitable adversary, as in the proof of Theorem M, we can ensure that every valid merging algorithm will have to make a rather large number of comparisons. (Some people have used the words 'oracle' or 'demon' instead of 'adversary'; but it is preferable to avoid such terms in this context, since 'oracles' have quite a different connotation in the theory of recursive functions, and 'demons' appear in still a different guise within languages for artificial intelligence.)

We shall make use of *constrained adversaries*, whose power is limited with regard to the outcomes of certain comparisons. A merging method which is under the influence of a constrained adversary does not know about the constraints, so it must make the necessary comparisons even though their outcomes have been predestined. For example, in our proof of Theorem M we constrained all outcomes by condition (5), yet the merging algorithm was unable to make use of this fact in order to avoid any of the comparisons.

The constraints that we shall use in the following discussion apply to the left and right ends of the files. Left constraints are symbolized by

§.2.11 lines 7 and 16

226

questions $\rightsquigarrow$ comparisons
be answered $\rightsquigarrow$ result in

§.2.12 lines 9, 10, 18

227

oracle $\rightsquigarrow$ adversary (four changes)

§.2.13 line 12

228

then we define $\rightsquigarrow$ thus,
to be $\rightsquigarrow$ is

§.2.14 line 15

229

our oracle $\rightsquigarrow$ that our adversary

Σ.202	line 18	230
	the oracle ~ he	
Σ.202	lines 2, 11, 16, 20, -9, -6	231
	oracle ~ adversary (six changes)	
Σ.203	line 1	232
	ORACLE ~ ADVERSARY	
Σ.204	line 4	233
	its ~ his	
Σ.207	exercise 10, line 2	234
	oracle ~ adversary	
Σ.209	exercise 23, line 6	235
	oracle ~ adversary	
Σ.210	line 2	236
	oracle is asked ~ adversary is about to decide	
Σ.210	line 3	237
	The oracle ~ He.	
Σ.212	lines 5, 11, 20, 24, 27, 30	238
	Say ~ Decide (six changes)	

§.212 line -2

239

"oracle", $\rightsquigarrow$ "adversary" as in Section 5.3.2,

§.213

240

line 13: finding an oracle $\rightsquigarrow$ constructing an adversary

line 15: oracle declare $\rightsquigarrow$ adversary cause

lines 17, 20, 23: oracle $\rightsquigarrow$ adversary

§.215 replace the eight lines preceding Table 1 by:

241

may be subject to further improvement. The fact that $V_4(7) = 10$ shows that (11) is already off by 2 when $n = 7$.

A fairly good lower bound for the selection problem has been obtained by David G. Kirkpatrick [Ph.D. thesis, U. of Toronto, 1974], who constructed an adversary which proves that

$$V_t(n) \geq n + t - 3 + \sum_{0 \leq j \leq t-2} \lceil \lg((n+2-j)/(t+j)) \rceil, \quad n \geq 2t-1. \quad (12)$$

Kirkpatrick has also established the exact behavior when $t=3$ by showing that $V_3(n) = n + \lceil \lg((n-1)/2.5) \rceil + \lceil \lg((n-1)/4) \rceil$ for all $n \geq 50$ (cf. exercise 22).

§.217

242

line 17: A. Schönhage $\rightsquigarrow$ M. Paterson, N. Pippenger, and A. Schönhage

line 18: has $\rightsquigarrow$ have

line -1: (12) $\rightsquigarrow$ (13)

§.218

243

line -7: (13) $\rightsquigarrow$ (14)

line -5: $V_t(n)$ $\rightsquigarrow$ $V_t(n)$

§.220

244

line -21: a *homogeneous* $\rightsquigarrow$ an *oblivious*

line -2 and -1: a *homogeneous* $\rightsquigarrow$ an *oblivious*

any *homogeneous* $\rightsquigarrow$ any *oblivious*

प्र.२२७ lines 5-6 245

a suitable oracle.] $\rightsquigarrow$ an adversary.]

प्र.२२७ substitute for exercise 22 246

22. [24] (David G. Kirkpatrick.) Show that when $4 \cdot 2^k < n-1 < 5 \cdot 2^k$, the upper bound (11) for $V_3(n)$ can be reduced by 1 as follows: (i) Form four "knockout trees" of size 2^k . (ii) Find the minimum of the four maxima, and discard all 2^k elements of its tree. (iii) Using the known information, build a single knockout tree of size $n-1-2^k$. (iv) Continue as in the proof of (11).

