Sharpening Spatial Filters (high pass)

- Previously we have looked at smoothing filters which remove fine detail.
- *Sharpening spatial filters* seek to highlight fine detail:
  - Remove blurring from images
  - Highlight edges
  - Useful for emphasizing transitions in image intensity
- *Sharpening filters* are based on *spatial differentiation*.

Hanan Hardan
Spatial Differentiation

- Differentiation measures the *rate of change* of a function
- Let’s consider a simple 1 dimensional example
Spatial Differentiation

A

B

Gray level profile

Ramp

Isolated point

Thin line

Flat segment

Step

Image strip

5 5 4 3 2 1 0 0 0 6 0 0 0 0 0 1 3 1 0 0 0 0 0 7 7 7 7 ••
Spatial filters : Sharpening ( high pass)

1. LAPLACE
2. SOBEL
Spatial filters : Sharpening
1) LAPLACE

Laplace kernels

\[
\begin{bmatrix}
0 & 1 & 0 \\
1 & -4 & 1 \\
0 & 1 & 0 \\
1 & 1 & 1 \\
-1 & 4 & -1 \\
-1 & 1 & -1 \\
0 & -1 & 0 \\
-1 & -1 & -1 \\
0 & -1 & 0 \\
-1 & -1 & -1 \\
\end{bmatrix}
\]
Spatial filters: Sharpening

LAPLACE – 1st derivative

**Use:** for highlighting fine detail or enhancing detail that has been blurred.

Example: apply the following laplace on the highlighted pixel

\[
\begin{pmatrix}
0 & -1 & 0 \\
-1 & 4 & -1 \\
0 & -1 & 0 \\
\end{pmatrix}
\]

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154*4 – 158- 156-158-158 = -14

So the value after filter = -14

We call the resultant image: **sharpened image.**

Filtered image=original + sharpened image

The value in the filter image=154-14 =130
Spatial filters: Sharpening

Sharpening can be done in 1 pass:

\[
\begin{array}{ccc}
0 & -1 & 0 \\
-1 & 4 & -1 \\
0 & -1 & 0 \\
\end{array}
\] + \[
\begin{array}{ccc}
0 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 0 \\
\end{array}
\] = \[
\begin{array}{ccc}
0 & -1 & 0 \\
-1 & 5 & -1 \\
0 & -1 & 0 \\
\end{array}
\]
Spatial filters : Sharpening

**LAPLACE – 1\(^{st}\) derivative**

In the sharpened image, we may get negative value, We deal with this case in 3 ways:

1. Covert negative value to zero (matlab does this)

2. Apply 2\(^{nd}\) derivative of laplace
   
   1. Apply laplace again to the resultant sharpened image
Spatial filters: Sharpening

LAPLACE – 2nd derivative

Example: apply the following laplace 2nd derivative on the highlighted pixel

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154*4 – 158- 156-158-158 = -14

Solution: apply laplace to all pixels

Then apply it again to our pixel: -14*4 – 10 -10 – (-6) -4 = -74
So the value after 2nd derivative filter = -74
The value of pixel in the filter image = 154-74 = 80
Spatial filters: Sharpening

1st VS 2nd derivative sharpening

1st derivative sharpening produces thicker edges in an image
1st derivative sharpening has stronger response to gray level change

2nd derivative sharpening has stronger response to fine details, such as thin lines and isolated points.

2nd derivative sharpening has double response to gray level change
Laplacian Image Enhancement

Original Image - Laplacian Filtered Image = Sharpened Image

- In the final sharpened image edges and fine detail are much more obvious

Hanan Hardan
Laplacian Image Enhancement

Laplacian Image Enhancement

**`Imfilter`**: for applying filter.

**`Fspecial`**: for choosing the filter:

Example: In MATLAB:
```
>> v=imread('picture2.jpg');
>> h=fspecial('laplacian',0);
>> Xp=imfilter(v,h);
>> imshow(Xp)
>> imshow(Xp+v)
```

Note: `Xp=imfilter(x,p, 'replicate')`  
This command will apply border padding instead of zero padding
Spatial filters: Sharpening

2) Sobel

![Sobel Filters](image)

- **Left**: Detects horizontal edges
- **Right**: Detects vertical edges
Spatial filters : Sharpening
2) Sobel

we can apply the sobel horizontal kernel or the sobel vertical kernel or both and adding them together.
Spatial filters: Sharpening

2) Sobel

Example:

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**sobel H:**

```
1  2  1
0  0  0
-1 -2 -1
```

filtered image = 157 + 8 = 165

**sobel V:**

```
1  0 -1
2  0 -2
1  0 -1
```

filtered image = 157 - 10 = 147
MATLAB

**Imfilter**: for applying filter.

**Fspecial**: for choosing the filter:

Example: In MATLAB:

```
>> v = fspecial('sobel')  \rightarrow horizontal sobel
>> Y = v'  \rightarrow vertical sobel
>> m = imread('cameraman.tif');
>> Fp = imfilter(m,v)  \rightarrow this command will apply sobel filter on image
>> imshow(Fp)  \rightarrow this command will show the sobel sharpened image
>> imshow(m+Fp)  \rightarrow this command will show the filtered image after applying sobel
```
Spatial filters : Sharpening

2) Sobel

```matlab
>> imshow(v),figure, imshow(f+v);
>> v=imread('picture2.jpg');
>> h=fspecial('sobel');
>> h1=h';
>> p1=imfilter(v,h); 
>> p2=imfilter(v,h1); 
>> p3=abs(p1)+abs(p2); 
>> imshow(v),figure,imshow(p3+v);
```
Sharpening Filters:

Laplacian

Sobel
Combining Spatial Enhancement Methods

- Successful image enhancement is typically not achieved using a single operation
- Rather we combine a range of techniques in order to achieve a final result
- This example will focus on enhancing the bone scan to the right

Hanan Hardan
Combining Spatial Enhancement Methods


(a) Laplacian filter of bone scan (a)

(b) Sharpened version of bone scan achieved by subtracting (a) and (b)

(c) Sobel filter of bone scan (a)

(d) Hanan Hardan

Combining Spatial Enhancement Methods (cont...)

The product of (c) and (e) which will be used as a mask.

Sharpened image which is sum of (a) and (f).

Result of applying a power-law trans. to (g).

Image (d) smoothed with a 5*5 averaging filter.
Combining Spatial Enhancement Methods (cont…)

- Compare the original and final images