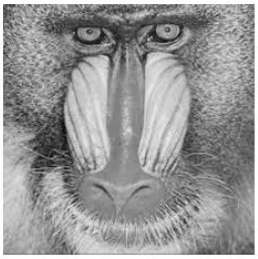
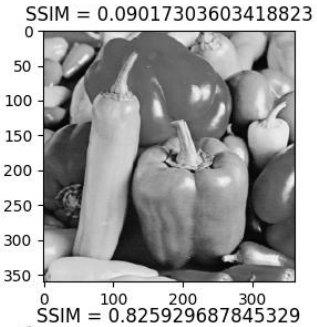
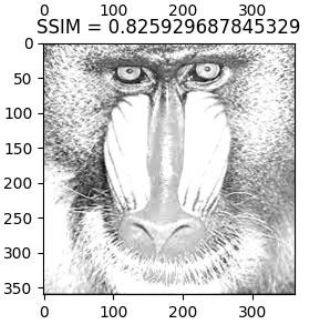
ADSP HW4 P10942A05 鄭閔軒

1. SSIM Result







(2)

$$X[m] = \sum_{n=0}^{4} \cos\left(\frac{\pi}{5} m \left(n+\frac{1}{2}\right)\right) x[n] \qquad \begin{matrix} n=0,1,2,3,4 \\ m=0,1,2,3,4 \end{matrix}$$

5 point DCT with the least number of nontrivial multiplication

	n=0	n=1	n=2	n=3	n=4
m=0	1	1	1	1	1
m=1	$\cos(\frac{\pi}{10})$ 18	$\cos\frac{3}{10}\pi$ 54	$\cos\frac{5}{10}\pi$ 90	$\cos\frac{7}{10}\pi$ 126	$\cos\frac{9}{10}\pi$ 162
m=2	$\cos(\frac{3}{10}\pi)$ 36	$\cos\frac{3}{5}\pi$ 108	$\cos\pi$ 180	$\cos\frac{7}{5}\pi$ 252	$\cos\frac{9}{5}\pi$ 324
m=3	$\cos(\frac{3}{10}\pi)$ 54	$\cos\frac{9}{10}\pi$ 162	$\cos\frac{3}{2}\pi$ 270	$\cos\frac{21}{10}\pi$ 18	$\cos\frac{27}{10}\pi$ 126
m=4	$\cos(\frac{4}{10}\pi)$ 72	$\cos\frac{6}{5}\pi$ 216	$\cos 2\pi$ 0	$\cos\frac{14}{5}\pi$ 144	$\cos\frac{18}{5}\pi$ 288

$a = \cos 18°$

$b = \cos 54°$

$c = \cos 36°$

$d = \cos 72°$

$$\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 18° & 54° & 0 & -(54°) & -(18°) \\ 36° & 108° & -1 & 108° & 36° \\ 54° & -(18°) & 0 & 18° & -(54°) \\ 72° & 144° & 1 & 144° & 72° \end{bmatrix} \qquad \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ a & b & 0 & -b & -a \\ c & -d & -1 & -d & c \\ b & -a & 0 & a & -b \\ d & -c & 1 & -c & d \end{bmatrix} \begin{bmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix}$$

$$\begin{bmatrix} a & b & -b & -a \\ c & -d & -d & c \\ b & -a & a & -b \\ d & -c & -c & d \end{bmatrix} \begin{bmatrix} x_0 \\ x_1 \\ x_3 \\ x_4 \end{bmatrix}$$

$$\begin{bmatrix} z_1 \\ z_2 \end{bmatrix} = \begin{bmatrix} a & b \\ b & -a \end{bmatrix} \begin{bmatrix} x_0 - x_4 \\ x_1 - x_3 \end{bmatrix} = \begin{bmatrix} b & b \\ b & b \end{bmatrix} \begin{bmatrix} \alpha \\ \beta \end{bmatrix} + \begin{bmatrix} a-b & 0 \\ 0 & -a-b \end{bmatrix} \begin{bmatrix} \alpha \\ \beta \end{bmatrix} \quad \underline{3 \text{ muls}}$$

$$\begin{bmatrix} z_3 \\ z_4 \end{bmatrix} = \begin{bmatrix} c & d \\ d & c \end{bmatrix} \begin{bmatrix} x_0 + x_4 \\ -x_1 - x_3 \end{bmatrix} = 2 \text{ muls}$$

