NITFS Technical Board Meeting

Slope Preserving DTED Compression

Level Set Systems, Inc.

Dr. Susan Chen
Dr. Stanley Osher
Dr. Guillermo Sapiro, consultant
Dr. Hongkai Zhao, consultant

Company Overview

LSS has developed a comprehensive image processing software package which includes the following :

- Accurate, efficient and feature preserving image compression
- Image enhancement e.g. noise removal, data recovery
- Storage, search and retrieval of images and image (terrain) features
- Quantification of relevant image features

Justification for Technology
Image Compression

- Digital terrain elevation data (DTED) is used in a majority of digital applications involving mapping
- Current lossy compression methods for DTED cause distortion which may “flatten” or “blur” terrain, rendering data useless for navigation or planning
- Lossless compression methods may constrain applications by slowing down transmission times due to large storage requirements

LSS Image Compression

- Key features e.g. terrain, slope and other user identified features are preserved under compression
- Compression software improves speed of data transfer and transmission of tactical imagery
- Method is computationally robust and adaptive
- Software can be used as an add-on to popular compression software such as JPEG-2000 or JPEG-LS

Image Compression

- DTED images provided courtesy of Larry Tingler/Fred Selzer from the PTAN/Tomahawk program.
- Data tested consist of Level 2 and Level 4 DTED, 16 bit tiff files
- Source is DEM files from the Shuttle Radar Topography Mission and LIDAR images from the Army RTV program

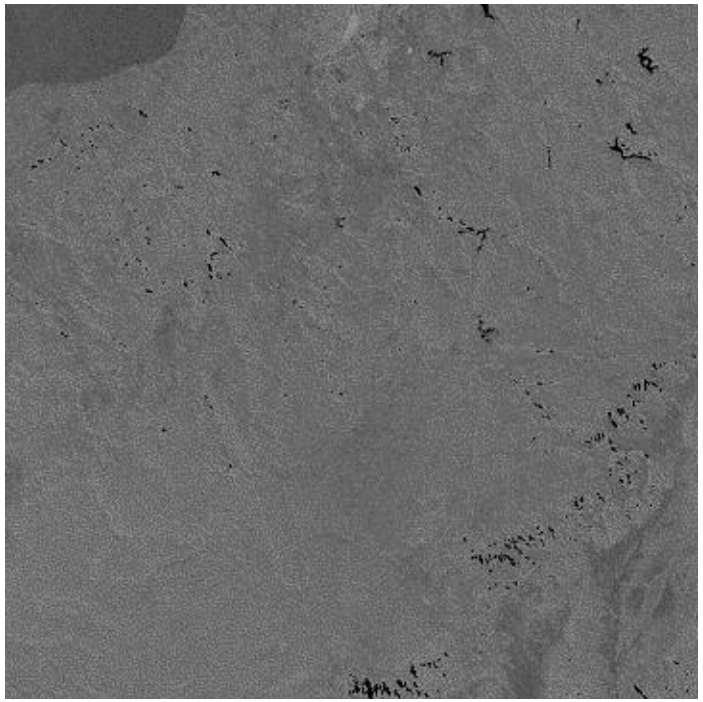


Image Compression Tests

- Data was compressed using either JPEG-2000, JPEG-LS or JPEG and compared to data compressed using LSS add-on
- Errors were measured in mean squared error (MSE) and $L\infty$ norm (maximal error over all pixels)
- Errors were calculated in height and slope, with slope represented by the magnitude of the gradient or as the cosine/sine of the angle

Image Compression Tests

- LSS software “wraps around” any compression package, e.g. JPEG-2000, JPEG-LS, JPEG
- Simple LSS pre-processing and post-processsing of compression data reduces errors in height and slope
- Error tables for fixed errors and fixed compression ratios are shown