प्र.२२७ caption 247

A homogeneous $\rightsquigarrow$ An oblivious

प्र.२२७ line 3 248

1972), Chapter 15] $\rightsquigarrow$ 1973), 163-172]

प्र.२३७ upper left corner of Fig. 51 249

there's a dot missing on the second line of the diagram for $n=6$

प्र.२३२ line 3 new sentence 250

A. C. Yao and F. F. Yao have proved that $\hat{M}(2,n) = C(2,n) = \lceil \frac{3}{2}n \rceil$ and that $\hat{M}(m,n) \geq \frac{1}{2}n \lg(m+1)$ for $m < n$ [JACM, to appear].

प्र.२३७ line 12 251

15 is in the wrong bold-face font

प्र.२३७ line 13 252

RECORD (Q) $\rightsquigarrow$ RECORD (Q)

253 line 10 253

delete "[Hint: ... 4.5.31.]" since the proof of that theorem is being changed in the second edition of vol. 2

254 line 6 254

other P . $\rightsquigarrow$ other P .]

255 line 15 255

to C5. $\rightsquigarrow$ to C5 if $m > 0$.

256 lines -16 and -15 256

$\text{SORT10} \rightsquigarrow \text{SORT10}$
 $\text{SORT01} \rightsquigarrow \text{SORT01}$

257 bottom line 257

$lg_2 \rightsquigarrow lg$ (twice)

258 lines -3 258

"Soundex" $\rightsquigarrow$ contemporary form of the "Soundex"

259 259

line 17: formulated $\rightsquigarrow$ popularized

lines 19-20: inversely ... Reading $\rightsquigarrow$ approximately proportional to $1/n$. [*The Psychology of Language* (Boston, Mass.: Houghton Mifflin, 1935); *Human Behavior and the Principle of Least Effort* (Reading

260 extra annotation on line 08 of Program B 260

$LrA/21. \rightsquigarrow LrA/21$ (rX changes too)

3.4210 line -7 261

only all $\sim$ only if all

3.4210 line 13 262

between $\sim$ between and outside the extreme values of the

3.422 (6) 263

$1 < j \sim 2 < j$

3.427 line -10 and also line -18 264

800 $\sim$ 500

3.427 line 18 265

memory. It $\sim$ memory. The difference between $\lg \lg N$ and $\lg N$ is not substantial unless N is quite large, and typical files aren't sufficiently random either. Interpolation

3.427 new paragraph after line 14: 266

Interpolation search is asymptotically superior to binary search: one step of binary search essentially replaces the amount of search, n , by $\frac{1}{2}n$, while one step of interpolation search essentially replaces n by $\sqrt{n}$ if the keys in the table are randomly distributed. Hence it can be shown that interpolation search takes about $\lg \lg N$ steps on the average. (See exercise 22.)

3.427 replace lines -5 thru -11 by: 267

01 13 09 34 29 08 08 53 20
01 13 14 31 52 30
01 13 43 10 48
01 13 48 10 30
01 14 04 26 40

49 12 27
49 09 07 12
48 49 41 15
48 16 22 59 25 25 55 33 20
48 36

3.428 bottom line 268

was $\sim$ seems to have been

3.429

269

line 11: 1 $\rightsquigarrow$ 1,2

line 12: February, $\rightsquigarrow$ February

3.429 line 2

270

the last part is in nearly perfect alphabetic order! $\rightsquigarrow$
the alphabetic order in the last part is substantially better.

3.422 replace exercise 22

271

22. [M43] (A. C. Yao and F. F. Yao.) Show that an appropriate formulation of interpolation search requires asymptotically $\lg \lg N$ comparisons, on the average, when applied to N independent uniform random keys that have been sorted. Furthermore, *all* search algorithms on such tables must make asymptotically $\lg \lg N$ comparisons, on the average.

3.424 line -8

272

A). $\rightsquigarrow$ A), since the necessary operations are trivial when $\text{ROOT} = A$.

3.428 line 17

273

Algorithm I. $\rightsquigarrow$ Algorithm T

3.431 lines 7 and 8

274

clearly constructed $n+1$ different deletions; $\rightsquigarrow$
constructed $n+1$ different deletions, one for each j ;

3.435

275

line 6: A fairly $\rightsquigarrow$ An even more

line -7: time. $\rightsquigarrow$ time. In fact, M. Fredman has shown that $O(n)$ units of time suffice, if the right data structures are used [ACM Symp. Theory of Comp. 7 (1975), 240-244].

