Corrections to

Discrete Fourier and Wavelet Transforms:
An Introduction through Linear Algebra
with Applications to Signal Processing
by Roe W. Goodman

Revised February 3, 2017
A negative line number means measured from the bottom, not including footnotes.

p. 9 l. -6: change $u_2 = \begin{bmatrix} 0 & 1 \\ -3 \end{bmatrix}$ to $u_2 = \begin{bmatrix} 0 & 1 \\ -3 \end{bmatrix}$

p. 11 l. 1 of §1.5.1: change $v_m$ to $v_n$

p. 23 l. 5 right side of equation: change to $2|\alpha|^2|f[n]|^2 + 2|\beta|^2|g[n]|^2$

p. 26 l. 9: change $u$ to $w$ (twice)

p. 46, line after equation (2.7): change For $N = 4$ we have $w = e^{2\pi i/4} = i$ to For $N = 4$ we have $\omega = e^{2\pi i/4} = i$

p. 46 l. -4: change right side to $N[d_0 d_1 \ldots d_{N-1}]^T$

p. 47 equation (2.10): change middle term to $N(d_0 E_0 + d_1 E_1 + \cdots + d_{N-1} E_{N-1})$

p. 55 4th line of Remark 2.3: change $y[k]$ to $\hat{y}[k]$

p. 57 l. -3: change $+i(1-c^2)/4$ to $-i(1-c^2)/4$

p. 57 l. -1: change $z[k] = 2c^2 \sin(3k\pi/4) + \frac{1-c^2}{2}\sin(9k\pi/4)$

p. 61 equation (2.31): change the index range to $j = 0, \ldots, m - 1$

p. 63 lines 3,4 of (b): change to can be downloaded or added as a MATLAB toolbox from

http://www.mathworks.com/moler/chapters

p. 71 (3)(c): change Definition 2.27 to Definition 2.5

p. 80, equation (3.3): change $T_s^{(k)} = \begin{bmatrix} I^{(k-1)} & I^{(k-1)} \\ I^{(k-1)} & -I^{(k-1)} \end{bmatrix}$ split

p. 90, formula (3.24): change $P = \begin{bmatrix} I \\ -(1/4)(\sqrt{3}I - (\sqrt{3} - 2)S) \end{bmatrix}$.
\[
P = \begin{bmatrix}
I & 0 \\
-(1/4)(\sqrt{3}I + (\sqrt{3} - 2)S) & I
\end{bmatrix}.
\]

p. 91 3rd line of the proof of Theorem 3.1: Change the matrix on the right to

\[
\begin{bmatrix}
(aI + cS) & -(bI + dS^{-1}) \\
(bI + dS) & (aI + cS^{-1})
\end{bmatrix}
\]

p. 94 l. -2, second row of matrix: Change \(z\) to \(z^{-1}\) (two changes).

p. 95 l. -7: Add missing left parenthesis to get

\[
d^{(1)}[n] = x_{\text{odd}}[n] - ((9/8)I + (3/8)S^{(-1)})s^{(1)}
\]

p. 99 l. -4: Change Section 2.4 to Section 2.5.

p. 103 After l. 4: In row 6 of \(x_s\), change the number 5 to 5.5.

p. 105 (3.47): In the formulas for \(U_3\) and \(V_3\) each \(1/2\) should be \(1/8\) and in the formula for \(V_2\) each \(1/2\) should be \(1/4\).

p. 106 l. -5: Change \(S_{(k-1)}\) to \(S_{(j-1)}\).

p. 109 l. 4: Change contained in 11 of the 64 coefficients to contained in 12 of the 64 coefficients.

p. 119, l. -9: Before We define the mean square error insert

For a matrix \(A = [a_{ij}]\) we define the norm (more precisely, the Frobenius norm) of \(A\) to be \(\|A\| = \left\{\sum_{i,j}|a_{ij}|^2\right\}^{1/2}\). When \(A\) is a row vector or a column vector, this is the same definition as in Section 1.7. In general, the Frobenius norm of a matrix \(A\) of size \(M \times N\) is the same as the norm of the column vector \(u\) of size \(MN \times 1\) obtained by concatenating the columns of \(A\). In MATLAB \(\|A\|\) is calculated by the command \(\text{norm}(A, 'fro')\).

p. 119, l. -5, -4, -3: Change for the round-wavy image we calculate that MSE = 0.008, while for the kitten image MSE = 0.695. The MSE for the compressed kitten image is about 85 times larger than the MSE for the compressed synthetic image to for the round-wavy image we calculate that MSE = 0.222, while for the kitten image MSE = 17.1. The MSE for the compressed kitten image is about 77 times larger than the MSE for the compressed synthetic image.

