Wavelet Based Data Hiding of DEM in the Context of Real-time 3D Visualization

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The Problem

To effect an optimal real-time 3D visualization:

- for a client server environment in a scalable and synchronized way
- compatible with the client’s computing resources and requirements.

![Diagram of client-server architecture with data visualization](image)
The Proposed Solution

• Our Approach:
  • Discrete Wavelet Transform (DWT): JPEG2000
  • Data Hiding: LSB based synchronized embedding

• Advantages:
  • Compression: reduce the amount of data
  • Scalability: different levels of detail for various:
    • Platforms
    • Users (quality needs)
    • Application & Network contexts (point of view & bandwidth)
  • Synchronization: reduce the number of files
3D Visualization

- Three files are necessary
  - Image of Texture
  - Altitude DEM (Fig. a)
  - Geo-referential coordinates (longitude / latitude)

- Two steps for visualization:
  - Creation of the 3D Mesh: Triangulation (Fig. b)
  - Aerial Photograph: mapped onto the triangles for 3D visualization (Fig. c)
The Proposed Method
The Proposed Method

- Transformation of texture image from **RGB** to **YCrCb**
- Wavelet Transformation
  - Lossy DWT of the Texture (**YCrCb**)
  - Lossless DWT of altitude (**DEM**)
- **Synchronized Data Insertion**
  - Data : DWT(DEM); Cover : DWT(Y)
    - Same number of decompositions
    - Correspondence between subbands
  - Factor of insertion (**E**)
    - 1 coeff DWT(DEM) of 2 bytes per 32x32 block of DWT(Y) for our example
    - LSB based Insertion: running a PRNG for pixel allocation
    - \( E = \frac{m^2}{N^2} \) (coefficients/ pixel) ; Block size = \( 1/E \)

- **Final Embedded Image**
Results

Texture Image
(A part magnified)

Texture Image
(2048x2048 pixels)

Altitude Image
(64x64 coefficients)
1 Pixel = 24 bits
1 coefficient = 16 bits
Level 1 Transformation

Texture
(2048x2048 pixels)

Altitude
(64x64 coefficients)
Level 3 Transformation

Texture
(2048x2048 pixels)

Altitude
(64x64 coefficients)
<table>
<thead>
<tr>
<th>Resolution Level</th>
<th>% Transmitted Data</th>
<th>PSNR Texture (dB)</th>
<th>PSNR Altitude (dB)</th>
<th>$\sqrt{\text{MSE}}$ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (all the data for DWT$^{-1}$)</td>
<td>100%</td>
<td>37.62</td>
<td>$\infty$</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>25%</td>
<td>26.54</td>
<td>40.37</td>
<td>$\sqrt{5.97} = 2.44\text{m}$</td>
</tr>
<tr>
<td>2</td>
<td>6.25%</td>
<td>22.79</td>
<td>33.51</td>
<td>$\sqrt{29.00} = 5.39\text{m}$</td>
</tr>
<tr>
<td>3</td>
<td>1.6%</td>
<td>20.90</td>
<td>29.25</td>
<td>$\sqrt{77.37} = 8.8\text{m}$</td>
</tr>
</tbody>
</table>
Reconstruction from the Image of Approximation at Level 3

Altitude Image
(64x64 coefficients)
1 coefficient = 16 bits

Texture Image
(2048x2048 pixels)
1 Pixel = 24 bits

Texture Image
(A part magnified)

Only 1.6% of the initial data utilized
Results

The Original Example

Altitude Image
(64x64 coefficients)
1 coefficient = 16 bits

Texture Image
(2048x2048 pixels)
1 Pixel = 24 bits

Texture Image
(A part magnified)
3D visualization of the Altitude from the Image of Approximation

Level 0 - all the information

Level 1

Level 2

Level 3
3D navigation of the Reconstructed Images

Level 3 lowest subband data

Only 1.6% of the initial data utilized
Conclusion

Encouraging results in the following contexts:

- Compression
- Scalability
- Synchronization

Perspectives:

- Integration of the method with standard JPEG2000 codec, e.g. OpenJPEG.
- Geometric Wavelets for DEM for compression
- Exploration of Chrominance planes
Questions?

For more information:

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