Compression Errors/JPEG-2000

Fixed CR	Cos/Sin error JPEG-2000	Cos/Sin error LSS	Height error (meters) JPEG-2000	Height error (meters) LSS
5:1	.063/.094	2/.2e-4	7.92	7.32
10:1	.18/.16	2/1.3e-4	162.46	153
15:1	.24/.19	.1/.08	366	178
20:1	.27/.22	.11/.09	774	289
30:1	.31/.21	.18/.17	9135	2971
40:1	.32/.26	.19/.18	10163	2963
50:1	.33/.27	.20/.19	10988	3011

Compression Errors

Error in magnitude of the gradient

Fixed CR	MSE JPEG-2000	MSE LSS	L∞norm JPEG-2000	L∞norm LSS
5:1	0.3	.27	.43	.37
10:1	5.46	5.1	1.97	1.76
15:1	13	9.2	3.1	2.96
20:1	20.56	16.7	4.2	3.67
30:1	177.8	19.8	9.8	5.9
40:1	221	20.1	10.2	5.9
50:1	229	21.3	10.3	5.9

Compression Errors/MSE

Fixed Error (cos θ)	CR JPEG-2000	CR LSS
.18	10:1	30:1
.20	13:1	50:1
.25	19:1	77:1
.30	29:1	86:1
.35	52:1	157:1
.40	60:1	185:1

Compression Errors/JPEG-LS

Fixed CR	Error in magnitude of the gradient JPEG-LS	Error in magnitude of the gradient LSS	Height error JPEG-LS (meters)	Height error LSS (meters)
5:1	.27	.2	7.5	7.4
10:1	5.83	5.5	172	167
15:1	13.5	9.63	368	175
20:1	20	16.6	751	301
30:1	174	20	9200	2551
40:1	227	22	10235	2671
50:1	234	23	11012	3312