p. 120, l. 8, 9: Change For the round-wavy image we calculate that PSNR = 69.0, while for the kitten image PSNR = 49.7. To For the round-wavy image we calculate that PSNR = 54.7, while for the kitten image PSNR = 35.8.
p. 123 l. 20:  CHANGE  You should get the same matrix as in Example 3.12
TO  You should get the analysis matrix in Example 3.12 multiplied by $1/(4\sqrt{2}) = 0.1767\ldots$

p. 123 l. -11:  CHANGE  From (3.58)  TO  From (3.19)

p. 124 lines 18, 19:  CHANGE
Ts = cdfsmat(8), norm(Ts*Ta - eye(8))
You should get the same matrix as in Example 3.12
TO
Ts = cdfsmat(8), norm(Ts*Ta - eye(8), 'fro'))
The matrix Ts should be the synthesis matrix in Example 3.12 multiplied by $4\sqrt{2}$, and the
norm value should be (essentially) zero.

p. 126 lines 2-4:  CHANGE
Check this property by setting Ts = Ta' and calculating the distance

$$\text{norm}(Ta*Ta' - eye(8))$$

between $T_sT_a$ and the identity matrix.
TO
Check this property by calculating

$$\text{norm}(Ta*Ta' - eye(8), 'fro'))$$

(the distance between $T_sT_a^T$ and the identity matrix). This norm value should be (essentially)
zero.

p. 126 line -12:  CHANGE  norm(Wa*Wa' - eye(8))
TO  norm(Wa*Wa' - eye(8), 'fro')

p. 130 Section 3.7.5 (a) l. 9 of the m-file:  MOVE
s1shift = [s1(N/2)
TO BEGINNING OF NEXT LINE
p. 130 Section 3.7.5 (a) l. 12 of the m-file:  end the line with semicolon ;
p. 130 Section 3.7.5 (a) Next to last line of the m-file:  MOVE
d = (sqrt(3)+1)/sqrt(2)*d1;
TO NEW LINE

p. 138 Exercise 7 (b):  CHANGE EQUATION TO

$$\begin{bmatrix} s^{(1)} \\ d^{(1)} \end{bmatrix} = U \begin{bmatrix} x_{\text{even}} \\ d^{(1)} \end{bmatrix}$$

p. 138 (9) l. 2  CHANGE  equations (3.42)
TO  equations (3.42) with $S_8$ replaced by $S_N$ and $k = 0,\ldots,N-1$.

p. 147 l. 4:  CHANGE  $Tx$  TO  $Hx$

p. 152, Proposition 4.1:  CHANGE
Let $u = [h[0] \ h[1] \cdots \ h[L-1] \ 0 \cdots 0]$ be the $1 \times M$ row vector consisting of the
filter coefficients padded by zeros.
Let $u = [h[0] \ 0 \ \cdots \ 0 \ h[L-1] \ h[L-2] \ \cdots \ h[1]]$ be the $1 \times M$ row vector consisting of the shifted and reversed filter coefficients padded by zeros as indicated.

p. 152, proof of Proposition 4.1: CHANGE
This follows immediately from (4.19), as in the proof of Theorem 3.2.

TO
Consider the $M$-periodic signals $x_p = (\delta_p)_{p \in \mathbb{Z}}$, for $p = 0, 1, \ldots, M-1$. Then $P_M x_p$ is the standard basis vector $e_p$ for $\mathbb{R}^M$, for $p = 0, 1, \ldots, M-1$. Thus we obtain columns $1, 2, \ldots, M$ of the matrix $U$ by calculating the vectors $P_M/2 \cdot T_x p$. Assume that $k = 0, 1, \ldots, M/2 - 1$. Then the value $T_x p[k]$ is the entry in row $k+1$ and column $p+1$ of $U$. From formula (4.19) we have

$$T_x p[k] = \sum_{0 \leq j \leq M-1} h[j].$$

There is only one term in this summation for each value of $k$. For $k = 0$, this term occurs with $j = 0$ if $p = 0$ and $j = M - p$ if $1 \leq p \leq M - 1$. Thus the first row of $U$ is

$$u = [h[0] \ h[M-1] \ h[M-2] \ \cdots \ h[1]] = [h[0] \ 0 \ \cdots \ 0 \ h[L-1] \ h[L-2] \ \cdots \ h[1]].$$

The successive rows of $U$ are obtained by shifting the vector $u$ to the right two positions (with wraparound), since the relation $2k - j \equiv p \mod M$ is the same as $2(k+1) - j \equiv p+2 \mod M$ (compare with the proof of Theorem 3.2).

p. 152, Example 4.6: CHANGE


Notice the wrap-around that occurs on the last row.

