**高等影像處理**

**作業#5**

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| **1.1** |
| Figure |
| |  | | --- | |  | | dft\_lena.png | |  | | dft\_baboon.png | |
| Discussion |
| 可以在lena的頻譜圖上看到比baboon多了兩個明顯斜的，整體而言更為集中，我這次DFT採用兩個1D的DFT變成2D DFT，比起直接用2DDFT會快上不少，並且利用公式進行平移，並在最後除以pixel數量並把虛部、實部取平方合開根號，最後四捨五入\*255，在contrast enhancement則是採用log的方式。 |

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| **1.2** |
| Figure |
| |  | | --- | |  | | idft\_lena.png | |  | | idft\_baboon.png | |  | |
| Discussion |
| IDFT的結果可以發現兩張圖與原圖完全一樣，MSE=0，PSNR都無限大，因此可以驗證得知DFT、IDFT的正確性，一開始錯拿SPECTRUM的圖去做IDFT讓結果一直顯示錯誤，後來才發現問題並改用虛數、實數對進行IDFT，IDFT則是採用兩個1D，因傳入的虛數、實數對尚未/pixel數量，因此需要在最後除以pixel數量並把虛部、實部取平方合開根號。 |

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| **1.3** |
| Figure |
| 手刻結果      Opencv結果   |  | | --- | |  | | cv\_dft\_lena.png | |  | | cv\_dft\_baboon.png | |
| Discussion |
| 上方為自己手刻版本的2個1D DFT，opencv的DFT可以明顯看出0.029秒比49秒快上許多，看了一下opencv的document可以發現opencv的DFT實際上是運行FFT，加上利用了multi-thread 進行優化，可以讓電腦更好的發揮出自己的效能， magnitude spectrum results也一樣，差別就在於運算時間。 |

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| **1.4** |
| Figure |
| 手刻結果      Opencv結果     |  | | --- | |  | | cv\_idft\_lena.png | |  | | cv\_idft\_baboon.png | |
| Discussion |
| 可以發現執行時間上opencv的0.02秒比己自己手刻版本的26秒快上許多，可能原因與上一題類似，演算法的優化、效能優化都是關鍵，而而MSE與PSNR與自己的手刻版本一樣，差別就在於運算時間。 |
| **1.5** |
| Figure |
| |  | | --- | |  | | dct\_lena.png | |  | | dct\_baboon.png | |
| Discussion |
| 延續之期的思路，DCT也是採用兩個1D組成，但這次少了虛部、實部的問題，可以用一個實數來解決，只需要在最後把計算結果取絕對值並四捨五入。 |

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| **1.6** |
| Figure |
| |  | | --- | |  | | idct\_lena.png | |  | | idct\_baboon.png | |
| Discussion |
| 可以發現IDCT的結果也可以完全還原成原圖，MSE=0,PSNR=inf，因此也算得上是一個優良的演算法，依據上圖公式，只需在最後再取絕對值即可。 |

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| **1.7** |
| Discussion |
| 可以發現在DFT會有實數、虛數，而DCT僅有實數，雖然兩者的計算時間在手刻版本中由DFT勝出，但是計算量尚有許多優化空間EX:DP技巧、multi-threads等等，玵在圖像壓縮中，bit rate是表示數據量的一個重要指標。由於DCT在能量集中和視覺特性上的優勢，它通常能夠以較低的bit rate實現相當於或更好於DFT的壓縮效果。這種bit rate的節省意味著在相同的壓縮比下，使用DCT進行圖像壓縮可以得到更小的數據文件，更適合在有限的儲存或傳輸帶寬條件下應用 |

