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CS-88-35 - ERRATA: THEORY OF COMPUTATION

AUTHOR: Derick Wood Blair

ABSTRACT:

This report provides two lists of corrections for my textbook "Theory of Computation". The first list are those corrections that have been incorporated into the second printing. The second list are those corrections that will be incorporated into the third printing.

The second printing of the North American hardback edition was published in April, 1988, by John Wiley & Sons. It has ISBN Number 0-471-60351-1. I expect that the third printing will not be produced until late 1989; therefore, these lists will continue to be helpful for at least one more year.

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CS-88-36 - FAST STRING MATCHING WITH k MISMATCHES

AUTHORS: Ricardo A. Baeza-Yates, Gaston H. Gonnet

ABSTRACT:

We describe and analyze three simple and fast algorithms for solving the problem of string matching with at most k mismatches. These are the naive algorithm, an algorithm based on the Boyer-Moore approach, and ad-hoc deterministic finite automata searching.

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CS-88-37 - NEW ALGORITHM FOR PATTERN MATCHING WITH OR WITHOUT MISMATCHES

AUTHORS: Ricardo A. Baeza-Yates, Gaston H. Gonnet

ABSTRACT:

We introduce a family of simple and fast algorithms for solving the classical string matching problem, string matching with don't care symbols and complement symbols, and multiple patterns. We also solve the same problems allowing up to k mismatches. Among the features of these algorithms is that they are real time algorithms, that they don't need to buffer the input, and that they are suitable to be implemented in hardware.

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CS-88-38 - A GLOBALLY CONVERGENT AUGMENTED LAGRANGIAN ALGORITHM FOR OPTIMIZATION WITH GENERAL CONSTRAINTS AND SIMPLE BOUNDS

AUTHORS: A.R. Conn, N.I.M. Gould, Ph.L. Toint

ABSTRACT:

The paper extends an algorithm for optimization with simple bounds (Conn, Gould and Toint, Siam Journal of Numerical Analysis 25, 433-460, 1988) to handle general constraints. The extension is achieved using an augmented Lagrangian approach. Global convergence is proved and it is established that a potentially troublesome penalty parameter is bounded away from zero.

PRICE: $2.00

CS-88-39 - THE COMPUTATIONAL STRUCTURE AND CHARACTERIZATION OF NONLINEAR DISCRETE CHEBYSHEV PROBLEMS

AUTHORS: A.R. Conn, Y. Li Mackenzie

ABSTRACT:

We present the generalisation of some concepts in linear Chebychev theory to the nonlinear case. We feel these generalisations capture the inherent structure and characteristics of the best Chebychev approximation and that they can be usefully exploited in the computation of a solution to the discrete Chebychev problem.

Key Words. nonlinear Chebyshev approximation

Subject Classification. 41A50, 65D99, 65K05, 65K10

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CS-88-48 - SWITCH-LEVEL TESTABILITY OF THE DYNAMITE CMOS PLA

AUTHORS:B.F. Cockburn, J.A. Brzozowski

ABSTRACT:

Functional testing, as opposed to parametric testing, plays an important role in testing VLSI integrated circuits. However, it appears that designs are not always carefully analysed a priori to determine precisely which faults are *clean*, i.e. testable by logic means alone. The programmable logic array (PLA) is a popular circuit form used to implement a system of Boolean functions over a set of input variables. This report considers the testability of the dynamic CMOS PLA with respect to an extended set of switch-level faults models, namely: node faults, transistor stuck-opens and stuck-ons, interconnect breaks, ohmic shorts, and crosspoint faults. Single occurrences of each fault model are classified as either clean, unclean, or clean subject to conditions on the logical products and output functions computed by the PLA. Finally, a modified dynamic CMOS PLA design is described and its increased switch-level testability properties are stated.

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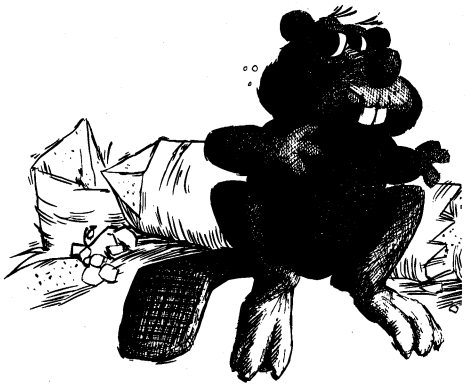

Errata: Theory of Computation

Derick Wood

Data Structuring Group
Research Report CS-88-35

September, 1988

Errata: Theory of Computation

Derick Wood *

September 1988

Abstract

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*Data Structuring Group, Department of Computer Science, University of Waterloo, WATERLOO, Ontario N2L 3G1, CANADA

Errata: Theory of Computation, 1st Printing

Derick Wood*

May 1988

Abstract

Unfortunately, my textbook "Theory of Computation" has many errors; the aim of this report is to document the reported errors that have been corrected in the second printing. The second printing of the North American hardback edition was issued in April, 1988. Since Harper & Row's Computer Science list was bought by John Wiley & Son the book has the new ISBN Number 0-471-60351-1.

Also, it is now available in an International Edition outside of North America. It is substantially cheaper, but unfortunately the current printing corresponds to the first printing of the North American version. Hence, I expect these errata to be useful for at least one more year.

Finally, because these errata have been typeset using LaTeX and the book was typeset in *troff*, there are some differences in some of the symbols. Perhaps the most noticeable are the empty set symbol and the very boldface uppercase letters denoting language families. The latter are denoted by uppercase calligraphic symbols in this report.

1 Preface

p. xv. Add two new sentences after the last sentence "In this second printing a number of the more glaring errors, in both the diagrams and the text, have been corrected. I am very grateful to David Hannay and my CS 360 students who have pointed out most of them."

2 Chapter 0

p. 5, l. 26. Emphasize the text to indicate a definition.
"B is a *smallest* $\circ$*-closed superset* of A."
p. 8, l. 10. Replace "$B =$" by "$2^A =$".
p. 15, Figure 0.2.5. It is missing the edge labels.

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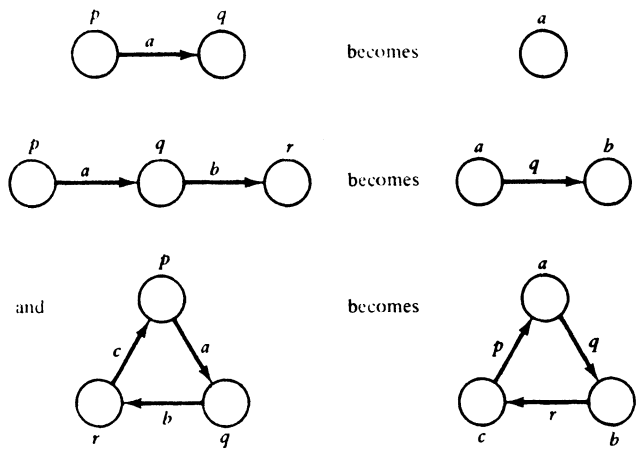


Figure: 0.2.5

p. 8, l. 14. Replace "r-tuple" by "$(r+1)$-tuple".
p. 22, l. 16. Replace "(a, b)" by "(a, d)".
p. 48. Add the new first line (it was inadvertantly omitted)

"**Induction Step:** Consider a group of k people, where $k = n + 1$. Remove"

3 Chapter 1

p. 61, l. 3. Replace "answers the question:" by "states the question:"
p. 76, l. 3. Replace "see Exercise 3.2." by "see Exercise 2.27."
p. 88, Exercise 2.11. It should begin "Let $L_i \subseteq \Sigma_i^*$, $i = 1, 2, 3$, be three languages."
p. 88, Exercise 2.11 (ii). Replace it by "$(L_1 \cup L_2)L_3 = L_1L_3 \cup L_2L_3$."
p. 88, Exercise 2.11 (v). Replace it by "$L_1(L_2 \cap L_3) \neq L_1L_2 \cap L_1L_3$ in general."
p. 88, Exercise 2.12. It should begin "Let L be a language over an alphabet Σ."
p. 88, Exercise 2.13. It should begin "Let L be a language over an alphabet Σ."
p. 89, Exercise 2.22(ii). It should be starred as a more difficult question.
p. 91, ll. 11-12 of Exercise P2.1. They should read "Write a procedure $CyclicShift(A, l, u, i)$ to perform a cyclic shift of $A[l..u]$, for $1 \leq l \leq u \leq m$, subject to the following conditions".

