Advanced Image Processing Methods Applied to Enhance the GPR Images

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Introduction

Motivation

Image Processing

Method

Examples

Discussion & Conclusion

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Process 1

Process 2

Process 3
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User defined display settings

Type of display

Interpolation methods
Intervals in x, y and z (cell sizes)

Color scale

Colorspace HSV, RGB, Diverging, Lab...
Number of colors
Color range

Type of data

Linear
Logarithmic
Normalized
Absolute value

Examples
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- **linear**
- **log**
- **Amplitude limits**
- **Colormap**

Experience

Trial-error
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**ENHANCEMENT**

Apply image processing filters to maps / sections / models

to enhance the geophysical images
to emboss desired attributes, structures or linearities
to suppress noise or unwanted features

1. To improve the subjective quality of an image for human viewing.

2. To modify the image in such a way as to make it more suitable for further analysis and automatic extraction of its contents.

- Standardized color scales, parameter range, presentation type?
- An automated colorscale-range-filter selector?
- Machine learning / Neural networks?
Monochrome (grayscale)

Color image
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1 Restoration / Smoothing / De-noising
2 Contrast adjustment / Sharpening
3 Histogram equalization
4 Directional derivatives / Edge detection
5 Shading & lighting
Geophysical Prospecting → Produce geophysical map / section → Prepare data for processing (e.g. conversions) → Select appropriate filters transforms or a workflow of processes → Process the image → Output image
Convolution with a filter

\[ g(x, y) = h \ast f(x, y) \]

Transforms

\[ g_y(x, y) \approx f(x + 1, y) - f(x - 1, y) \]
\[ g_x(x, y) \approx f(x + 1, y) - f(x - 1, y) \]

Gradients

\[
\begin{bmatrix}
0.075 & 0.124 & 0.075 \\
0.124 & 0.204 & 0.124 \\
0.075 & 0.124 & 0.075
\end{bmatrix}
\]
Examples

- \( h = \text{fspecial}('average', \text{hsize}); \)
- \( h = \text{fspecial}('disk', \text{radius}); \)
- \( h = \text{fspecial}('gaussian', \text{hsize}, \text{sigma}); \)
- \( h = \text{fspecial}('laplacian', \text{alpha}); \)
- \( h = \text{fspecial}('log', \text{hsize}, \text{sigma}); \)

\( S = \text{conv}(R,h); \)
CONTRAST ADJUSTMENT

\[ \text{low}\_\text{in}=0.3; \]
\[ \text{high}\_\text{in}=0.62; \]
\[ S = \text{imadjust}(R,[\text{low}\_\text{in} \text{ high}\_\text{in}]); \]
T is usually a cumulative density function (CDF)

```
radius=6;
h = fspecial('disk',radius);
F=imfilter(I,h);
H=histeq(F,256);
```
HISTOGRAM EQUALIZATION

Original Image

Filtered (smoothed) Image

Histogram equalized image
**IMAGE SHARPENING**

Unsharp Masking

Original | Smooth | Sharp

\[ S = \text{imsharpen}(I,'\text{Radius}',5,'\text{Amount}',2); \]

Radius: Standard deviation of the Gaussian lowpass filter
Amount: Strength of the sharpening effect \([0, 2]\)
SHADING

\texttt{shadem(\textquote{\textasciitilde sh\textasciitilde y\textasciitilde n\textasciitilde}, [90 35])} \hspace{1cm} \texttt{shadem(\textquote{ui\textquote{)}}}

\begin{figure}[h]
\centering
\begin{subfigure}{0.24\textwidth}
\includegraphics[width=\textwidth]{image1.png}
\end{subfigure}\hfill
\begin{subfigure}{0.24\textwidth}
\includegraphics[width=\textwidth]{image2.png}
\end{subfigure}\hfill
\begin{subfigure}{0.24\textwidth}
\includegraphics[width=\textwidth]{image3.png}
\end{subfigure}\hfill
\begin{subfigure}{0.24\textwidth}
\includegraphics[width=\textwidth]{image4.png}
\end{subfigure}
\caption{Examples of shading methods applied to images.}
\end{figure}
**GRADIENTS**

<table>
<thead>
<tr>
<th>Roberts</th>
<th>Prewitt</th>
<th>Sobel</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h_x = )</td>
<td>( h_y = )</td>
<td>( h_y = )</td>
</tr>
</tbody>
</table>
| \[
\begin{bmatrix}
0 & -1 \\
1 & 0
\end{bmatrix}
\] | \[
\begin{bmatrix}
-1 & 0 & 1 \\
-1 & 0 & 1 \\
-1 & 0 & 1
\end{bmatrix}
\] | \[
\begin{bmatrix}
-1 & 0 & 1 \\
-2 & 0 & 2 \\
-1 & 0 & 1
\end{bmatrix}
\] |
| \[
\begin{bmatrix}
-1 & 0 & 1 \\
0 & 0 & 0 \\
1 & 1 & 1
\end{bmatrix}
\] | \[
\begin{bmatrix}
-1 & -1 & -1 \\
0 & 0 & 0 \\
1 & 1 & 1
\end{bmatrix}
\] | \[
\begin{bmatrix}
-1 & -2 & -1 \\
0 & 0 & 0 \\
1 & 2 & 1
\end{bmatrix}
\] |
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GRADIENTS

Prewitt

Sobel

Original

x-direction

y-direction

Original

x-direction

y-direction

|x|+|y|
1. Image processing methods should be used as an auxiliary tool to enhance geophysical images
2. Image processing may be incorporated directly into geophysical processing
3. Histogram of a geophysical image tells us much about the presentation of results
4. Linear anomalies seen in GPR images such as the buried archaeological structures, pipelines and similar shallow targets may be emphasized by image processing methods
5. Image processing methods make GPR images more suitable for further analysis and automatic or visual extraction of its contents.
6. This process should be an interactive process since there exist also several user dependent settings in image processing
Further research and investigation: 3D filtering and image processing procedures
Thank you for your attention


Mathworks File Exchange.