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| **2.1** |
| Figure |
| |  |  |  | | --- | --- | --- | | High pass filter without origin shifting | | | | D | image | spectrum | | 10 | HPF\_D0\_10.000000\_IMG.png | HPF\_D0\_10.000000\_SPRCTRUM.png | | 20 | HPF\_D0\_20.000000\_IMG.png | HPF\_D0\_20.000000\_ SPRCTRUM.png | | 40 | HPF\_D0\_40.000000\_IMG.png | HPF\_D0\_40.000000\_ SPRCTRUM.png | | 100 | HPF\_D0\_100.000000\_IMG.png | HPF\_D0\_100.000000\_ SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | High pass filter with origin shifting | | | | D | image | spectrum | | 10 | ORIGIN\_HPF\_D0\_IMG10.000000\_IMG.png | ORIGIN\_HPF\_D0\_10.000000\_SPRCTRUM.png | | 20 | ORIGIN\_HPF\_D0\_IMG20.000000\_IMG.png | ORIGIN\_HPF\_D0\_20.000000\_SPRCTRUM.png | | 40 | ORIGIN\_HPF\_D0\_IMG40.000000\_IMG.png | ORIGIN\_HPF\_D0\_40.000000\_SPRCTRUM.png | | 100 | ORIGIN\_HPF\_D0\_IMG100.000000\_IMG.png | ORIGIN\_HPF\_D0\_100.000000\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | Low pass filter without origin shifting | | | | D | image | spectrum | | 10 | LPF\_D0\_10.000000\_IMG.png | LPF\_D0\_10.000000\_SPRCTRUM.png | | 20 | LPF\_D0\_20.000000\_IMG.png | LPF\_D0\_20.000000\_SPRCTRUM.png | | 40 | LPF\_D0\_40.000000\_IMG.png | LPF\_D0\_40.000000\_SPRCTRUM.png | | 100 | LPF\_D0\_100.000000\_IMG.png | LPF\_D0\_100.000000\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | Low pass filter with origin shifting | | | | D | image | spectrum | | 10 | ORIGIN\_LPF\_D0\_10.000000\_IMG.png | ORIGIN\_LPF\_D0\_10.000000\_SPRCTRUM.png | | 20 | ORIGIN\_LPF\_D0\_20.000000\_IMG.png | ORIGIN\_LPF\_D0\_20.000000\_SPRCTRUM.png | | 40 | ORIGIN\_LPF\_D0\_40.000000\_IMG.png | ORIGIN\_LPF\_D0\_40.000000\_SPRCTRUM.png | | 100 | ORIGIN\_LPF\_D0\_100.000000\_IMG.png | ORIGIN\_LPF\_D0\_100.000000\_SPRCTRUM.png | |
| Discussion |
| 可以看到沒有做Origin shifting的版本不論是HPF或是LPF都顯得很怪異因為作用在高頻上所以跟我們的預期結果會相反，HPT幾乎不受到模糊影響，LPF則幾乎完全看不到資訊，而經過origin shifting的可以發現D越大LPF細節越多，HPF則越來越模糊，因此題圖片數量較多另有開資料夾在image\_file中的gaussian內。。 |