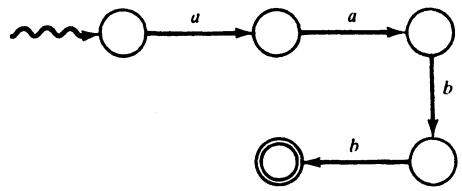


Figure: 2.2.8

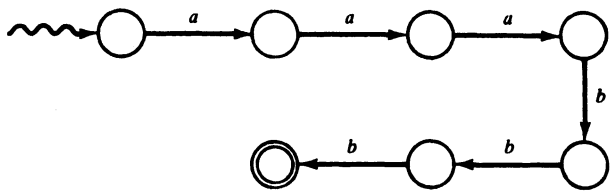


Figure: 2.2.9

4 Chapter 2

p. 103, l. 27. Replace "Thus, for example 0*aabc*" by "Thus, for example 0*aabb*".
p. 105, Figure 2.2.8. Some edges should be removed.
p. 105, Figure 2.2.9. Some edges should be removed.
p.111, l. 12. Replace " *state* coleq" by "*state* :=".
p. 118, l. 5. Replace "$\{0\}aab \vdash \{1,3\}ab \vdash \{1,3\}ab$" by "$\{0\}aab \vdash \{1,3\}ab \vdash \{1,3\}b$".
p. 118, ll. 21-22. The second sentence of the lemma should have added commas as follows "*Then, for all words x in Σ^* and for all $K \subseteq Q$,*"
p. 119, l. 9. The second sentence of the lemma should begin as follows "*Then, for all words x in Σ^* and ...*"
p. 122, Table 2.3.2. It should not have the empty set in braces.

Table 2.3.2

δ	a	b	c
0	$\{1,3\}$	$\emptyset$	$\emptyset$
1	$\{1\}$	$\{2\}$	$\emptyset$
2	$\emptyset$	$\{2\}$	$\emptyset$
3	$\{3\}$	$\emptyset$	$\{4\}$
4	$\emptyset$	$\emptyset$	$\{4\}$

p. 122, Table 2.3.3. The second and third rows should be interchanged.

Table 2.3.3

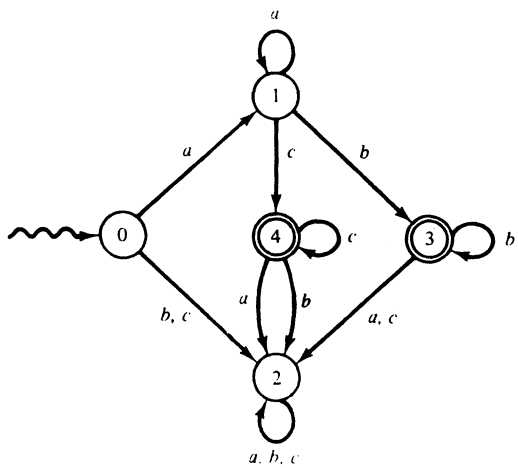


Figure: 2.3.5

δ'	a	b	c
$\{0\}$	$\{1,3\}$	$\emptyset$	$\emptyset$
$\{1,3\}$			
$\emptyset$			

p. 123, Tables 2.3.4 and 2.3.5. The braces around the empty set should be removed and the third and fourth rows should be interchanged.

Table 2.3.4

δ'	a	b	c
$\{0\}$	$\{1,3\}$	$\emptyset$	$\emptyset$
$\{1,3\}$	$\{1,3\}$	$\{2\}$	$\{4\}$
$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$
$\{2\}$			
$\{4\}$			

Table 2.3.5

δ'	a	b	c
$\{0\}$	$\{1,3\}$	$\emptyset$	$\emptyset$
$\{1,3\}$	$\{1,3\}$	$\{2\}$	$\{4\}$
$\emptyset$	$\emptyset$	$\emptyset$	$\emptyset$
$\{2\}$	$\emptyset$	$\{2\}$	$\emptyset$
$\{4\}$	$\emptyset$	$\emptyset$	$\{4\}$

p. 124, Figure 2.3.5. One edge is wrongly labeled.
p. 124, l. 3. The theorem statement should begin "*Given an NFA, M =*

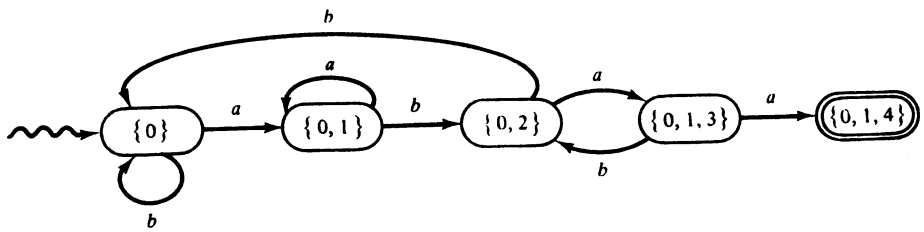


Figure: 2.3.7

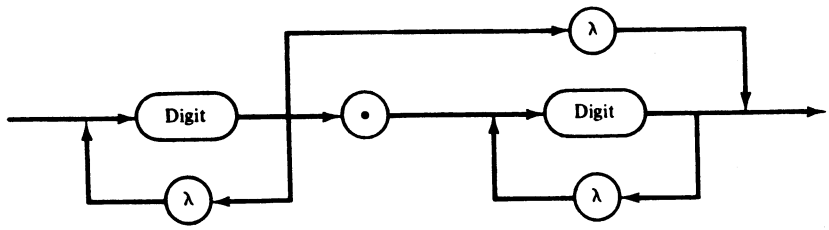


Figure: 2.6.5

$(Q, \Sigma, \delta, s, F)$; *then* ..."
p. 124, ll. 9-10. Replace "Observing that ...proving that" by "Observing that $P \cap F \neq \emptyset$ if and only if P is in F' and $\{s\}x \vdash^* P$ in M, for some x in Σ^*, in either of the two constructions, we are left with proving that".
p. 124, l. 13. Replace "But this follows ...and 2.3.2." by "But this follows from Lemmas 2.3.1 and 2.3.2."
p. 126, Figure 2.3.7. There is a missing edge.
p.129, l. 1, second sentence. It should begin "Then, for ..."
p. 129, l.3. Replace "either f ...conversely." by "either f and g are in F or f and g are in $Q - F$."
p. 129, l. 5. Replace "$\ldots\delta(p,a) \stackrel{i}{\equiv} \delta(p,a),\ldots$" by "$\ldots\delta(p,a) \stackrel{i}{\equiv} \delta(q,a),\ldots$"
p. 133, l. 3. Replace "$\ldots qz \vdash^* q \ldots$" by "$\ldots qz \vdash^* g \ldots$"
p. 138, Figure 2.6.5. There is a wrongly placed edge.
p. 138, l. 1. Replace "Then observe that a can" by "Then observe that aa can".
p. 139, Figure 2.6.6. There is a missing label.
p. 140, Figure 2.6.7. The start state is not indicated.
p. 141, Figure 2.6.8. The a-transition between states 4 and 5 is in the wrong direction.
p. 149, Exercise 3.5. Replace the text by

3.5 Let $M = (Q, \Sigma, \delta, s, F)$ be an NFA. A *control word* for M is a word over Q. Given the $NFAs$ of Exercises 3.1 and 3.3 demonstrate how