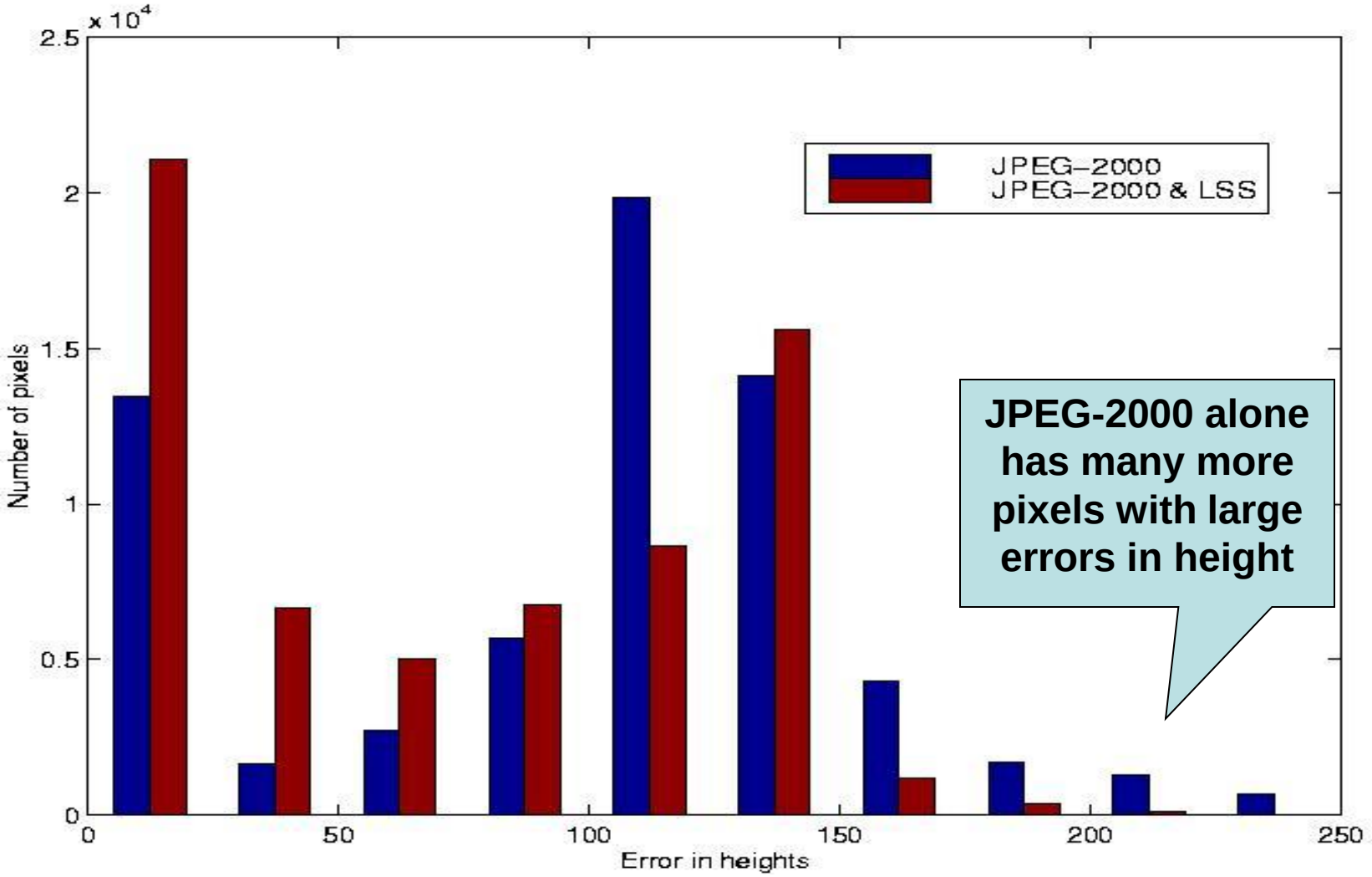
Compression Errors/JPEG

Fixed CR	Error in magnitude of the gradient JPEG	Error in magnitude of the gradient LSS	Height error JPEG (meters)	Height error LSS (meters)
5:1	.4	.36	10.8	10.3
10:1	6	5.73	181	172
15:1	14	9.73	391	199
20:1	25	21.2	814	335
30:1	209	25	10047	3255
40:1	215	26	10298	3406
50:1	224	27	11256	3560