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| **2.2** |
| Figure |
| |  |  |  | | --- | --- | --- | | High pass filter without origin shifting n=1 | | | | D | image | spectrum | | 10 | Butterworth\_HPF\_D0\_10\_n\_1.png | HPF\_D0\_10\_n\_1\_SPRCTRUM.png | | 20 | Butterworth\_HPF\_D0\_20\_n\_1.png | HPF\_D0\_20\_n\_1\_SPRCTRUM.png | | 40 | Butterworth\_HPF\_D0\_40\_n\_1.png | HPF\_D0\_40\_n\_1\_SPRCTRUM.png | | 100 | Butterworth\_HPF\_D0\_100\_n\_1.png | HPF\_D0\_100\_n\_1\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | High pass filter without origin shifting n=2 | | | | D | image | spectrum | | 10 | Butterworth\_HPF\_D0\_10\_n\_2.png | HPF\_D0\_10\_n\_2\_SPRCTRUM.png | | 20 | Butterworth\_HPF\_D0\_20\_n\_2.png | HPF\_D0\_20\_n\_2\_SPRCTRUM.png | | 40 | Butterworth\_HPF\_D0\_40\_n\_2.png | HPF\_D0\_40\_n\_2\_SPRCTRUM.png | | 100 | Butterworth\_HPF\_D0\_100\_n\_2.png | HPF\_D0\_100\_n\_2\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | High pass filter without origin shifting n=3 | | | | D | image | spectrum | | 10 | Butterworth\_HPF\_D0\_10\_n\_3.png | HPF\_D0\_10\_n\_3\_SPRCTRUM.png | | 20 | Butterworth\_HPF\_D0\_20\_n\_3.png | HPF\_D0\_20\_n\_3\_SPRCTRUM.png | | 40 | Butterworth\_HPF\_D0\_40\_n\_3.png | HPF\_D0\_40\_n\_3\_SPRCTRUM.png | | 100 | Butterworth\_HPF\_D0\_100\_n\_3.png | HPF\_D0\_100\_n\_3\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | High pass filter without origin shifting n=4 | | | | D | image | spectrum | | 10 | Butterworth\_HPF\_D0\_10\_n\_4.png | HPF\_D0\_10\_n\_4\_SPRCTRUM.png | | 20 | Butterworth\_HPF\_D0\_20\_n\_4.png | HPF\_D0\_20\_n\_4\_SPRCTRUM.png | | 40 | Butterworth\_HPF\_D0\_40\_n\_4.png | HPF\_D0\_40\_n\_4\_SPRCTRUM.png | | 100 | Butterworth\_HPF\_D0\_100\_n\_4.png | HPF\_D0\_100\_n\_4\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | Low pass filter without origin shifting n=1 | | | | D | image | spectrum | | 10 | Butterworth\_LPF\_D0\_10\_n\_1.png | LPF\_D0\_10\_n\_1\_SPRCTRUM.png | | 20 | Butterworth\_HPF\_D0\_20\_n\_1.png | LPF\_D0\_20\_n\_1\_SPRCTRUM.png | | 40 | Butterworth\_LPF\_D0\_40\_n\_1.png | LPF\_D0\_40\_n\_1\_SPRCTRUM.png | | 100 | Butterworth\_LPF\_D0\_100\_n\_1.png | LPF\_D0\_100\_n\_1\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | Low pass filter without origin shifting n=2 | | | | D | image | spectrum | | 10 | Butterworth\_LPF\_D0\_10\_n\_2.png | LPF\_D0\_10\_n\_2\_SPRCTRUM.png | | 20 | Butterworth\_LPF\_D0\_20\_n\_2.png | LPF\_D0\_20\_n\_2\_SPRCTRUM.png | | 40 | Butterworth\_LPF\_D0\_40\_n\_2.png | LPF\_D0\_40\_n\_2\_SPRCTRUM.png | | 100 | Butterworth\_LPF\_D0\_100\_n\_2.png | LPF\_D0\_100\_n\_2\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | Low pass filter without origin shifting n=3 | | | | D | image | spectrum | | 10 | Butterworth\_LPF\_D0\_10\_n\_3.png | LPF\_D0\_10\_n\_3\_SPRCTRUM.png | | 20 | Butterworth\_LPF\_D0\_20\_n\_3.png | LPF\_D0\_20\_n\_3\_SPRCTRUM.png | | 40 | Butterworth\_LPF\_D0\_40\_n\_3.png | LPF\_D0\_40\_n\_3\_SPRCTRUM.png | | 100 | Butterworth\_LPF\_D0\_100\_n\_3.png | LPF\_D0\_100\_n\_3\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | Low pass filter without origin shifting n=4 | | | | D | image | spectrum | | 10 | Butterworth\_LPF\_D0\_10\_n\_4.png | LPF\_D0\_10\_n\_4\_SPRCTRUM.png | | 20 | Butterworth\_LPF\_D0\_20\_n\_4.png | LPF\_D0\_20\_n\_4\_SPRCTRUM.png | | 40 | Butterworth\_LPF\_D0\_40\_n\_4.png | LPF\_D0\_40\_n\_4\_SPRCTRUM.png | | 100 | Butterworth\_LPF\_D0\_100\_n\_4.png | LPF\_D0\_100\_n\_4\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | High pass filter with origin shifting n=1 | | | | D | image | spectrum | | 10 | ORIGIN\_Butterworth\_HPF\_D0\_10\_n\_1.png | ORIGIN\_HPF\_D0\_10\_n\_1\_SPRCTRUM.png | | 20 | ORIGIN\_Butterworth\_HPF\_D0\_20\_n\_1.png | ORIGIN\_HPF\_D0\_20\_n\_1\_SPRCTRUM.png | | 40 | ORIGIN\_Butterworth\_HPF\_D0\_40\_n\_1.png | ORIGIN\_HPF\_D0\_40\_n\_1\_SPRCTRUM.png | | 100 | ORIGIN\_Butterworth\_HPF\_D0\_100\_n\_1.png | ORIGIN\_HPF\_D0\_100\_n\_1\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | High pass filter with origin shifting n=2 | | | | D | image | spectrum | | 10 | ORIGIN\_Butterworth\_HPF\_D0\_10\_n\_2.png | ORIGIN\_HPF\_D0\_10\_n\_2\_SPRCTRUM.png | | 20 | ORIGIN\_Butterworth\_HPF\_D0\_20\_n\_2.png | ORIGIN\_HPF\_D0\_20\_n\_2\_SPRCTRUM.png | | 40 | ORIGIN\_Butterworth\_HPF\_D0\_40\_n\_2.png | ORIGIN\_HPF\_D0\_40\_n\_2\_SPRCTRUM.png | | 100 | ORIGIN\_Butterworth\_HPF\_D0\_100\_n\_2.png | ORIGIN\_HPF\_D0\_100\_n\_2\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | High pass filter with origin shifting n=3 | | | | D | image | spectrum | | 10 | ORIGIN\_Butterworth\_HPF\_D0\_10\_n\_3.png | ORIGIN\_HPF\_D0\_10\_n\_3\_SPRCTRUM.png | | 20 | ORIGIN\_Butterworth\_HPF\_D0\_20\_n\_3.png | ORIGIN\_HPF\_D0\_20\_n\_3\_SPRCTRUM.png | | 40 | ORIGIN\_Butterworth\_HPF\_D0\_40\_n\_3.png | ORIGIN\_HPF\_D0\_40\_n\_3\_SPRCTRUM.png | | 100 | ORIGIN\_Butterworth\_HPF\_D0\_100\_n\_3.png | ORIGIN\_HPF\_D0\_100\_n\_3\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | High pass filter with origin shifting n=4 | | | | D | image | spectrum | | 10 | ORIGIN\_Butterworth\_HPF\_D0\_10\_n\_4.png | ORIGIN\_HPF\_D0\_10\_n\_4\_SPRCTRUM.png | | 20 | ORIGIN\_Butterworth\_HPF\_D0\_20\_n\_4.png | ORIGIN\_HPF\_D0\_20\_n\_4\_SPRCTRUM.png | | 40 | ORIGIN\_Butterworth\_HPF\_D0\_40\_n\_4.png | ORIGIN\_HPF\_D0\_40\_n\_4\_SPRCTRUM.png | | 100 | ORIGIN\_Butterworth\_HPF\_D0\_100\_n\_4.png | ORIGIN\_HPF\_D0\_100\_n\_4\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | Low pass filter with origin shifting n=1 | | | | D | image | spectrum | | 10 | ORIGIN\_Butterworth\_LPF\_D0\_10\_n\_1.png | ORIGIN\_LPF\_D0\_10\_n\_1\_SPRCTRUM.png | | 20 | ORIGIN\_Butterworth\_LPF\_D0\_20\_n\_1.png | ORIGIN\_LPF\_D0\_20\_n\_1\_SPRCTRUM.png | | 40 | ORIGIN\_Butterworth\_LPF\_D0\_40\_n\_1.png | ORIGIN\_LPF\_D0\_40\_n\_1\_SPRCTRUM.png | | 100 | ORIGIN\_Butterworth\_LPF\_D0\_100\_n\_1.png | ORIGIN\_LPF\_D0\_100\_n\_1\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | Low pass filter without origin shifting n=2 | | | | D | image | spectrum | | 10 | ORIGIN\_Butterworth\_LPF\_D0\_10\_n\_2.png | ORIGIN\_LPF\_D0\_10\_n\_2\_SPRCTRUM.png | | 20 | ORIGIN\_Butterworth\_LPF\_D0\_20\_n\_2.png | ORIGIN\_LPF\_D0\_20\_n\_2\_SPRCTRUM.png | | 40 | ORIGIN\_Butterworth\_LPF\_D0\_40\_n\_2.png | ORIGIN\_LPF\_D0\_40\_n\_2\_SPRCTRUM.png | | 100 | ORIGIN\_Butterworth\_LPF\_D0\_100\_n\_2.png | ORIGIN\_LPF\_D0\_100\_n\_2\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | Low pass filter without origin shifting n=3 | | | | D | image | spectrum | | 10 | ORIGIN\_Butterworth\_LPF\_D0\_10\_n\_3.png | ORIGIN\_LPF\_D0\_10\_n\_3\_SPRCTRUM.png | | 20 | ORIGIN\_Butterworth\_LPF\_D0\_20\_n\_3.png | ORIGIN\_LPF\_D0\_20\_n\_3\_SPRCTRUM.png | | 40 | ORIGIN\_Butterworth\_LPF\_D0\_40\_n\_3.png | ORIGIN\_LPF\_D0\_40\_n\_3\_SPRCTRUM.png | | 100 | ORIGIN\_Butterworth\_LPF\_D0\_100\_n\_3.png | ORIGIN\_LPF\_D0\_100\_n\_3\_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | Low pass filter without origin shifting n=4 | | | | D | image | spectrum | | 10 | ORIGIN\_Butterworth\_LPF\_D0\_10\_n\_4.png | ORIGIN\_LPF\_D0\_10\_n\_4\_SPRCTRUM.png | | 20 | ORIGIN\_Butterworth\_LPF\_D0\_20\_n\_4.png | ORIGIN\_LPF\_D0\_20\_n\_4\_SPRCTRUM.png | | 40 | ORIGIN\_Butterworth\_LPF\_D0\_40\_n\_4.png | ORIGIN\_LPF\_D0\_40\_n\_4\_SPRCTRUM.png | | 100 | ORIGIN\_Butterworth\_LPF\_D0\_100\_n\_4.png | ORIGIN\_LPF\_D0\_100\_n\_4\_SPRCTRUM.png | |
| Discussion |
| 可以發現沒有做Origin shift的版本作用是在高頻上因此跟我們的預期結果會相反，著重討論在經過origin shift 我們常見的正常版本中D0 的大小取決於應用需求。較小的 D0 適用於平滑圖像，而較大的 D0 適用於保留細節並強調邊緣，選擇 N 的大小可以根據應用的要求進行調整。較大的 N 適用於需要更陡的減弱的情況，例如對噪聲的高度抑制，LPF圖像平滑、去除噪聲、模糊化等應用場景，HPF邊緣增強、特徵提取、去除平均背景等應用場景，總的來說，Butterworth 濾波器的 D0 大小和 N 大小的設定會影響濾波器的截止頻率和過渡區域的行為，這對於平滑、去噪或強調特定頻率成分都至關重要。同時，選擇是使用低通濾波器還是高通濾波器，取決於應用的特定需求，因此題圖片數量較多另有開資料夾在image\_file中的butterworth資料夾內 |