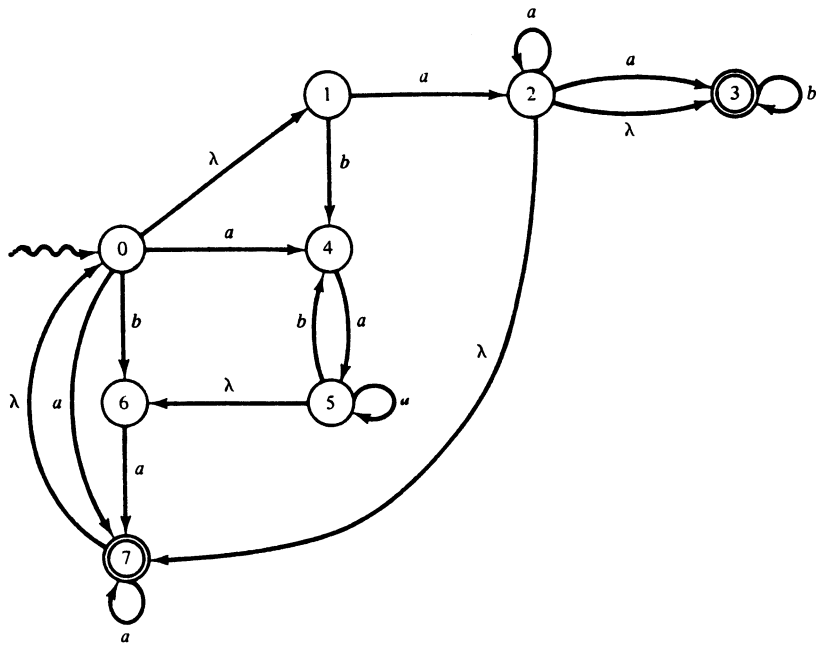


Figure: 2.6.6

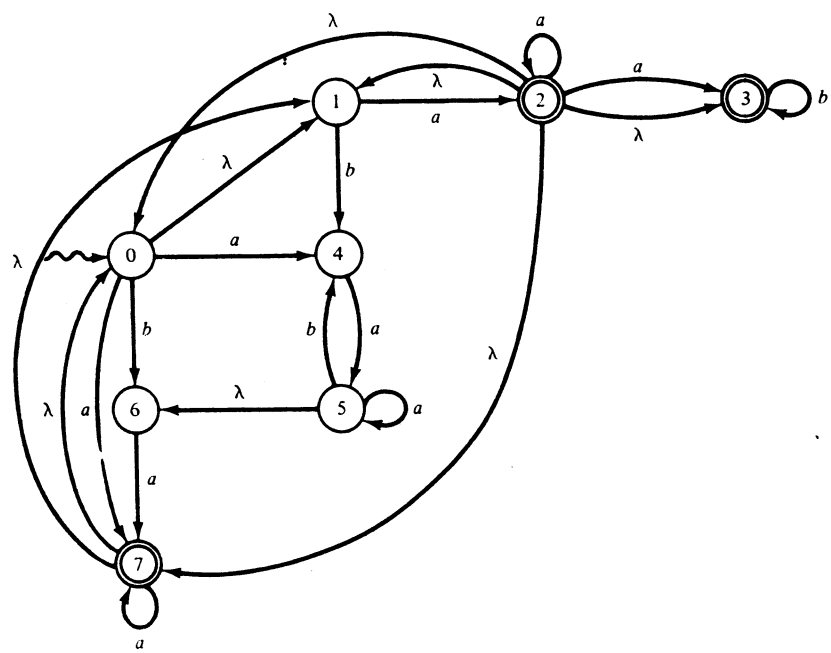


Figure: 2.6.7

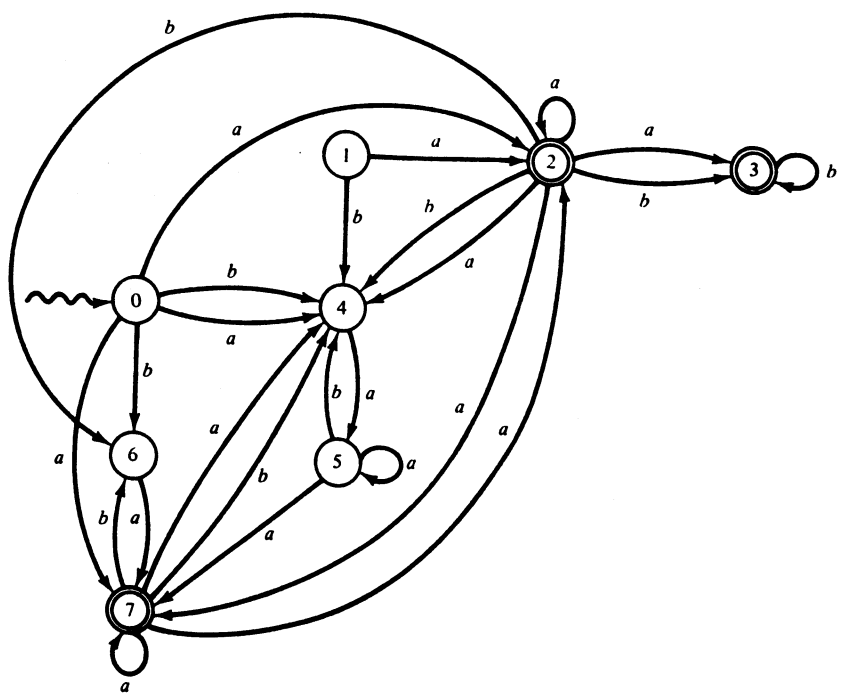
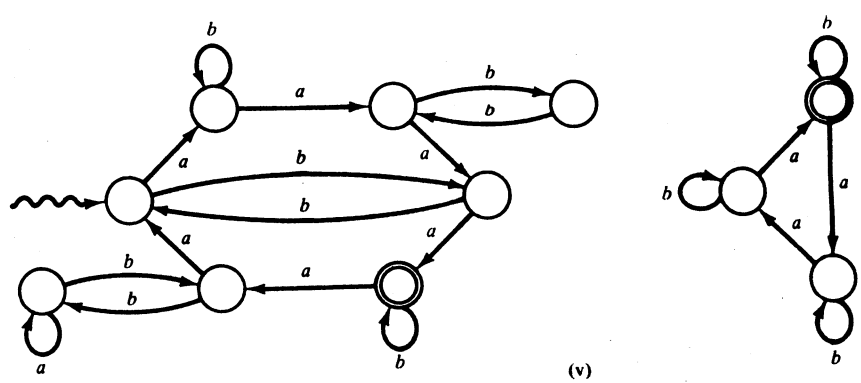


Figure: 2.6.8

they can be viewed as deterministic machines if control words are used as additional separate input.

p. 151, Exercise 4.3(v). There should be a b-transition in both directions between the start state and the state on the same horizontal line.



p. 152, Exercise 4.7. It has two parts numbered (iii). Renumber the second as (iv).

p. 152, Exercise 4.10. It has a number of missing commas. A comma should be added after "The number of equivalence classes is $\underset{L}{\equiv}$". Commas should

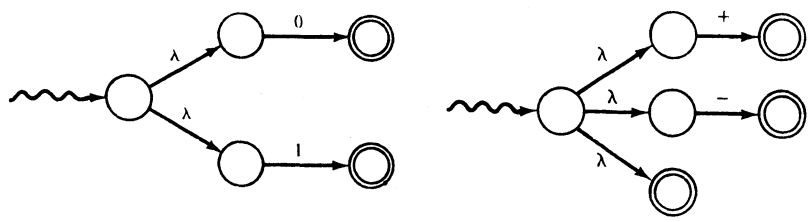


Figure: 3.2.8

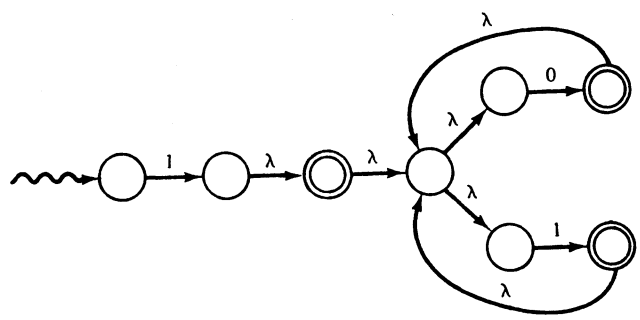


Figure: 3.2.9

also be inserted after each of the "for $L = \{\ldots\}$" constructions in parts (i) to (iv).

5 Chapter 3

p. 157, Figures 3.1.1 and 3.1.2. They should be repositioned so that the first figure comes before l.1 and the second before the sentence beginning "Observe how ..." on l. 4.
p. 166, Example 3.2.1. Replace the second two sentences of the example by "From $0 \cup 1$ and $+ \cup - \cup \lambda$ we obtain Figure 3.2.8 and from $1[0 \cup 1]^*$ we have Figure 3.2.9. These give the λ-NFA M of Figure 3.2.10."
p. 166, Figure 3.2.8. It is incomplete.
p. 167, Figures 3.2.9 and 3.2.10. They are wrong.
p. 167, l. 1. In the definition of an extended finite automaton the specification of f should be amended to read "f in Q is a *final* state, $f \neq s$."
p. 174, l. 4. Add extra spacing after the two appearances of $\overline{\delta}$.

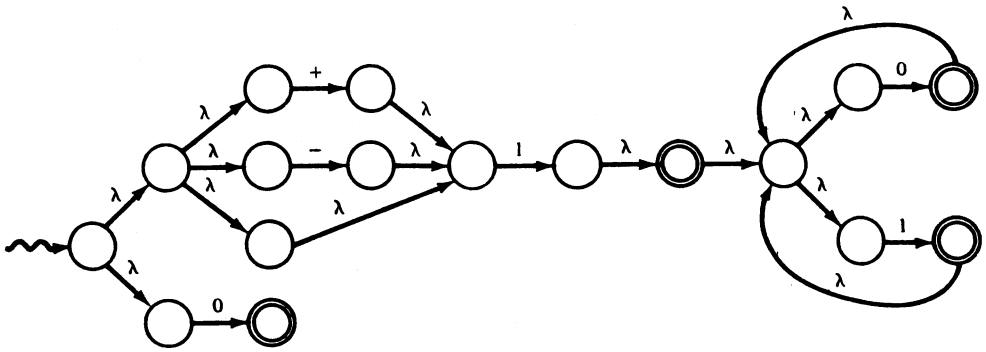
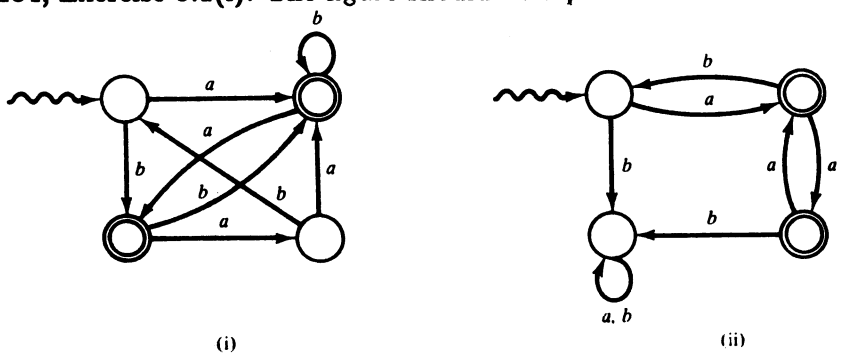


Figure: 3.2.10

p. 184, Exercise 1.8. This new exercise should be added.