Error Histogram

error in heights vs. # of pixels

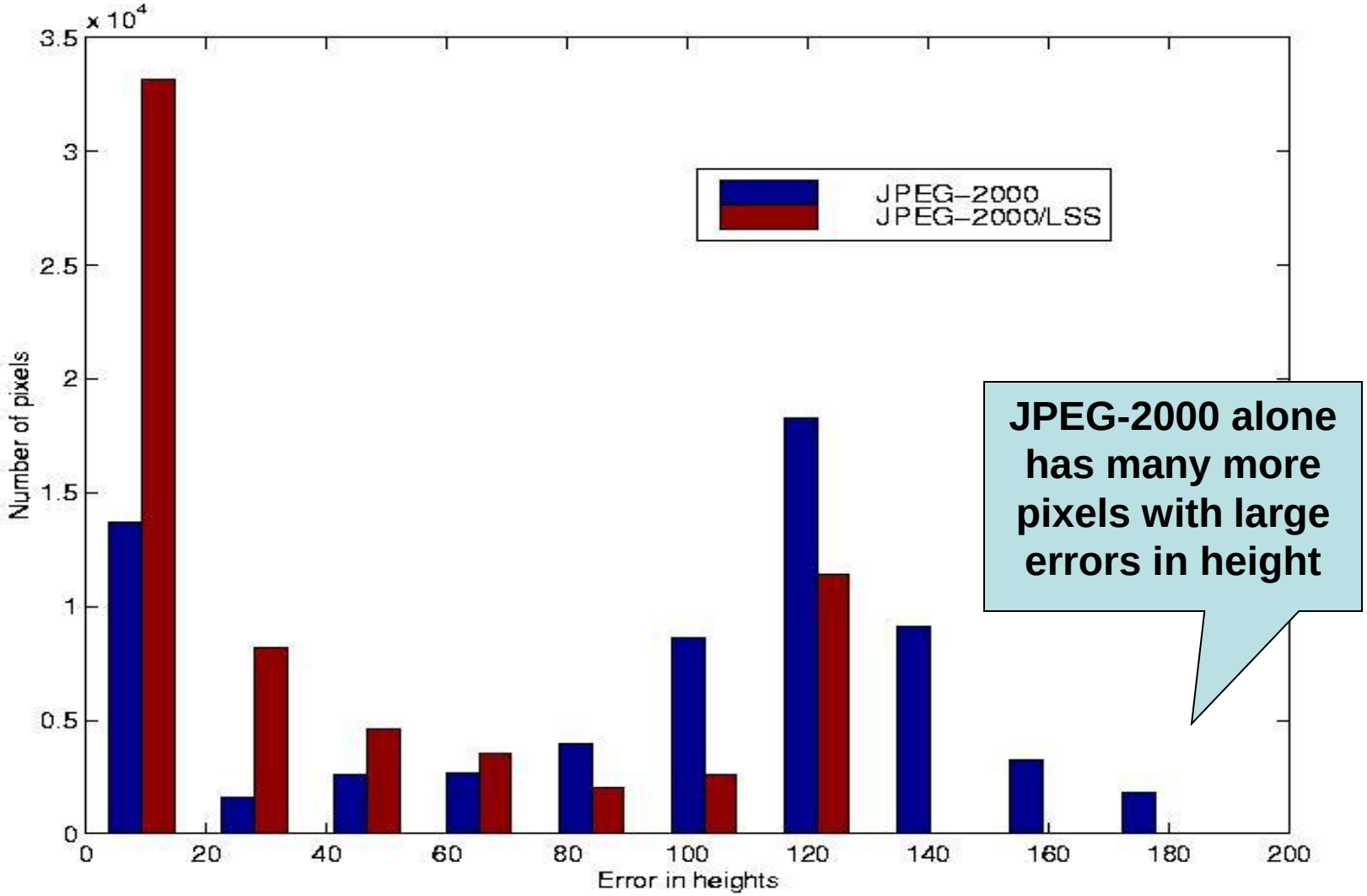
CR = 150:1



Error Histogram

error in heights vs. # of pixels

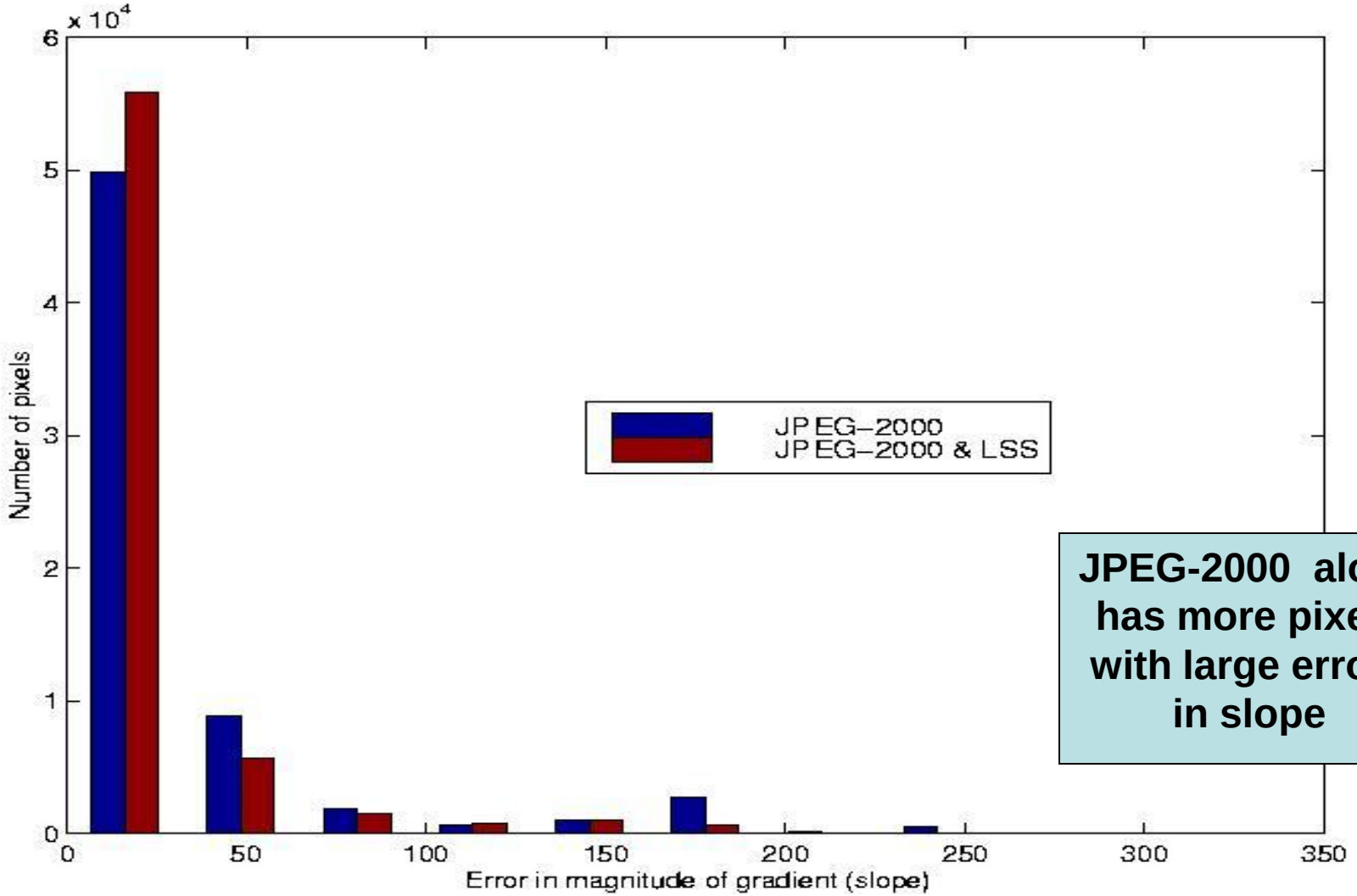
CR = 50:1



Error Histogram

error in slopes vs. # of pixels