§.4.39 and following pages

276

in the second edition of vol. 3 I must revise the subsection about the Hu-Tucker algorithm to take account of the new Garsia-Wachs algorithm. Meanwhile I could have improved my treatment of Hu-Tucker by leaving the external nodes out of the priority queues (cf. (23) on p. 444, an unnecessarily cumbersome approach).

§.4.39 replace lines 3-5 by:

277

that the resulting maximum subtree weight, $\max(w(0,k-1), w(k,n))$, is as small as possible. This approach can also be fairly poor, because it may choose a node with very small p_k to be the root; however, Paul J. Bayer has proved that the resulting tree will always have a weighted path length near the optimum (see exercise 36).

§.4.40 exercise 30

278

M46 $\rightsquigarrow$ M41

§.4.40 new version of exercise 36

279

36. [M40] (Paul J. Bayer.) Generalizing the upper bound of Theorem G, prove that the cost of any optimum binary search tree with nonnegative weights must be at most the total weight $S = \sum_{1 \leq i \leq n} p_i + \sum_{0 \leq i \leq n} q_i$ times $H + 2$, where

$$H = \sum_{1 \leq i \leq n} (p_i/S) \lg(S/p_i) + \sum_{0 \leq i \leq n} (q_i/S) \lg(S/q_i);$$

in fact, the top-down procedure which repeatedly chooses roots that minimize the maximum subtree weights will yield a binary search tree satisfying this bound. Show further that the cost of the optimum binary tree search tree is $\geq S$ times $H - \lg(2H/e)$.

§.4.44 diagrams (2)

280

put extra little vertical lines above the topmost nodes (B and X, respectively), for consistency with (1)

§.4.46 line 2

281

K $\rightsquigarrow$ K

3.4.60 replace lines -4 and -3 by: 282

indicate that the average number of comparisons needed to insert the N th item is approximately $1.01 \lg N + 0.1$ except when N is small.

3.4.61 bottom line of Table 1 283

2.8 $\rightsquigarrow$ 2.78

3.4.62 Eq. (14) 284

$p/(1-p) \approx 1.851$. $\rightsquigarrow$ $1/(1-p) \approx 2.851$.

3.4.63 line -12 285

$k - 1$ is $p/(1-p)$. $\rightsquigarrow$ k is $1/(1-p)$.

3.4.64 286

line 1: $\lg N + 0.25 \rightsquigarrow 1.01 \lg N + 0.1$
line 2: $11.17 \lg N + 4.8 \rightsquigarrow 11.3 \lg N + 3$
line 6: $6.5 \lg N + 4.1 \rightsquigarrow 6.6 \lg N + 3$

3.4.65 Figure 24 287

below the third node from the left, the 1 has a bar across it, making it look like a 4 by mistake

3.4.66 line -9 288

$R(P) \rightsquigarrow \text{RANK}(P)$

3.4.67 line 16 289

$\text{RANK}(R) \rightsquigarrow \text{RANK}(R)$. Go to C10.

§.4.6 line -4

290

(unpublished) $\rightsquigarrow$ {see Aho, Hopcroft, and Ullman, *The Design and Analysis of Computer Algorithms* (Reading, Mass.: Addison-Wesley, 1974), Chapter 4}

§.4.6 lines 11-12 should be replaced by:

291

trees which arise when we allow the height difference of subtrees to be at most k . Such structures may be called $HB[k]$ trees (meaning "height-balanced"), so that ordinary balanced trees represent the special case $HB[1]$. Empirical tests on $HB[k]$ trees have been discussed by F. L. Karlton et al, *CACM* 19 (1976), 23-28.

§.5.7.2 new exercise

292

31. [1] (M. L. Fredman.) Invent a representation of linear lists with the property that insertion of a new item between positions $m-1$ and m , given m , takes $O(\log m)$ units of time.

§.7.7.9 new paragraph before the exercises

293

Andrew Yao has proved that the average number of nodes after random insertions without the overflow feature will be $N/(m \ln 2) + O(N/m^2)$, for large N and m , so the storage utilization will be approximately $\ln 2 \approx 69.3$ percent [*Acta Informatica*, to appear].