1.8 Given an alphabet Σ, how many regular languages over Σ are there?

p. 184, Exercise 3.1(i). The figure should be replaced.



6 Chapter 4

p. 197, l. 1. Replace "$\ldots 2n+1\ldots$" by "$\ldots 2n+3\ldots$"
p. 197, l. 2. Replace "$\ldots, x_{2n}, \ldots \leq 2n\ldots$" by "$\ldots, x_{2n+2}, \ldots \leq 2n+2\ldots$"
p. 197, l. 3. Replace "$\ldots \leq 2n\ldots$" by "$\ldots \leq 2n+2\ldots$"
p. 197, l. 4. Replace "$\ldots |x_{2n}|_a - |x_{2n}|_b$" by "$\ldots |x_{2n+2}|_a - |x_{2n+2}|_b$".
p. 197, l. 6. Replace "$\ldots < n \ldots$" by "$\ldots < n+1 \ldots$"
p. 197, l. 7. Replace "$\ldots < n \ldots = x_{2n-2}$," by "$\ldots < n+1 \ldots = x_{2n}$,"
p. 197, l. 13. Replace "$\ldots < n \ldots$" by "$\ldots < n+1 \ldots$"
p. 202, l. 13. Replace "...labeled with B..." by "...labeled with some nonterminal B..."
p. 212, l. 27. Replace "...An arbitrary..." by "...A ..."
p. 213, l. 27. Replace "...an arbitrary..." by "...a ..."
p. 214, l. 4. Replace "...an arbitrary..." by "...a ..."

p. 214, l. 14. Replace "...An arbitrary..." by "...A ..."
p. 215, l. 10. Replace "...an arbitrary..." by "...a ..."
p. 215, l. 17. Replace "...an arbitrary..." by "...a ..."
p. 215, l. 21. Replace "...an arbitrary..." by "...a ..."
p. 216, l. 21. Replace "...An arbitrary..." by "...A ..."
p. 216, l. 37. Replace "$C \to \lambda$," by "$C \to \lambda$".
p. 217, l. 13. Replace "...an arbitrary..." by "...a ..."
p. 217, l. 31. Replace "...an arbitrary..." by "...a ..."
p. 218, l. 14. Replace "$\{B \to \beta_0 X_m \beta_1 \ldots$" by "$\{B \to \beta_0 X_1 \beta_1 \ldots$".
p. 220, l. 3. Replace "...an arbitrary..." by "...a ..."
p. 220, l. 8. Replace "...an arbitrary..." by "...a ..."
p. 220, l. 19. Replace "...an arbitrary..." by "...a ..."
p. 221, l. 12. Replace "...an arbitrary..." by "...a ..."
p. 221, l. 18. Replace "...an arbitrary..." by "...a ..."
p. 221, l. 34. Replace "...An arbitrary..." by " ...A ..."
p. 222, l. 28. Replace "...an arbitrary..." by "...a ..."
p. 223, l. 3. Replace "...an arbitrary..." by "...a ..."
p. 223, l. 8. Replace "...an arbitrary..." by "...a ..."
p. 228, l. 25. Replace "...an arbitrary..." by "...a ..."
p. 229, l. 2. Replace "...an arbitrary..." by "...a ..."
p. 229, l. 18. Replace "...an arbitrary..." by "...a ..."
p. 232, l. 8. Delete ", on the other hand,"
p. 232, l. 12. Replace "...linear." by "...linear, although the grammar is not."
p. 241, Exercise 1.4(v). It should read

(v) $\{a^i b^j b^i a^k : i, j, k \geq 0\}$.

p. 241, Exercise 1.7. Its first sentence should be "Let $G = (N, \Sigma, P, S)$ be a CFG and let $SF(G) = \{\alpha : S \to^* \alpha, \text{where } \alpha \text{ is in } (N \cup \Sigma)^*\}$, the sentential form language."
p. 242, Exercise 1.12. It should be

1.12 Consider the CFG of Example 4.1.5. Construct the portion of the search tree corresponding to the following input words

(i) a.

(ii) $(a) * a$.

(iii) $(a) * (a)$.

(iv) $(a + a)$.

p. 243, Exercise 2.4(iii). It should be

(iii) Construct a λ-free CFG G' λ-equivalent to G.

p. 243, Exercise 2.5. Replace "...two arbitrary..." by "...two ..." p. 243. Renumber Exercises 2.8 - 2.17 as Exercises 2.9 -2.18, respectively, and insert a new Exercise 2.8.

2.8 In *EliminateOneUnitProduction*, as written, the ordering of productions is arbitrary. Is there a better ordering?

7 Chapter 5

p. 250, l. 6. Replace "...then $\delta(p, a, \perp) = (q, \perp, g)$,..." by "...then $\delta(p, a, \perp) = (q, \perp g)$,..."
p. 252, l. 11. Replace "...obtained from *qcpax*..." by "...obtained from *gcpax*..."
p. 259, ll. 8-15. Replace "Fortunately, ...8.2 and 11.3." by "Indeed, accepting only by final state increases the expressive power of λ-$DPDA$. We consider this issue further in the Exercises. For this reason, we base the definition of *deterministic CFLs* on λ-*DPDAs* with acceptance only by final state and refer to $L_f(M)$ in this case.
Definition For a λ-$DPDA$ $M = (Q, \Sigma, \Gamma, \delta, s, F)$, let $L_f(M) = \{x : \perp sx \vdash^* \alpha f$, for some f *in* $F\}$. A CFL, L, is a *deterministic* CFL, or a $DCFL$, if it is accepted, by final state only, by some λ-$DPDA$, M, that is, $L = L_f(M)$. The *family of DFCLs* is denoted by $\mathcal{L}_{DCF}$ and forms an important subclass of $\mathcal{L}_{CF}$. We return to this topic in Sections 8.2 and 11.3."
p. 263, l. 30. Replace "...$(s, a, \perp, f, g)$..." by "...$(s, a, \perp, f, \perp g)$ ..."
p. 276, Exercise 1.6 (ii). It should be

(ii) If $L = L(M)$, for some λ-$DPDA$, M, then there is a λ-$DPDA$, M', with $L_f(M') = L$.

p. 277, Exercise 2.3. The two parts should be

(i) $S \to cSS|bSA|aSB|aB|bA$; $A \to a$; $B \to b$.

(ii) $S \to aAB$; $A \to aAB|b$; $B \to bBa|a$.

8 Chapter 6

p. 281, ll. 25-26. Replace "(a) If ...final state." by

(a) If $p = f$, then M *halts*, that is, by definition, M does not move. This is the reason we require only one final state.

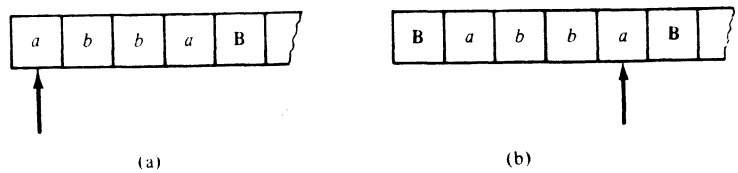


Figure: 6.1.12

p. 282, ll. 4-5. Replace "(d)...possible." by

(d) In (b) and (c) if $\delta(p, \mathbf{B})$ or $\delta(p, a)$ is undefined or a move left on the leftmost cell occurs, them M hangs, that is, M cannot move.

p. 285, l. 13. Before the closing semicolon of (a) insert the following clarification "(if $h_1 = \lambda$, h' may be λ)".
p. 285, l. 14. Before the closing semicolon of (b) insert the following clarification "(if $h_1 = \lambda$ and $B = \mathbf{B}$, $h' = \lambda$)".
p. 285, l. 15. In (c) "than" should be "then"
p. 287, Figure 6.1.12(b). The arrow is pointing to the wrong cell.
p. 291, Figure 6.1.19. There is a missing edge label on the lowest, rightmost edge.
p. 295, Figure 6.1.27. The edge from the second upper horizontal state to the second leftmost vertical state is wrongly labeled.
p. 300, l. 28. Replace "*symbols*" by "*symbol*".
p. 306, l. 11. Replace "off-line TM" by "off-line DTM".
p. 306, l. 14. Replace "off-line TM" by "off-line DTM".
p. 312, l. 9. Before the sentence beginning "Initially,..." insert the following new sentence "This implies the definition of a configuration should be modified to take account of this symmetry."
p. 312, l. 26. Replce "Apart from this" by "Apart from this,"
p. 312, ll. 28-31. Replace "The symbol...rather than right." by "The symbol 1 appears only in cell 0 so that the DTM can determine if it is at cell 0. On the other hand, when the DTM is at cell -1, it must move left to get to cell 0."
p. 313, Figure 6.4.2(b). The first cell is incorrectly labeled.
p. 314, l. 4. Replace "$\delta'([p, B], bb) =$" by "$\delta'([p, B], \mathbf{B}) =$".
p. 314, Figure 6.4.3(a). The first cell is incorrectly labeled.
p. 315, Figure 6.4.4. The first cells are incorrectly labeled.
p. 321, ll. 20-23. Replace the displayed equation (6.5.1) and the text up to and including "...L or R." by

$$[\delta(i_1), A_1) = (code(j_1), C_1, D_1); \cdots] \quad (6.5.1)$$

where i_k and j_k are the states in the kth transition and $code(i)$ is an encoding of state i; A_k and C_k are the symbols a, b, or B, where B denotes $\mathbf{B}$,