CR = 150:1

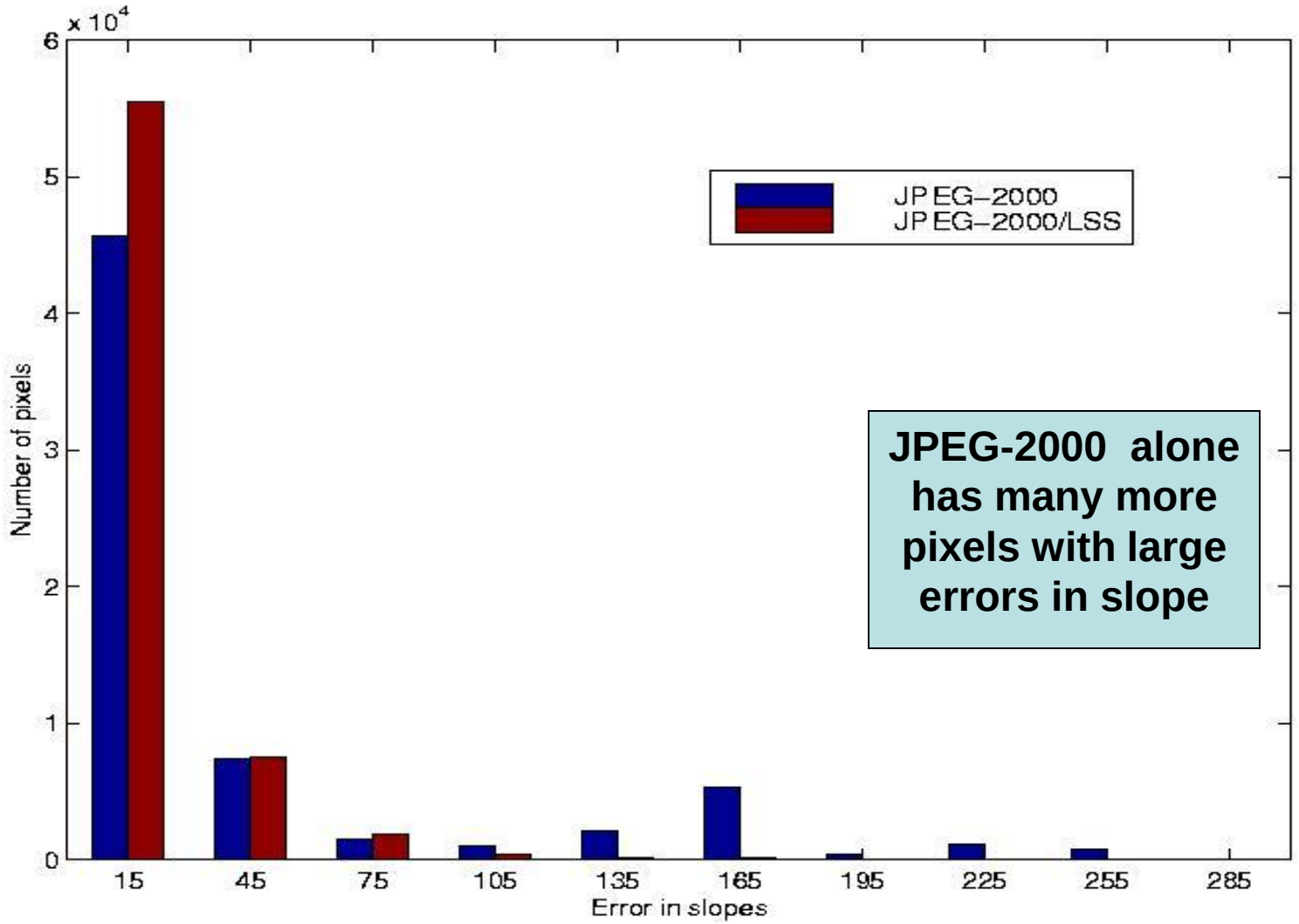


JPEG-2000 alone has more pixels with large errors in slope

Error Histogram

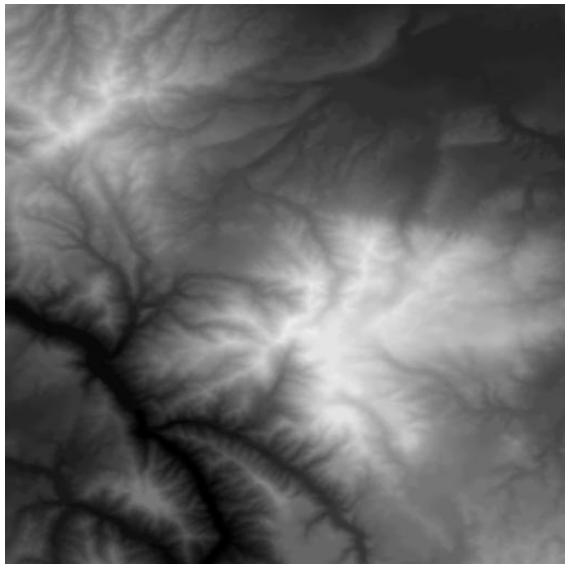
error in slopes vs. # of pixels

CR = 50:1

