# 2021 Spring VLSI DSP Homework Assignment #2

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a) *For a 256×256 gray scale image (will be provided from the course web site), please conduct a 2-D 3-level DWT transform (as shown in Figure 1) and show the transformed result. Then conduct a 2-D 3-level IDWT to convert it back. Please compare if the reconstructed image (after IDWT) is same as the original image*

Ans :

輸入 Lenna.dat 輸入後，將 LowPass Filter 與 HighPass Filter，輸入分別為 h 和 g。因需要使用 9/7 的 Linear Phase Filter，因此自己建構了 dwt 的 function（如圖一，my_dwt function)。再依照題目進行 3-level dwt。得到圖二。

```
function [cA, cH, cV, cD] = my_dwt(image, h, g)
    Li = filter_operation(image, h, 2);
    Hi = filter_operation(image, g, 2);

    Li = dyaddown(Li,1); %odd downsample for LOW
    Hi = dyaddown(Hi,0); %even downsample for HIGH

    cA = filter_operation(Li, h, 1);
    cH = filter_operation(Li, g, 1);
    cV = filter_operation(Hi, h, 1);
    cD = filter_operation(Hi, g, 1);

    cA = dyaddown(cA,1, 'r'); %odd downsample for LOW
    cH = dyaddown(cH,0, 'r'); %even downsample for HIGH
    cV = dyaddown(cV,1, 'r'); %odd downsample for LOW
    cD = dyaddown(cD,0, 'r'); %even downsample for HIGH

    cA = double(cA);
    cH = double(cH);
    cV = double(cV);
    cD = double(cD);
end
```

（圖一）自己撰寫的 **dwt function**

（圖二）左圖為原圖，右圖為 dwt 後的放大圖

再進行 idwt（如圖三，my_idwt function），將原本的壓縮後的圖轉回原本的型態，結果於圖四。

```
function x = my_idwt(ca, ch, cv, cd, h, g)
    ca = double(ca);
    ch = double(ch);
    cv = double(cv);
    cd = double(cd);

    %odd upsample for row
    ca = dyadup(ca, 1, 'r');
    ch = dyadup(ch, 1, 'r');
    cv = dyadup(cv, 1, 'r');
    cd = dyadup(cd, 1, 'r');

    ca = filter_operation(ca, h, 2);
    ch = filter_operation(ch, g, 2);
    cv = filter_operation(cv, h, 2);
    cd = filter_operation(cd, g, 2);

    c1 = ca + ch;
    c2 = cv + cd;

    c1 = dyadup(c1, 1, 'c');
    c2 = dyadup(c2, 1, 'c');

    c1 = filter_operation(c1, h, 1);
    c2 = filter_operation(c2, g, 1);

    x = c1 + c2;
end
```

（圖三）自己撰寫的 idwt function

（圖四）左圖為原圖，右圖為 **idwt** 後結果

*b) By setting all three level 1 sub-bands HL1, LH1 and HH1 coefficients to zeros and perform IDWT. See how the reconstructed image different from the original one*

（圖五）左圖為原圖，右圖為將所有係數設為 **0** 的 **idwt** 後結果

c) *please conduct fixed point simulations to determine the DWT word length for the following items. Assume a floating point version IDWT is used, the PSNR (peak signal to noise ratio) of the reconstructed image should be no less than 40dB. Please use as small word length as possible to achieve this goal.*

我將原本dwt function改成寫圖七的部分，可以使原本的dwt資料格式改成fixed point格式。

```
%part c
[cA0, cH0, cV0, cD0] = my_dwt(image, h, g, 1, 8);
[cA1, cH1, cV1, cD1] = my_dwt(cA0, h, g, 1, 8);
[cA2, cH2, cV2, cD2] = my_dwt(cA1, h, g, 1, 8);
```

（圖六）此自己撰寫之 **dwt** 可使用 **fixed point** 格式

```
function [cA, cH, cV, cD] = my_dwt(image, h, g, fixed_mode, length)
    if nargin<4
        fixed_mode = 0;
        length = 0;
    elseif nargin<5
        length = 8;
    end

    if fixed_mode == 1
        image = fi(image, 1, length);
    end

    Li = filter_operation(image, h, 2);
    Hi = filter_operation(image, g, 2);

    if fixed_mode == 1
        Li = fi(Li, 1, length);
        Hi = fi(Hi, 1, length);
    end

    Li = dyaddown(Li,1); %odd downsample for LOW
    Hi = dyaddown(Hi,0); %even downsample for HIGH

    cA = filter_operation(Li, h, 1);
    cH = filter_operation(Li, g, 1);
    cV = filter_operation(Hi, h, 1);
    cD = filter_operation(Hi, g, 1);

    if fixed_mode == 1
        cA = fi(cA, 1, length);
        cH = fi(cA, 1, length);
        cV = fi(cA, 1, length);
        cD = fi(cA, 1, length);
    end


     cA = dyaddown(cA,1, 'r'); %odd downsample for LOW
     cH = dyaddown(cH,0, 'r'); %even downsample for HIGH
     cV = dyaddown(cV,1, 'r'); %odd downsample for LOW
     cD = dyaddown(cD,0, 'r'); %even downsample for HIGH

     cA = double(cA);
     cH = double(cH);
     cV = double(cV);
     cD = double(cD);
end
```

（圖七）此自己撰寫之 **dwt** 可使用 **fixed point** 格式

結果約略再8 fixed point 可以符合40左右的PSNR。

```
The Question for 8 fixed point PSNR value is 40.9613
```

下圖圖八為使用 8 fixed-point PSNR 的結果。

（圖八）左圖為原圖，右圖為 **8 fixed-point** 結果

但是若使用4 fixed point 卻只能得到17.62的PSNR。

（圖九）左圖為原圖，右圖為 **4 fixed-point** 結果