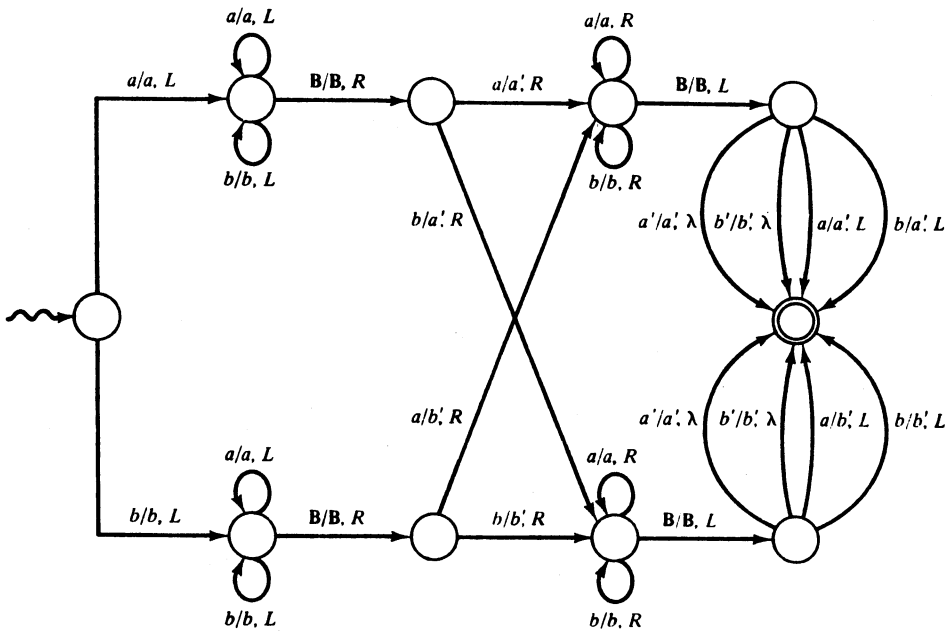


Figure: 6.1.19

since **B** cannot appear in an input word; and D_k is either L or R.
p. 323, Figure 6.5.3. The contents of the first two tapes should be interchanged and the first cell of the third tape is wrongly labeled.
p. 323, l. 4. Replace "head 1 is over the first cell," by "head 2 is over the first cell,"
p. 324, Figure 6.5.4. The contents of the first two tapes should be interchanged and the first cell of the third tape is wrongly labeled.
p. 324, l. 1. Replace "<> [" by "<>]".
p. 325, l. 3. Add ")" before the "**do**".
p. 325, l. 9 should be "**end** {if}"
p. 325, l. 21. Replace "*Then*" by "*Then,*"
p. 325, l. 22. Replace "$\{a,b\}^{*}$" by "$\{a,b\}^{*}$,"
p. 325, l. 23. Expand "*iff*" as "*if and only if*".
p. 326, ll. 6-7. The encoding is wrong; it should be

bbbabaaabaaabaaabaabbababaabaabaabbabaabaabaabaab

baaabaaabaaabaaabaabbaaababaaabaabaabbaaabaabaaabaabaabbbb

p. 327, l. 4. Replace "a *DTM*" by "an off-line *DTM*".