§.4.6 line 11

294

long $\rightsquigarrow$ long, but always a multiple of 5 characters,

§.4.6 line -10

295

tree. $\rightsquigarrow$ tree.

§.4.9 line -4

296

HOUSE $\rightsquigarrow$ HOUSE (twice)

3,490 line 5 297

the nodes of the tree $\rightsquigarrow$ the tree is nonempty and that its nodes

3,492 line 19 298

follows, $\rightsquigarrow$ follows:

3,500 exercise 4 299

there will be a new illustration, with positions numbered from 1 to 49 instead of 1 to 55.
The respective entries will be:

---	(20)	---	WAS	THAT	(18)	OF
BE	THE	HIS	WHICH	WITH	THIS	---
(4)	ON	I	HE	A	OR	(19)
(3)	TO	HAD	---	(14)	BUT	(1)
(17)	FOR	BY	IN	FROM	AND	NOT
(1)	HER	ARE	IS	IT	AS	AT
(7)	---	HAVE	(3)	---	YOU	---

line 2: 55 $\rightsquigarrow$ 49

lines after new illustration: 20,1,14,...,2 within $\rightsquigarrow$ 20,19,3,14,1,17,1,7,3,20,18,4 within

3,503 line 2 300

that $\rightsquigarrow$ that, if $n > 2$,

3,504 exercise 39 301

M47 $\rightsquigarrow$ M43

3,512 line -5 add new sentence after "of M." 302

(A precise formula is worked out in exercise 34.)

3,520 program line 13 303

empty $\rightsquigarrow$ nonempty

3.521 304

delete lines 15-18 ($m+1$ not really needed after all)

3.522 line -1 305

antrially $\rightsquigarrow$ stantially

3.527 line 13 306

similar $\rightsquigarrow$ weaker

3.528 three lines after (34) 307

purposes. $\rightsquigarrow$ purposes. In fact, Leo Guibas and Endre Szemerédi have succeeded in proving the difficult theorem that double hashing is asymptotically equivalent to uniform probing, in the limit as $M \rightarrow \infty$. [To appear.]

3.529 just after (37), insert new sentence: 308

By convention we also set $f(0,0) = 1$.

3.537 new formula for (58) 309

$$C_N = 1 + (e^{-h\alpha} h^\alpha / 2h!) (2 + (\alpha-1)h + (\alpha^2 + (\alpha-1)^2(h-1))R(\alpha, h)) + O(1/M).$$

3.541 line -2 310

until Morris's ... 1968, $\rightsquigarrow$ until the late 1960's,

3.542 311

line 1: The only ... among $\rightsquigarrow$ The first published appearance of the word seems to have been in H. Hellerman's book *Digital Computer System Principles* (New York: McGraw-Hill, 1967), p. 152; the only previous occurrence among

line 6: 1968 $\rightsquigarrow$ 1967

§.E42 exercise 5 lines 3 and 4 312

ten or less $\rightsquigarrow$ at most ten

§.E43 exercise 10 313

M48 $\rightsquigarrow$ M43

§.E44 line -4 314

$M' > M \rightsquigarrow M' > M$

§.E47 exercise 45 315

M48 $\rightsquigarrow$ M43

§.E49 exercise 66 316

66. $\rightsquigarrow$ 66.

§.E49 new exercise 317

67. [M25] (Andrew Yao.) Prove that all fixed-permutation single-hashing schemes in the sense of exercise 62 satisfy the inequality $C_N > \frac{1}{2}(1 + 1/(1-\alpha))$. [Hint: Show that an unsuccessful search takes exactly k probes with probability $p_k < (M-N)/M$.]

§.E54 lines -10, -8, -6 318

LONGITUDE $\rightsquigarrow$ LONGITUDE (three places)

§.E55 319

in the second edition I will be revising Section 6.5 again, deleting the material on post-office trees, paying more attention to Bentley's k -d trees, and discussing the search procedure of Burkhard and its analysis by Dubost and Trousse (cf. Stanford CS report of Sept. 1975)

§.555 line 13, add: 320

[CACM 18 (1975), 509-516.]

§.555 line 8 321

3 (to appear) ~ 4 (1971), 1-10

§.562 the numbers in (5) should be respectively: 322

.07948358; .00708659; .00067094; .00006786; .00000728; .00000082.