$3 + 2 = 5$ multiplications #

3. x is complex number

$e^{j\theta} = \cos\theta + j\sin\theta$

If $c + jd = \exp(j\theta)$ $c = \cos\theta$ $d = \sin\theta$

$$\begin{bmatrix} c & -d \\ d & c \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix}$$

when $\theta = \frac{\pi}{4}$ $\begin{bmatrix} \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} + \begin{bmatrix} 0 & -\frac{2}{\sqrt{2}} \\ 0 & 0 \end{bmatrix}$

Include $(45 \times N)^\circ$ which $N = 1, 3, 5$ (odd number)

且 $\theta = \begin{cases} \cos^{-1}\left(\frac{1}{2^n}\right) & n \in z \\ \sin^{-1}\left(\frac{1}{2^n}\right) & n \in z \end{cases}$ 能夠藉由 bitwise operation

求解其中一對角之值

4.

220 , 231 , 245

(1) 220 points $2^2 \times 5 \times 11$

$MUL_{220} = 55\,MUL_4 + 4\,MUL_{55}$

$= 55\,MUL_4 + 4(11\,MUL_5 + 5\,MUL_{11})$

$= 4 \times (\overset{110}{11 \times 10} + \overset{20}{5 \times 40})$

$= \underline{1240}$ #

(2) 231 points

$11 \times 3 \times 7$

$MUL_{231} = 77\,MUL_3 + 3(11\,MUL_7 + 7\,MUL_{11})$

$= 77 \times 2 + 3(\overset{176+280}{11 \times 16 + 7 \times 40})$

$= 154 + 1368 = \underline{1522}$ #

(3) 245 points

$MUL_{245} = 49\,MUL_5 + 5\,MUL_{49}$

$= 49 \times 10 + 5(\overset{112}{7\,MUL_{16}} + \overset{112}{7\,MUL_{16}} + \overset{108}{3 \times 6 \times 6})$

$= 490 + 1660 = \underline{2150}$ #

5.

1. $O(n)$ computation complexity

2. fixed hardware architecture

(Only p-point DFT is required P is fixed

6.

$x_s[n] = x[n] * h[n]$ $h[1] = h[-1] = 0.24$ $h[2] = h[-2] = 0.06$

$h[3] = h[-3] = 0.03$ $h[0] = 0.34$ $h[n] = 0$ otherwise

$$x_s[n] = x[n] * h[n] = \sum_m x[n-m]\, h[m]$$

$$= 0.34\,x[0] + 0.03\,[\,8(h[1]+h[-1]) + 2(h[2]+h[-2]) + (h[3]+h[-3])\,]$$

We only need 2 MUL. bitwise operation

in $n = \pm 1, \pm 2, \pm 3$ and combine them to reduce numbers of multiplication.

7. $len(x[n]) = 1100$ $N+M-1$

(a) $length(y[n]) = 200$ $3N/M$

$P \geq 1299$ $MUL_{1344} = 252$

$\geq MUL_{1344} + 3 \times 1344 = 165044032$

$= 20536$ #

(b) $length(y[n]) = 20$

$S = ceil(N/L)$ $P \geq L+M-1$

$N = 1100$
$M = 20$
$L_0 = 105$
$P_0 = 124$

① $P = 120$
$L = 101$
$S = \frac{N}{L} = 11$

$25 \times MUL_{120} + 35 \times 120$
$= 22 \times 380 + 33 \times 120$
$= 8360 + 3960 = 12320$

② $P = 84$
$L = 65$
$S = 17$

$34 \times 248 + 51 \times 84$
$= 8432 + 4284$
$= 12716$

③ $P = 72$
$L = 53$
$S = 21$

$42 \times 164 + 63 \times 72$
$= 6888 + 4536$
$= 11424$ #

④ $P = 48$
$L = 29$
$S = 38$

$76 \times 92 + 114 \times 72$

P=16/24/28/36

(c) length(y[n]) = 7 N=1100 M=7 L.=25 P.=31

① P=36 74x64+111x36
L=30 =4736+3996
S=N/L=37 =8732

② P=28 100x64+150x28
L=22
S=50

③ P=24 124x28+186x24
L=18 =3472+4464
S=62 =7936 #

(d) length(y[n])=2

3xMxN = 3x2x1100 = 6600 #

Bonus 0.5

N=256 M=50 P=312≥305

We use 312-Point