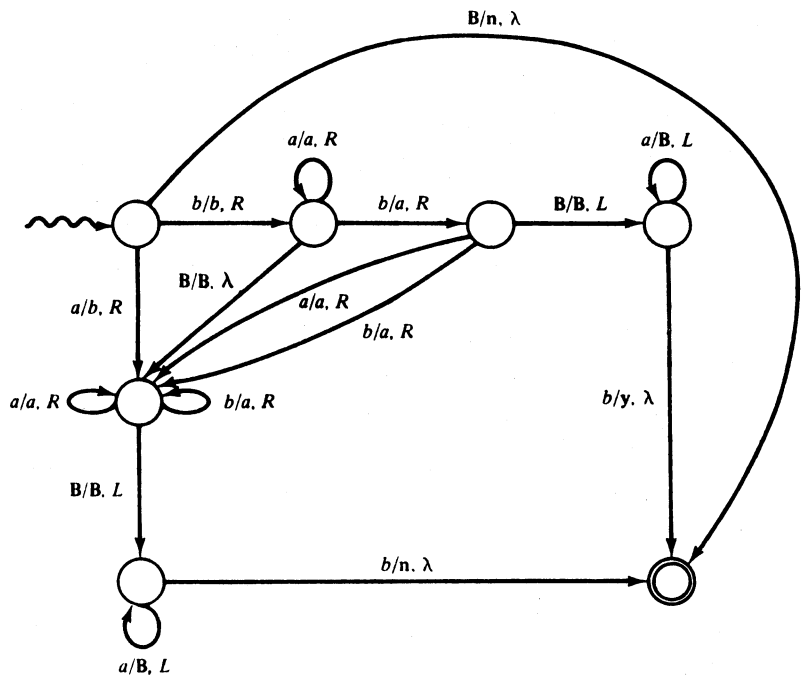


Figure: 6.1.27

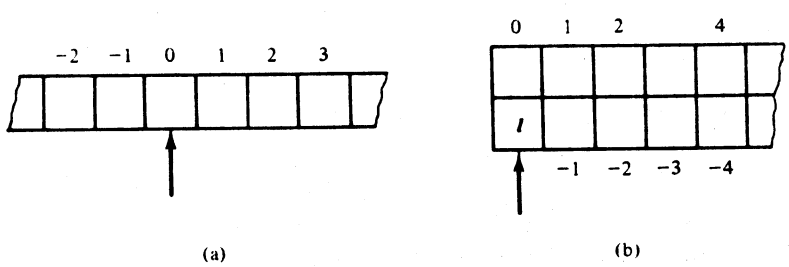


Figure: 6.4.2

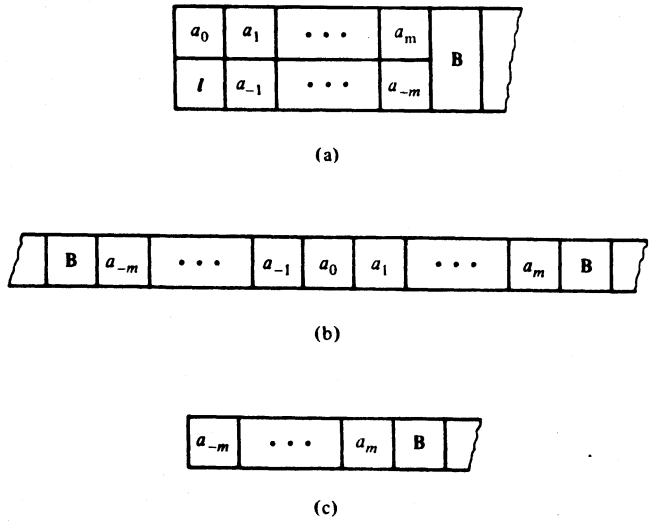


Figure: 6.4.3

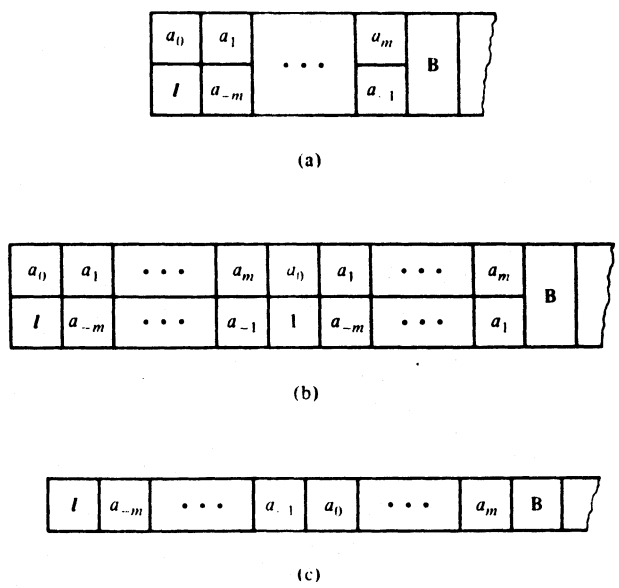


Figure: 6.4.4

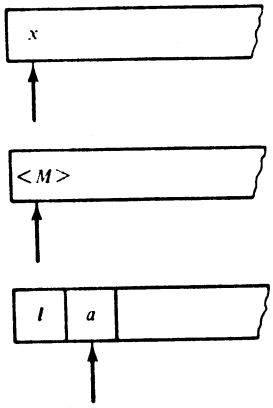


Figure: 6.5.3

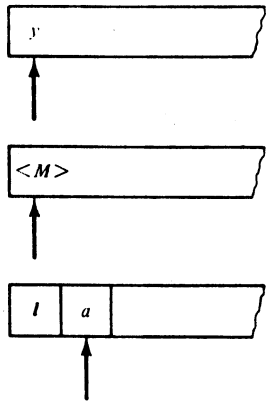


Figure: 6.5.4

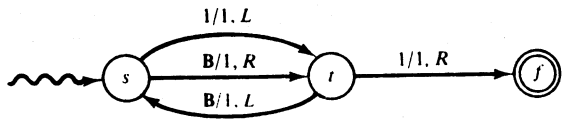


Figure: 6.8.2

p. 327, l. 33. Replace "to be accepted" by "to be decided".
p. 331, l. 31. Replace "{1, b}" by "{1, B}".
p. 332, Figure 6.8.2. The lowest transition should be reversed.
p. 335, Exercise 1.2. After part (i) add the following clarification phrase: ";this erases the first cell."
p. 337. Add two new Exercises.

5.3 Give an example of a *DTM* M that accepts all $\ll M \gg$-encodings, but not all words of $\{a, b\}^*$.

5.4 Give a *DTM* M that accepts some, but not all of its $\ll M \gg$-encodings.

9 Chapter 7

p. 342, ll. 10-11. Interchange the references to the two figures to be "...Figure 7.2.2 ...Figure 7.2.3 ..."
p. 360, l. 9. Replace "...g is also total." by "...h is also total."
p. 363, l. 4. The definition should begin "**Definition** The *minimalization* of an ..."
p. 363, l. 16. In Example 7.6.6 add the following clarification phrase to the first definition of g, "that is, i and j are prime and $j = i + 2$. Then g is not..."
p. 363, l. 22. In Example 7.6.7 add the following clarification phrase after the use of the ceiling function, "...can define $\lceil i/j \rceil$, the least integer greater than or equal to i/j, by using the ..."
p. 367, Exercise 4.1 (i). It should be

(i) $\{(a^i b^i c^j, a^i b^j c^j) : i, j \geq 1\}$.

p. 367, Exercise 4.4. Delete it.

10 Chapter 8

p. 376, l. 10. Replace "a nonregular language." by "a nonregular (or non-*DFA*) language."

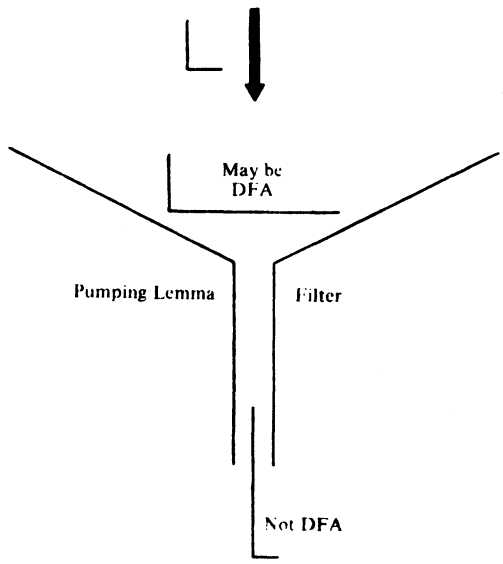


Figure: 8.1.1

p. 376, l. 11. Replace "then it may be regular." by "then it may be regular (or DFA)."
p. 376, Figure 8.1.1. It should be modified to reflect the above changes. The phrases "May be regular" and "Nonregular" become "May be DFA" and "Not DFA", respectively. p. 376, l. 15. In Example 8.1.1 the language $L(M)$ should be defined as follows

$$L(M) = \{b^{2i} : i \geq 1\} \cup \{b^{2i}ab^{2j} : i, j \geq 0\}$$

p. 378, l. 32. Replace "...that satisfy $|uv| < p$..." by "...that satisfy $|uv| \leq p$ ..."
pp. 382-383. The proof of Theorem 8.2.1 should be replaced by the following text
Proof: We prove there is a CFL which is not a λ-$DPDA$ language.

Consider the language $L = \{a^ib^i, a^ib^{2i} : i \geq 1\}$. We prove, by contradiction, that it is not a λ-$DPDA$ language. Assume that there is some λ-$DPDA$, $M = (Q, \{a, b\}, \Gamma, \delta, s, F)$, such that $L(M) = L$. We claim that there are positive integers i and j, $i < j$, such that

$$\perp sa^ib^{2i} \vdash^+ \perp pb^i \vdash^+ \perp f$$

and

$$\perp sa^jb^{2j} \vdash^+ \perp pb^j \vdash^+ \perp fb^{j-i}$$

for some p in Q and f in F. Observe that this claim implies

$$\perp sa^j b^{i+j} \vdash^+ \perp pb^i \vdash^+ \perp f$$

that is, $a^j b^{i+j}$ is in L — a contradiction.

To establish the claim, note that, for all $k \geq 1$, for some p in F,

$$\perp sa^k b^k \vdash^+ \perp p$$

since $a^k b^k$ is in L. Now, F is finite and there are an infinite number of words of the form $a^k b^k$ in L. Therefore, there at least two distinct values of k, say $k = i$ and $k = j$, where $i < j$, such that

$$\perp sa^i b^i \vdash^+ \perp p$$

and

$$\perp sa^j b^j \vdash^+ \perp p$$

for some p in F. Immediately, we have

$$\perp sa^i b^{2i} \vdash^+ \perp pb^i$$

and

$$\perp sa^j b^{2j} \vdash^+ \perp pb^j$$

because M is deterministic. Since $a^i b^{2i}$ is in L we must have also

$$\perp pb^i \vdash^+ \perp f$$

for some f in F, and, therefore,

$$\perp pb^j \vdash^+ \perp fb^{j-i}$$

This establishes the claim; thus $L \neq L(M)$, for any λ-$DPDA$ M. □

p. 383, ll. 29-31. The text in the two displayed formulas should be moved to the following lines. This results in

$$gqx \underset{\text{push } A}{\vdash} g'q'x'$$

if $gqx \vdash g'q'x'$ and $g' = gA$. In other words, A is pushed onto the pushdown. Similarly, we write

$$gqx \underset{\text{pop } A}{\vdash} g'q'x'$$

if $gqx \vdash g'q'x'$ and $g = g'A$, that is, A is popped from the pushdown.
p. 383, l. 36. Replace "...an PDA..." by "...a PDA..."

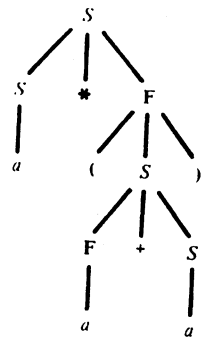


Figure: 8.2.4

p. 387, Figure 8.2.4. There is a missing "+" label. p. 392, l. 4. In the second sentence of the Claim the inequality should read "$|y(T)| \leq m^h$".
p. 393, ll. 10-12. Replace the three sentences beginning "The number of nodes ..." by "Therefore, the height of T_A, the subtree rooted at the upper A, is at most $\#N + 1$. This implies that $|y(T_A)| \leq m^{\#N+1} < p$, and, therefore, condition (i) is now satisfied."
p. 400, l. 39. Replace "if x has an accepting..." by "if all accepting configuration sequences of x are of length at most $T(|x|)$."
p. 409, Exercise 2.1 (ii). Replace it by

(ii) $\{a^i b^i c, a^i b^{2i} c : i \geq 1\}$.

11 Chapter 9

p. 421, Table 9.2.1. The Morse code of C is given incorrectly; it should be "$h(C) = - \cdot - \cdot$".

12 Chapter 10

p. 448, l. 2. Replace "Hence, $k \leq 2.1 - 1 = 1$ as desired." by "Hence, $k \leq 2 \times 1 - 1 = 1$ as desired."
p.449, l. 20. Add a hyphen before "encoding" to give "...x is the $\{a, b\}$-encoding ..."
p.450, l. 22. Replace "$|w| \geq 1$, $|uw| < \#Q$ " by "$|v| \geq 1$, $|uv| < \#Q$ ".
p.451, ll. 24-25. Replace these two lines by "word has length less than or equal to $\#Q$. Thus, when $|x| \geq 2\#Q$, the smallest x' that can be obtained after one reduction step has length at least $\#Q$."

13 Chapter 11

Nothing reported yet; perhaps no one has read it carefully!

14 Bibliography

p. 540. Insert a missing reference.

Landin, P.J., A Correspondence between Algol 60 and Church's Lambda-Notation, *Communications of the ACM 8*, (1965), 89-101 and 158-165.