§.572 quotation 323

Alice's Adventures in Wonderland ~ Alice's Adventures in Wonderland

§.576 lines 1-3 324

So we may ... $(p-1)/2$. ~

In general if f is any divisor of $p-1$ and d any divisor of $\text{rad}(f, n)$, we can similarly determine $(n/d) \bmod f$ by looking up the value of $h^{(p-1)/f}$ in a table of length f/d . If $p-1$ has the prime factors $q_1 < q_2 < \dots < q_t$ and if q_t is small, we can therefore compute n rapidly by finding the digits from right to left in its mixed-radix representation, for radices $q_1, \dots, q_t$. (This idea is due to R. L. Silver.)

§.579 exercise 6 325

the 1's in the exponents rule too high (twice)

§.581 exercise 13 326

$b_{m-1}, \dots, b_{m-1}, b_{m+1},$

§.582 exercise 20 327

Zolnowsky (to appear). ~ Zolnowsky, *Discrete Math.* 9 (1974), 293-298.

§.5.5.1 new answer

328

22. $\lfloor mj/n \rfloor - \lfloor mi/n \rfloor - \lfloor m(j-i)/n \rfloor = 0$ or 1; and it is 0 iff $mj \bmod n > mi \bmod n$. Hence the number of inversions is $\sum_{0 \leq i < j < n} (\lfloor mj/n \rfloor - \lfloor mi/n \rfloor - \lfloor m(j-i)/n \rfloor) = \sum_{0 \leq r < n} \lfloor mr/n \rfloor (r - (k-r) - (k-r-1))$, which can be transformed to $\frac{1}{2}(n-1)(n-2) - \frac{1}{2}n\sigma(m, n, 0)$. [J. für die reine und angew. Math. 198 (1957), 162-166.]

§.5.5.2 exercise 19

329

delete lines 3-7 of this answer.

line 8: The answer $\rightsquigarrow$ (This formula now add a new paragraph:

Note: A general formula for the number of ways to place the integers $\{1, 2, \dots, n\}$ into an array which is the "difference" of two tableau shapes $(n_1, \dots, n_m) \setminus (l_1, \dots, l_m)$, where $0 < l_i < n_i$ and $n = \sum n_i - \sum l_i$, has been found by W. Feit [Proc. Amer. Math. Soc. 4 (1953), 740-744]. This number is $n! \det (1/(n_j - j) - (l_i - i)!)$.

§.5.5.7 line -4

330

$4.5N^2 + 2.5N - 6$. $\rightsquigarrow (4.5N^2 + 2.5N - 6)u$.

§.5.5.9 addendum to exercise 15

331

It is interesting to note that $G(w, z) = F(-wz, z)/F(-w, z)$, where $F(z, q) = \sum_{n \geq 0} z^n q^{n^2} / \prod_{1 \leq k \leq n} (1 - q^k)$ is the generating function for partitions $p_1 + \dots + p_n$ into n parts, where $p_j \leq p_{j+1} + 2$ for $1 \leq j < n$ and $p_n > 0$ (cf. exercise 5.1-16).

§.5.5.12 exercise 31 line 03

332

INPUT-N, 4 $\rightsquigarrow$ -INPUT-N, 4

§.5.5.15 addition to answer 2

333

[Algorithm 5.2.3S does exactly $\text{sch}(\pi)$ exchanges, see exercise 5.2.3-4.]

§.5.5.16 line 12

334

[to appear]. $\rightsquigarrow$ 11 (1975), 29-35].

3.6.11 bottom two (clobbered) lines should start respectively thus:

335

43. As $n \rightarrow 0+$,
 $\Gamma(1)/n \rightarrow \Gamma'(1) = -\gamma,$

3.6.12 line -4

336

$\int$ is in wrong font (see line -2 for correct $\int$)

3.6.13 exercise 13

337

397-404 $\rightsquigarrow$ 263-269

3.6.14 lines -8, -7, -6, -3

338

oracle $\rightsquigarrow$ adversary

3.6.15 lines 2, 17

339

oracle $\rightsquigarrow$ adversary

3.6.16 exercise 9

340

comparisons.) $\rightsquigarrow$ comparisons, yet the procedure is not optimal.)

3.6.17 exercise 14

341

line 1: found in $\rightsquigarrow$ found in $U_i(n) <$

also add new sentence: (Kirkpatrick's adversary actually proves that (12) is a lower bound for $U_i(n+1) - 1$.)