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| **2.3** |
| Figure |
| |  |  |  | | --- | --- | --- | | Low pass filter without origin shifting | | | | D | image | spectrum | | 10 | ORIGIN\_Idealfilter\_LPF\_D0\_10.png | ORIGIN\_LPF\_D0\_10\_ SPRCTRUM.png | | 20 | ORIGIN\_Idealfilter\_LPF\_D0\_20.png | ORIGIN\_LPF\_D0\_20\_SPRCTRUM.png | | 40 | ORIGIN\_Idealfilter\_LPF\_D0\_40.png | ORIGIN\_LPF\_D0\_40 \_SPRCTRUM.png | | 100 | ORIGIN\_Idealfilter\_LPF\_D0\_100.png | ORIGIN\_LPF\_D0\_100 \_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | High pass filter without origin shifting | | | | D | image | spectrum | | 10 | ORIGIN\_Idealfilter\_HPF\_D0\_10.png | ORIGIN\_HPF\_D0\_10\_ SPRCTRUM.png | | 20 | ORIGIN\_Idealfilter\_HPF\_D0\_20.png | ORIGIN\_HPF\_D0\_20 \_SPRCTRUM.png | | 40 | ORIGIN\_Idealfilter\_HPF\_D0\_40.png | ORIGIN\_HPF\_D0\_40 \_SPRCTRUM.png | | 100 | ORIGIN\_Idealfilter\_HPF\_D0\_100.png | ORIGIN\_HPF\_D0\_100 \_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | Low pass filter with origin shifting | | | | D | image | spectrum | | 10 | Idealfilter\_LPF\_D0\_10.png | LPF\_D0\_10 \_SPRCTRUM.png | | 20 | Idealfilter\_LPF\_D0\_20.png | LPF\_D0\_20 \_SPRCTRUM.png | | 40 | Idealfilter\_LPF\_D0\_40.png | LPF\_D0\_40 \_SPRCTRUM.png | | 100 | Idealfilter\_LPF\_D0\_100.png | LPF\_D0\_100 \_SPRCTRUM.png |  |  |  |  | | --- | --- | --- | | High pass filter with origin shifting | | | | D | image | spectrum | | 10 | Idealfilter\_HPF\_D0\_10.png | HPF\_D0\_10\_SPRCTRUM.png | | 20 | Idealfilter\_HPF\_D0\_20.png | HPF\_D0\_20\_SPRCTRUM.png | | 40 | Idealfilter\_HPF\_D0\_40.png | HPF\_D0\_40\_SPRCTRUM.png | | 100 | Idealfilter\_\_HPF\_D0\_100.png | HPF\_D0\_100 \_SPRCTRUM.png | |
| Discussion |
| 首先與前面問題一樣可以發現未做過origin shifting的結果愈預期部太相同、效果極差，同時可以發現ideal filter之所以叫ideal是因為在實際應用中有一些問題，如它的頻率響應在截止頻率處有不連續性，這可能導致實際實現時的一些問題。實際應用中常常使用其他濾波器，如巴特沃斯（Butterworth）濾波器或高斯(Gaussian)濾波器，這些濾波器在頻率響應方面更平滑，同時這題的照片也太多所以在image\_file中多放一個資料夾idealfilter來儲存本題圖片。。 |

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| **3.1** |
| Figure |
| |  |  | | --- | --- | |  |  | | spetial\_sobel\_90\_suilding.png | spetial\_sobel\_0\_suilding.png | |  |  | | idft\_sobel\_90\_building.png | idft\_sobel\_0\_building.png | |  |  | | dft\_sobel90.png | dft\_sobel0.png | |
| Discussion |
| 在計算上Spatial domain的捲積速度比起DFT快上許多，但是考量到FFT的話會比起捲積更快，因此在Frequency domain上計算具有更多優勢，在視覺呈現上Spatial domain讓人眼能夠更直覺地看出效果，邊界處理上Spatial domain更為容易利用mirroring、padding的方式處理，Frequency domain則較容易引起人為干擾的落差，這一題用自己手刻的方式而沒有採用opencv ，把原圖做完DFT、Filter用3\*3並把他放到中間再把周圍用0-padding 後丟入DFT並與原圖的DFT結果相乘，最後做IDFT，在數值處理上>255則設為255，<0則設為0，與原圖的落差可能來自較小的filter、0-padding有關。。 |