TO


Notice the wrap-around in the second, third, and fourth rows..

p. 152 l. 4 of Theorem 4.4: CHANGE $\omega_N = e^{2\pi ki/N}$ TO $\omega_N = e^{2\pi i/N}$

p. 170 l. 4 CHANGE $x^2(x + 3y) + y^2(1 + 3x)$ TO $x^2(x + 3y) + y^2(y + 3x)$

p. 170 l. 6 CHANGE $x^3(1 + 5xy + 10y^2) + y^3(1 + 5xy + 10x^2)$ TO $x^3(1 + 5xy + 10y^2) + y^3(10x^2 + 5xy + y^2)$

p. 172, Example 4.16: CHANGE $g_0 = \frac{\sqrt{2}}{8} (\delta_{-3} + 3\delta_{-2} + 3\delta_1 + \delta_0)$
TO \( g_0 = \frac{\sqrt{2}}{5} (\delta_{-3} + 3\delta_{-2} + 3\delta_{-1} + \delta_0) \)

p. 175 last line of Section 4.5: CHANGE Exercise 4.12 #13 TO Exercise 4.12 #11

p. 192 l. 6: The right side should be \(-\frac{1}{2} \ldots\) (with a small space after the minus sign)

p. 192 l. -1 CHANGE TO

\[
4\sqrt{2}H_1(z) = -b - dz^{-2} + z(a + cz^{-2}) = az - b + cz^{-1} - dz^{-2} \\
= 4\sqrt{2}z^{-2}H_1(z^{-1})
\]

p. 195 Section 4.11.1 end of line 10 and line 11 of (a): CHANGE +1.5 TO +1

p. 197 Section 4.11.2 (a): end the first line of code with semicolon ;

p. 200 Section 4.11.3 (c): CHANGE measured by the Mean Square Error (MSE):

\[
\text{MSE} = \frac{(\text{norm}(X_1 - X_2)^2)}{2^{16}}
\]

TO measured by the Mean Square Error (MSE):

\[
\text{MSE} = \frac{(\text{norm}(X_1 - X_2, 'fro')^2)}{2^{16}}
\]

(see Section 3.6.4).

p. 203 Section 4.11.4 (a): CHANGE Calculate norm(X) and norm(Y). TO Calculate norm(X, 'fro') and norm(Y, 'fro').

p. 204 l. 9: CHANGE idea conditions TO ideal conditions

p. 204 l. 15, 16: CHANGE random normal integers (with mean zero, standard deviation 50) TO random integers (the integer parts of independent normal random variables with mean zero, standard deviation 50)

p. 258 lines 4-7 of Section A.3.1 CHANGE click on Desktop Environment, and run the playback files \ldots TO Click on Getting started with MATLAB and run the video. Then click on Language Fundamentals. Now click on Basic Matrix Operations, then click on Matrix Manipulation.

p. 258 l. -1: CHANGE C TO B

p. 266 Exercise (4)(b): CHANGE Theorem 2.29 TO Equation (2.29)

p. 267 Exercise (5)(c): CHANGE TO \( \lambda_2 = \cdots = 4 + 7\omega^{-2} + 5\omega^{-1} \)

p. 270 Exercise (11) (a): CHANGE THIRD ROW IN \( \mathbf{T}_a \) TO \([-2 \ 0 \ 0 \ -2 \ 6 \ 6] \)

p. 271 Exercise (11) (c): CHANGE BOTTOM ENTRY IN FINAL FORMULA FOR \( x_s \) TO 12
p. 272 Exercise (15) (d): change values to $\text{MSE} = 0.1875$ and $\text{PSNR} = 55.40$

p. 274 Exercise (4)(b) change formulas to
\[ G_0(z) = -z^{-1}H_1(-z) = -z^{-1}(1 + z)(1 - bz) = -z^{-1} + (b - 1) + bz \]
\[ g_0 = -\delta_1 + (b - 1)\delta_0 + b\delta_{-1} \]

p. 274 Exercise (5) (a) change formula to
\[ f(z) = (4 - b) + (4 - 6b + 4c)z^2 + (4c - b)z^4 \]
change answers to
Case i. $b = 4/5$, $c = 1/5$, and $H_1(z) = (1 - z)(5 + 4z + z^2)/5$
Case ii. $b = 4$, $c = 1$, and $H_1(z) = (1 - z)(1 + 4z + z^2)$
Case iii. $b = 4$, $c = 5$, and $H_1(z) = (1 - z)(1 + 4z + 5z^2)$

p. 274 Exercise (5) (b): change formula to
\[ G_0(z) = -z^{-1}H_1(-z) \]
change answers to
Case i. $b = 4/5$, $c = 1/5$, and
\[ G_0(z) = -z^{-1}(1 + z)(5 - 4z + z^2)/5 \]
Case ii. $b = 4$, $c = 1$, and
\[ G_0(z) = -z^{-1}(1 + z)(1 - 4z + z^2) \]
Case iii. $b = 4$, $c = 5$, and
\[ G_0(z) = -z^{-1}(1 - z)(1 - 4z + 5z^2) \]