3.6.18 line 2

342

oracle $\rightsquigarrow$ adversary

3.637 new answer 343

22. In general when $2^r \cdot 2^k < n+2-t < (2^r+1) \cdot 2^k$ and $t < 2^r \leq 2t$, this procedure starting with $t+1$ knockout trees of size 2^k will yield $L(t-1)/2J$ fewer comparisons than (11), since at least this many of the comparisons used to find the minimum in (ii) can be "reused" in (iii).

3.640 exercise 36 last line 344

to appear.] $\rightsquigarrow$ 333-339.]

3.640 insert new paragraph before line -2: 345

G. Baudet and D. Stevenson have observed that exercises 37 and 38 combine to yield a simple sorting method with $(n \lg n)/k + O(n)$ comparison cycles on k processors: First sort k subfiles of size $\leq \lceil n/k \rceil$, then merge them in k passes using the "odd-even transposition merge" of order k . (To appear.)

3.651 exercise 2 line 4 346

DB $\rightsquigarrow$ CB

3.664 new answer 347

10. See *Proc. ACM Symp. Theory of Computing* 6 (1974), 216-229.

3.665 exercise 3 for section 5.5, last line 348

variables. $\rightsquigarrow$ variables, without transforming the records in any way.

3.667 line -6 349

Strauss $\rightsquigarrow$ Straus

3.675 exercise 7 line 3 350

80]. $\rightsquigarrow$ 80; see also L. Guibas, *Acta Informatica* 4 (1975), 293-298.]

3.673

351

line -9 (displayed nodes):

$r_1 \rightsquigarrow r_0$

$r_2 \rightsquigarrow r_1$

$s_1 \rightsquigarrow s_0$

$s_2 \rightsquigarrow s_1$

line -8:

$r_1 \rightsquigarrow r_0$

$s_1 \rightsquigarrow s_0$

$k > 1 \rightsquigarrow k > 0$

lines -6 and -5: the right subtrees of ... and the result $\rightsquigarrow$ the result

3.674 new answer

352

30. This has been proved by Russell Wessner [to appear].

3.675 replace answer to 36 by:

353

36. See *MAC Tech. Memo*, 69 (M.I.T., November 1975), 41 pp.

3.676 exercise 19

354

the fourth rectangle in the left-hand figure is too short -- it should be extended so that its bottom line is at the same level as the bottom of the first and third rectangles

3.677 answer 20, the line following the tree should become:

355

It may be difficult to insert a new node at the extreme left of this tree.

3.678 answer 30 line 4

356

left subtree of that $\rightsquigarrow$ subtree rooted at that

3.679 new answer

357

29. Partial solution by A. Yao: With $N > 6$ keys the lowest level will contain an average of $\frac{1}{2}(N+1)$ one-key nodes, $\frac{1}{2}(N+1)$ two-key nodes. The average total number of nodes lies between $0.70N$ and $0.79N$, for large N . [*Acta Informatica*, to appear.]

Σ.Ε.78 new answer

358

31. Use a nearly balanced tree, with additional upward links for the leftmost part, plus a stack of postponed balance factor adjustments along this path. (Each insertion does a bounded number of these adjustments.)

Σ.Ε.ΕΕ exercise 4 line 3

359

IONIC ~ TRASH

seven ~ six

insert new sentence on last line: [This remarkable 49-place packing is due to J. Scott Fishburn, who showed that 48 places do not suffice.]

Σ.Ε.ΕΣ new answer to exercise 11 (extends to p. 623)

360

11. No; eliminating a node with only one empty subtree will "forget" one bit in the keys of the nonempty subtree. To delete a node, it should be replaced by one of its *terminal* descendants, e.g., by searching to the right whenever possible.

Σ.Ε.ΕΣ exercise 12

361

line 3: Algorithm 6.2.1D. ~ the algorithm suggested in the previous answer.

last line: } ~ {

Σ.Ε.ΕΣ exercise 34 line 1

362

$$B_k 2^{j(k-1)} \sim B_k / 2^{j(k-1)}$$

Σ.Ε.ΕΣ exercise 34, new answer to part (b)

363

(b) In the $1/(e^x - 1)$ part, it suffices to consider values of j with $x < 2 \ln n$. For $1 < x < 2 \ln n$ we have $\sum_{1 \leq k \leq n/x} (1 - kx/n)^{n-1} = \sum_{k=1}^{\infty} e^{-kx} = O(x^2 e^{-x}/n)$. For $x < 1$ we have $\sum_{0 < k < n} \binom{n}{k} B_k (x/n)^k = \sum_{k=0}^{\infty} B_k x^k / k! = O(x^2/n)$.

