Modified operators for digital image enhancement of radiograph films digitized by low cost flatbed scanner.
Aim of the work

The aim of this work is to develop modified sharpening spatial operators which can be used alone or in addition to the existent smoothing spatial operators to enhance digitized images of radiographic films captured using low cost flatbed scanner.
Content

- Introduction
- Digital image processing (DIP)
- Modified operators
- Materials
- Method
- Results
- Conclusions
- Future work
Image is a two-dimensional function $f(x, y)$ when $x$ and $y$ are the spatial coordinates of the pixels, which are the finite elements of the picture.
The mathematical model of the digital image is a matrix in the following form:

\[
\begin{bmatrix}
  f(0,0) & f(0,1) & \ldots & f(0, N-1) \\
  f(1,0) & f(1,1) & \ldots & f(1, N-1) \\
  \vdots & \vdots & \ddots & \vdots \\
  f(M-1,0) & f(M-1,1) & \ldots & f(M-1, N-1)
\end{bmatrix}
\]

\[f(x, y) = \begin{bmatrix}
  f(0,0) & f(0,1) & \ldots & f(0, N-1) \\
  f(1,0) & f(1,1) & \ldots & f(1, N-1) \\
  \vdots & \vdots & \ddots & \vdots \\
  f(M-1,0) & f(M-1,1) & \ldots & f(M-1, N-1)
\end{bmatrix}\]
The first application of digital images (DI) was in the newspaper industry when pictures were first sent by submarine cable between London and New York in 1920s.

The beginning of (DIP) started with the race of space discoveries.
DIP techniques began in the late 1960s and early 1970s to be used in medical imaging.
Digital image processing

Applications of DIP

- Digital image enhancement
- Image restoration
- Color image processing
- Morphological process
- Image matching
- Edge detection
Components of DIP systems

- Sensor
- Digitizer
- Computer
- Software
- Memory
Types of image digitizers

- Flatbed scanner
- Sheet-fed scanner
- Drum scanner
- Digital camera
- Film scanner
Digital image enhancement

- Frequency domain techniques
- Spatial domain techniques
Spatial domain techniques

- One pixel processing

- Multi pixels processing
One pixel processing

- Simple intensity processing
  - Image negatives
  - Contrast stretching
  - Compression of the dynamic range
  - Gray level slicing
- Histogram processing
  - Histogram equalization
  - Histogram specification
Multi pixels processing

The 8-neighbors of pixel \( P(x, y) \)

<table>
<thead>
<tr>
<th>((x-1, y-1))</th>
<th>((x-1, y))</th>
<th>((x-1, y+1))</th>
</tr>
</thead>
<tbody>
<tr>
<td>((x, y-1))</td>
<td>((x, y))</td>
<td>((x, y+1))</td>
</tr>
<tr>
<td>((x+1, y-1))</td>
<td>((x+1, y))</td>
<td>((x+1, y+1))</td>
</tr>
</tbody>
</table>
Smoothing spatial operators

- The goal is to increase the blur of the image to remove small details from an image and bridging of small gaps or smoothing the false contours.

- There are mainly two mathematical concepts used in smoothing process
  - Averaging
  - Mediating (nonlinear)
<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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</table>

\[ \frac{1}{9} \times \]

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<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>2</td>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

\[ \frac{1}{16} \times \]

**A:** Mask of averaging filter with equal weight for all neighbors

**B:** Weighted averaging mask
Sharpening spatial operators

- Sharpening is the opposite process of smoothing which used to highlight fine details of an image.