15 Index

Nothing has been reported here either. Does that imply people don't use it?

Errata: Theory of Computation, 2nd Printing

Derick Wood *

August 1988

Abstract

This is a list of errata and their corrections that will be incorporated into the third printing of my textbook "Theory of Computation". The second printing of the North American hardback edition was issued in April, 1988 with ISBN Number 0-471-60351-1.

I expect that the third printing will not be produced until later in 1989; therefore, this list will continue to be helpful for at least one more year.

I assume there are yet more errata lurking in the text that remain to be discovered, so please let me know of any new errors that you find.

Also, since I am planning (even if the publisher is not) a second edition, I would be grateful for comments of a more general, philosophical, and stylistic nature.

1 Preface

p. xv. Replace the last two sentences with "In this third printing further errors, in both the diagrams and the text, have been corrected. I am very grateful to Byron Becker, Josep Diaz, David Hannay, and my CS 360 students who have pointed out most of them."

2 Chapter 0

p. 40, Exercise 2.2. Add the following sentence at the end of the first paragraph. "Let A^n be the Boolean product of A with itself n times and $A^{\leq n}$ be the Boolean sum of A, A^2,...,A^n.
p. 40, Exercise 2.2. Replace the sentence "Prove that $R = I$ or A^n..." by "Prove that $R = I$ or $A^{\leq n}$, where I is the $n \times n$ identity matrix and A is the $n \times n$ adjacency matrix."

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p. 40, Exercise 2.3. Replace "...is the matrix product..." by "...is the usual matrix product..."
p. 40, Exercise 2.5. Replace "(i) $A^n_{ii} = 1$ if and only if p_i is recursive." by "(i) $A^{\leq n}_{ii} = 1$ if and only if p_i is recursive, where $A^{\leq n}$ is defined in Exercise 2.2."
p. 40, Exercise 2.5. Replace the three occurrences of "A^n_{ij}" by "$A^{\leq n}_{ij}$".
p. 41, Exercise 2.6. Replace "...$A^n_{ij} = 1$, for all i, j, $1 \leq i, j \leq n$." by "...$A^{\leq n}_{ij} = 1$ for all i, j, $1 \leq i, j \leq n$, where $A^{\leq n}$ is defined in Exercise 2.2."
p. 42, Exercise 3.6. Replace "...for $n \geq 1$,...only if n is prime." by "...for $n \geq 2$,...only if $n = 2$."
p. 43, Exercise 3.7. Replace "...is onto if and only if it is total." by "...is total if it is onto."
p. 47, Exercise 5.9. Replace it by

5.9 Given a binary tree, assign values to its nodes using the rules

(i) all external nodes have value 0;

(ii) all internal nodes have a value which is one greater than the maximum of the values of its successors.

This value is usually called the *height* of a node; the height of the root node is the height of the tree. Prove, by induction, that the maximum number of internal nodes in a binary tree of height $h \geq 0$ is $2^h - 1$. Extend this result to m-ary trees, $m \geq 2$; compare Exercise 5.7.

p. 47, Exercise 5.11. Replace "Given a binary tree prove that, for..." by "Given a binary tree, prove that, for..."

3 Chapter 1

p. 71, l. 25. Replace "$f : Char \rightarrow OctalCode$." by $f : Char^* \rightarrow OctalCode^*$."
p. 88, Exercise 2.15. Replace "...$g : \Sigma^* \rightarrow \Delta^*$ then we can say..." by "...$g : \Sigma^* \rightarrow \Delta^*$, we say..."
p. 88, Exercise 2.16. Replace "...$g : \Sigma^* \rightarrow \Delta$ equality...2.14." by "...$g : \Sigma^* \rightarrow \Delta^*$, equality...2.15."
p. 89, Exercise 2.21. Replace "(ii)..." by "(ii) $(L_1L_2 \cup L_1)^* = \{\lambda\} \cup L_1(L_2L_1 \cup L_1)^*$."

4 Chapter 2

p. 99, l. 17. Replace "...DFA, then..." by "...DFA; then..."
p. 99, l. 19. Replace "control, see..." by "control; see..."

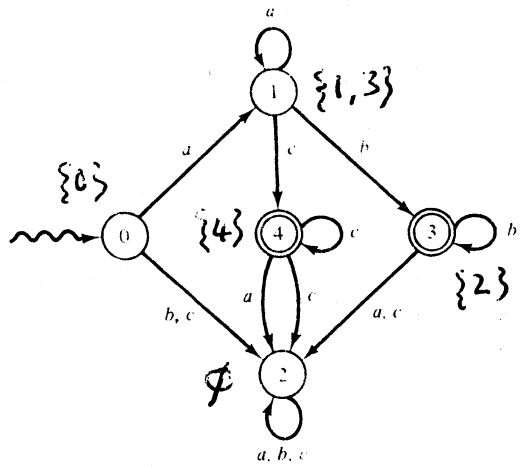
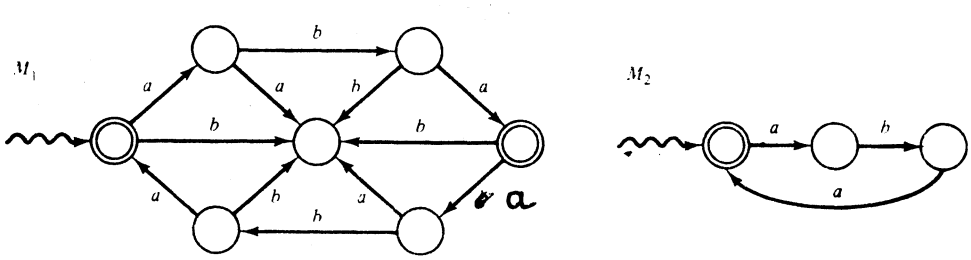


Figure 2.3.5

p. 103, l. 27. Replace "...example 0*aabb*..." by "...example, 0*aabb*..."
p. 106, l. 28. Replace "$X = (e, B, f, r, S)$,..." by "$X = (A, B, f, r, S)$,..."
p. 119, l. 14. Replace "...so q..." by "...so p..."
p. 121, ll. 11-12. Replace them by

for each a **in** Σ **do**
  if $\delta(Q_i, a) = Q_j$, **for some** j, $0 \leq j \leq last$ **then**
    $\delta'(i, a) := j$ **else**

p. 124, Figure 2.3.5. Add additional node labels indicating sets of states they correspond to.
p. 137, l. 5. Add the closing horizontal rule after this line.
p. 151, Exercise 4.5. In M_1 the b-transition from the rightmost final state to the the state to its south-west should be an a-transition.



p. 151, Exercise 4.6. Replace "As in Section 2.7.1..." by "As in Section 2.8.1..."

p. 154, Exercise P5.1. Replace it by

P5.1 Write a program which given a DFA decides if it is loop-free and if so, whether it is a tree.

5 Chapter 3

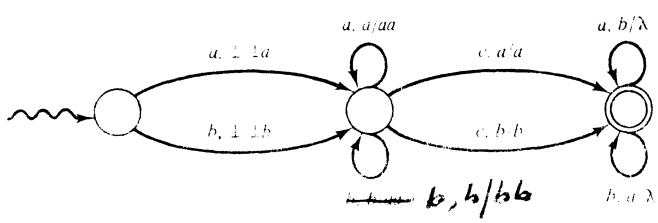
p. 169, ll. 8-9. Replace "We... $= L(M)$." by "We now demonstrate how to construct a regular expression E from an EFA, M, with such a start state such that $L(E) = L(M)$."

6 Chapter 4

p. 223, l. 1. Replace "...following by..." by "...following result by..."
p. 223, l. 20. Replace "(5) $A \rightarrow Bc$;" by "(5) $A \rightarrow Bc$"
p. 224, l. 9. Replace "...$\mp$;" by "...$\mp$".
p. 225, l. 30. Replace "$A \rightarrow +S$;" by "$A \rightarrow +S$".
p. 240, Exercise 1.1. Replace "$S \rightarrow aSbSa|\lambda$." by "$S \rightarrow aSbSa|\lambda$".
p. 241, Exercise 1.6. Replace "...CFG." by "...CFG; see Exercise 1.5."
p. 243, Exercise 2.7. Replace "$A_k \rightarrow a_k$" by "$A_k \rightarrow a$".

7 Chapter 5

p. 250, l. 8. Replace "...$= (q,p)$..." by "...$= (q,g)$..."
p. 259, l. 13. Replace "...some f *in*..." by "...some f in..."
p. 276, Exercise 1.2. Replace the lower looping transition on the center state, that is, "$b, b/aa$" by "$b, b/bb$".



p. 276, Exercise 1.6. Replace "...following" by "...following results."

8 Chapter 6

p. 286, ll. 4-6. Replace them by "Observe that the transition from state 2 can never be taken, since, by definition, M halts on entering a final state.