Σ.Ε.ΕΣ line -9

364

$$+f(n), \sim +f(n) \cdot 2/n,$$

$$k < 1 \sim k > 1$$

3.6.67 new answer 365

39. See Miyakawa, Yuba, Sugito, and Hoshi, *SIAM J. Computing*, to appear.

3.6.92 line 12 366

and $\sim$ with $0/0 = 1$ when $k = N = M-1$, and

3.6.94 367

in the second edit on I will revise several of these answers, using Mike Paterson's simplified new approach to such analyses

3.6.94 exercise 39 368

line 6 (third line of displayed formulas): delete " $j>1$," (on this line only)

line 6 (fourth line of displayed formulas): $(j) \sim \sum_{j>1} (j)$ (two places)

3.6.96 new answer 369

46. Yes. See L. Gurbas (to appear).

3.6.99 new answer 370

67. Let $q_k = p_k + p_{k+1} + \dots$; then $C_N = \sum_{k>1} q_k$ and $q_k > \max(0, 1 - (k-1)M - N)/M$.

3.7.11 line 1 371

$\sum_i p_i p_i \sim \sum_i p_i p_i$, minus the probability that a particular record is a "true drop", namely $(N-q)/\binom{N}{r}$, where $N = \binom{n}{k}$.

3.7.12 line -20 last column 372

1154 $\sim$ 1155

§.7.15 after line 7, a new paragraph: 373

A few interesting constants without common names have arisen in connection with the analysis of sorting and searching algorithms; 10-digit values of these constants appear in the answers to exercises 5.2.3-27, 5.2.4-13, and 6.3-27.

§.7.16 left column 374

$\det(A) \rightsquigarrow \det(A)$

§.7.16 line -2 375

$\dots \rightsquigarrow \dots$

§.7.17 definition of factorial 376

$1 \cdot 2 \cdot \dots \cdot n \rightsquigarrow 1 \cdot 2 \cdot \dots \cdot n$

§.7.17 definitions of x lower k and Stirling numbers of both kinds 377

$\dots \rightsquigarrow \dots$

§.7.17 line -12 378

5.1.3. $\rightsquigarrow$ 5.1.3

§.7.18 379

Adversaries, 200-201, 209, 211-212, 220.

§.7.18 Aho entry 380

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delete the entry for "Homogeneous comparisons"

Σ,7'2'5L Hyafil entry 393

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Σ,7'2'5L two new entries 394

HB(k) trees, 468. Height-balanced trees, 468, *see* Balanced trees.

Σ,7'2'5L Knockout tournament entry 395

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Σ,7'2'5L Linear list representation entry 396

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3.72213

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3.72213 line 25

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3.7221

420

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3.7221 Turski entry

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add p. 468

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add p. 686

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add pp. 232, 422, 479, 549, 678

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Zeta function, 612, 666.

ᐃᐱᐱᐱᐱ just before 2-3 trees entry 430

2D trees, 555, 570.

ᐃᐱᐱᐱ (namely the endpapers of the book) 431

delete "Table 1"

also change 1 to italic 1 in box number 35

ᐃᐱᐱ changes to MIX booklet 432

p30, Fig. 3: Step P3 should say "500 found?"

p34, Fig. 4: third card should say L EQU 500

p43, line 1: 6667 ~ 66667

p43, line 2: 193,331 ~ 133,331

p44, problem 16, line 2: row...diagonal ~ row and column

p44, problem 16, line 8: 10 ~ 9

and change "record" to "block" everywhere in the discussion of MIX I/O operators.

9.1 changes to the book Surreal Numbers

433

p99, line 2: (4) $\rightsquigarrow$ (3)

p111, lines 4 and 5, interchange the inside of the braces:

$(\{x-x^2, x-x^2+x^3-x^4, \dots\},$

$\{x, x-x^2+x^3, x-x^2+x^3-x^4, x^5, \dots\})$.

p117, problem 18, lines 3 and 4 should be:

X_L has a greatest element or is null if and on

X_R has a least element or is null.