- Mathematically sharpening process can be modeled as a differentiation operation. That sharpening depends on increasing the difference in gray level of neighborhood pixels.
Second derivative operator

- It was founded that the simplest isotropic second derivative operator is the Laplacian which have the following form

\[ \nabla^2 f(x, y) = \frac{\partial^2 f(x, y)}{\partial x^2} + \frac{\partial^2 f(x, y)}{\partial y^2} \]

So it can be written as the following

\[ \nabla^2 f(x, y) = [f(x+1, y) + f(x-1, y) + f(x, y+1) + f(x, y-1)] - 4f(x, y) \]
<table>
<thead>
<tr>
<th>A</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>-4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
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</table>

Laplacian mask to sharpen the horizontal and vertical lines

<table>
<thead>
<tr>
<th>B</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>-8</td>
<td>1</td>
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<tr>
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<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Laplacian mask to sharpen the oblique lines in addition to the horizontal and vertical ones
## First derivative operators

<table>
<thead>
<tr>
<th>Mask</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>a</td>
<td>horizontal Roberts</td>
</tr>
<tr>
<td>b</td>
<td>vertical Roberts</td>
</tr>
<tr>
<td>c</td>
<td>horizontal Prewitt</td>
</tr>
<tr>
<td>d</td>
<td>vertical Prewitt</td>
</tr>
<tr>
<td>e</td>
<td>horizontal Sobel</td>
</tr>
<tr>
<td>f</td>
<td>vertical Sobel</td>
</tr>
</tbody>
</table>

- **a**: horizontal Roberts
- **b**: vertical Roberts
- **c**: horizontal Prewitt
- **d**: vertical Prewitt
- **e**: horizontal Sobel
- **f**: vertical Sobel
Nonlinear sharpening

- The following equation represents one of the used equations for nonlinear sharpening

\[
P(x, y) = \frac{P(x-1, y-1) + P(x, y-1) + P(x+1, y-1)}{3}
+ \frac{P(x-1, y+1) + P(x, y+1) + P(x+1, y+1)}{3}
+ P(x-1, y) + P(x+1, y) - P(x, y)
\]
**The modified operators**

- Increase the intensity
- Sharpening
- Smoothing (optional)
## Materials

- Radiograph films

<table>
<thead>
<tr>
<th>Sample</th>
<th>Quality</th>
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<tbody>
<tr>
<td>Pelvic</td>
<td>poor</td>
</tr>
<tr>
<td>Chest</td>
<td>acceptable</td>
</tr>
<tr>
<td>Knee</td>
<td>proper</td>
</tr>
</tbody>
</table>
- **Digitizer**

<table>
<thead>
<tr>
<th>Scanner type</th>
<th>Flatbed scanner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical resolution</td>
<td>1200 dpi</td>
</tr>
<tr>
<td>Max resolution</td>
<td>1200 x 600 dpi</td>
</tr>
<tr>
<td>Form factor</td>
<td>desktop</td>
</tr>
<tr>
<td>Max size of media</td>
<td>216 x 297 mm</td>
</tr>
</tbody>
</table>

- **Computer**

<table>
<thead>
<tr>
<th>Processor</th>
<th>Intel Pentium III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>701 MHz</td>
</tr>
<tr>
<td>RAM</td>
<td>256 Mb</td>
</tr>
</tbody>
</table>
Flow chart of the program

- Scan the radiograph film
- Save image as jpg file in reachable director
- Call one of the modified functions
- Is treated image satisfy the needs
- Yes
  - Save / Print / Send
- No
  - Call one of the modified functions
Results

Second derivative operators

Original

Linear sharpening A

Linear sharpening B

Nonlinear sharpening
First divertive operators

Original  Roberts (H)  Roberts (V)  Prewitt (H)

Prewitt (V)  Sobel (H)  Sobel (V)
Modified operators

Original
Sharpen3
Sharpen4
Sharpen5
Sharpen6
Sharpen7
Modified operators plus smoothing
Comparison

Original

Sharpen 4

Sharpen 4 plus smoothing

Nonlinear sharpening
Conclusion

- The modified operators achieve acceptable enhancement of the images.
- Centers or departments of radiology can get the benefits of
  - Digital image processing
  - Digital image transmitting
  - Digital archiving
  - Teleradiology, Telemedicine with considerable costs of resources.
Future works

- In the real time application
- Dealing with color images
Thank you