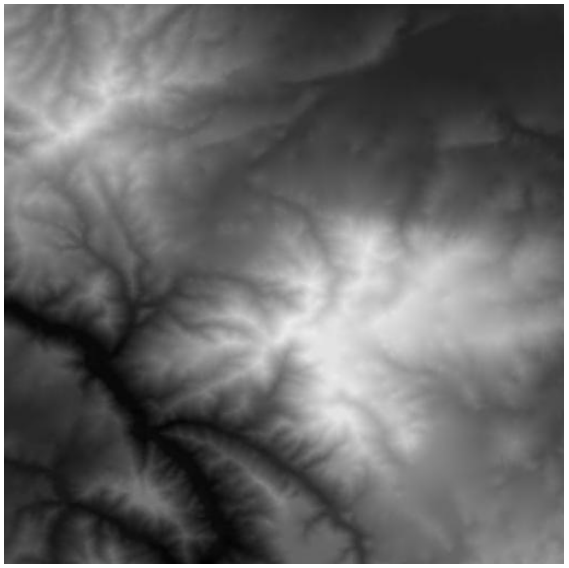


JPEG-2000 alone has many more pixels with large errors in slope

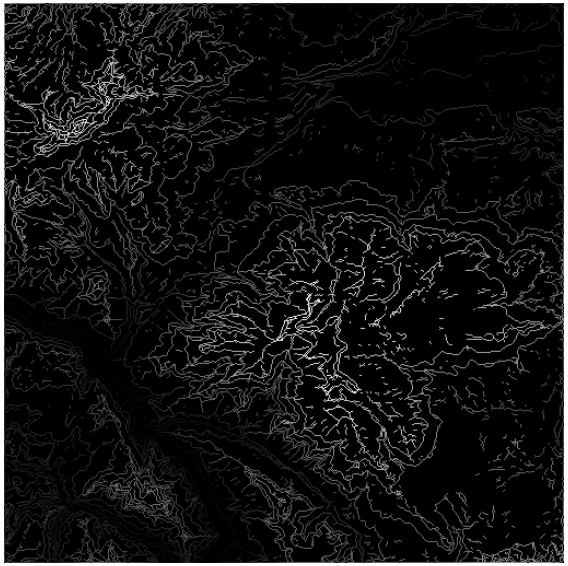
Image Compression



Topographical and geometric features can be extracted, compressed, stored and then used to reconstruct