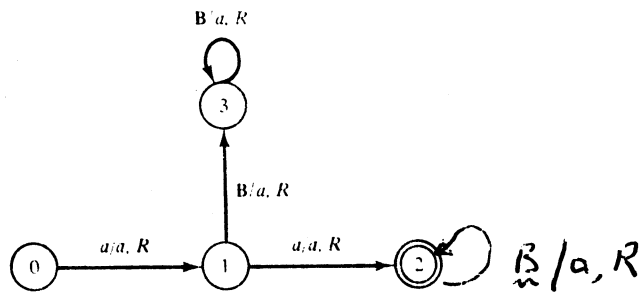


Figure 6.1.11

Similarly, if state 3 were final, the input configuration $0a$ would give

$$0a \vdash a1 \vdash aa3$$

that is, M would halt on entering state 3.
p. 286, Figure 6.1.11. Add a new transition from state 2.
p. 291, ll. 4-5. Replace "...word that represents a nonnegative integer in binary." by "...word."
p. 291, l. 15. Replace "...*machine* if..." by "...*machine* or *dmDTM* if..."
p. 294, l. 22. Replace this line by "important family.
Definition *The family of recursive languages* is denoted by $\mathcal{L}_{REC}$".
p. 300, l. 24. Replace "$[a_1, 1, 1]$);" by "$[a_1, 1, 1]$)"
p. 301, l. 20. Replace "$2^{k-1} \leq \Gamma$..." by "$2^{k-1} \leq \#\Gamma$..."
p. 311, l. 23. Replace "...that is,..." by "...that is ..."
p. 312, l. 7. Replace "...a sextuple by" by "...by a sextuple".
p. 312, l. 8. Replace "...*TM* ..." by "...*DTM* ..."
p. 312, l. 10. Replace "...this symmetry..." by "...the symmetry..."
p. 317, l. 17. Replace "..., a_n,..." by "..., i_n,..."
p. 321, l. 15. Replace "...Theorem 6.3.2...." by "...Theorem 6.3.2. By Theorem 6.3.1 we only need directions L and R...."
p. 335, Exercise 1.2. Replace "...erases the first cell..." by "...erases the first symbol..."

9 Chapter 7

p. 343, Figure 7.2.4. The upper transition for M in $XMAS$ is labeled incorrectly.
p. 353, l. 13. Replace "...Γ^*." by "...Δ^*."

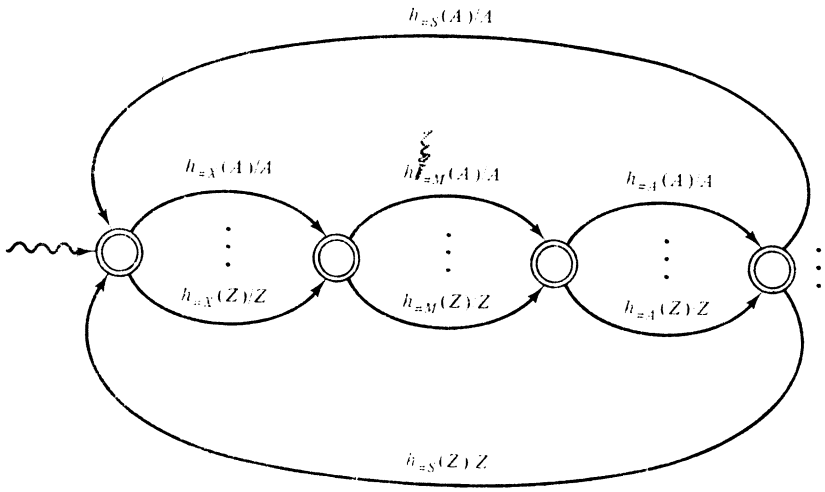


Figure 7.2.4

10 Chapter 8

p. 378, l. 28. Replace "$\ldots z \ldots |z| \ldots$" by "$\ldots x \ldots |x| \ldots$"
p. 378, l. 31. Replace "$\ldots z \ldots$" by "$\ldots x \ldots$"
p. 389, l. 5. Remove the comma before "*and*".
p. 390, ll. 1-7. Replace them by "*Then, for all words z in $L(G)$ such that $|z| \geq p$, z has a decomposition*

$$z = uxwyv$$

for some u, v, w, x, y in Σ^* such that
(i) $|xwy| < p$;
(ii) $|xy| \geq 1$; *and*
(iii) *for all $i \geq 0$, ux^iwy^iv is in $L(G)$.*"
p. 390, Example 8.2.1. Renumber it Example 8.2.2.
p. 390, l. 10. Replace "classical" with "classic".
p. 390, ll. 17-19. Replace them by "By the CFG pumping lemma we know that there is a decomposition

$$z = uxwyv = a^p b^p c^p$$

for some u, v, w, x, y in Σ^* with $|xwy| < p$. This implies"
p. 393, ll. 1-3. Replace them by "for some $i > 0$, and then reattach T_{start} and T_{finish}. This yields the word ux^iwy^iv, which is in $L(G)$. Therefore, condition (iii) is satisfied. Condition (ii) is satisfied immediately, since G

is λ-free and unit-free and, therefore, T_{repeat} contains at least two external nodes. Hence, $|y(T_{repeat}| \geq 1$. However, condition (i) may not be satisfied."
p. 393, l. 12. Add ■ at the end of the line.
p. 393, ll. 13-14. Delete them.
pp. 393-394, Example 8.2.2. Renumber it Example 8.2.3 and replace the text as follows.
Example 8.2.3 Let $L = \{wcw : w \text{ is in } \{a,b\}^*\} \subseteq \{a,b,c\}^*$. We prove L is not a CFL using an argument by contradiction. Assume L is a CFL. Then there is a λ-free, unit-free CFG $G = (N, \{a,b,c\}, P, S)$ such that $L = L(G)$. Let p be the constant of the CFG Pumping Lemma and consider a word $z = a^p b^p c a^p b^p$ in L. Clearly, $|z| \geq p$. The CFG Pumping Lemma states that z has a decomposition into $uxwyv$, for some u, v, w, x, y in Σ^*, where $|xwy| < p$, $|xy| \geq 1$, and such that $ux^i wy^i v$ is in $L(G)$, for all $i \geq 0$.

Hence, to obtain a contradiction, we need to show that no such decomposition exists. To this end consider where the subword xwy falls in z. There are two cases to consider.
(i) xwy is in $[a \cup b]^*$.
(ii) xwy is in $[a \cup b]^* c [a \cup b]^*$.
Case (i) leads to an immediate contradiction by considering the word $ux^0wy^0v = uwv$. Because, xwy does not contain a c, it falls either to the left or to the right of the c in z. But, this implies that uwv has shrunk with respect to z either to the left or to the right of c; that is, uwv is not in $L(G)$.

In Case (ii), if c appears in either x or y, then uwv does not contain a c and, therefore, is not in $L(G)$. Otherwise, if c appears in w, because of the restriction on the lengths of x and y, x is in b^* and y is in a^*. Immediately, uwv is not in $L(G)$, once more.
p. 394, Example 8.2.3. Renumber it Example 8.2.4.
p. 395, l. 10. Replace "lemma." by "lemma that is phrased in terms of derivations because this is more useful.
p. 395, l. 21. Replace "...we have..." by "...we can obtain..."
p. 404, l. 15. Replace "But x_k is in ..." by "But, x_k in ..."
p. 404, l. 17. Replace "But x_k is not in ..." by "But, x_k not in ..."
p. 406, l. 23. Replace "where...where" by "where".
p. 409, Exercise 2.3(ii). Replace "...$= \emptyset$ and ..." by "...$= \emptyset$. Its language is..."

11 Chapter 9

p. 412, l. 22. Replace "classical" with "classic".

12 Chapter 10

p. 446, l. 10. Replace "...machines,..." by "...machines or *dmDTMs*,..."
p. 449, l. 16. Replace ...some *DTM*..." by "...some *dmDTM*..."
p. 449, l. 26. Replace "...*DTM*," by "...*dmDTM*,"
p. 450, l. 17. Replace "*if for*..." by "*if, for*..."
p. 453, l. 10. Replace "...some *DTM*," by "...some *dmDTM*,"
p. 453, l. 11. Replace "...a *DTM*..." by "...a *dmDTM*..."
p. 453, l. 23. Replace "...any *DTM*..." by "...any *dmDTM*..."
p. 453, l. 24. Replace "...any *DTM*..." by "...any *dmDTM*..."
p. 453, l. 32. Replace "...some *DTM*..." by "...some *dmDTM*..."
p. 453, l. 33. Replace "*DTM*..." by "*dmDTM*..."
p. 454, l. 2. Replace "...for some encoding of" by "...for".
p. 454, l. 19. Replace "...a *DTM*..." by "...a *dmDTM*..."

13 Chapter 11

p. 524, l. 23. Replace "...(1987) ..." by "...(1988) ...".

14 Bibliography

p. 544, l. 34. Replace "*Parsing Theory*,...1987." by "*Parsing Theory: Volume I: Languages and Parsing*,...1988."

15 Index

p. 550, l. 15. Add the new entry "*dmDTM* 291" after this line.