an image. Features can be used to improve navigation and identification.



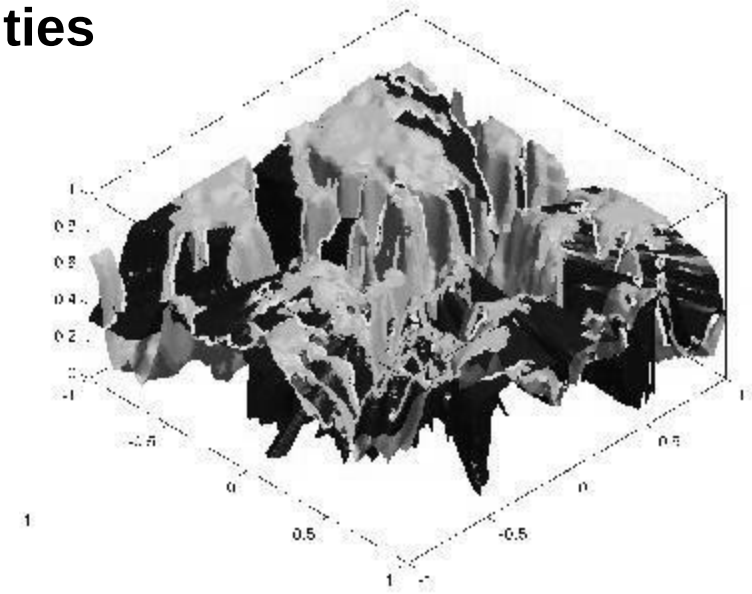
Extraction of geometric information: Critical level-lines, maxima, minima, crests, valleys, etc.



PDE's based reconstruction

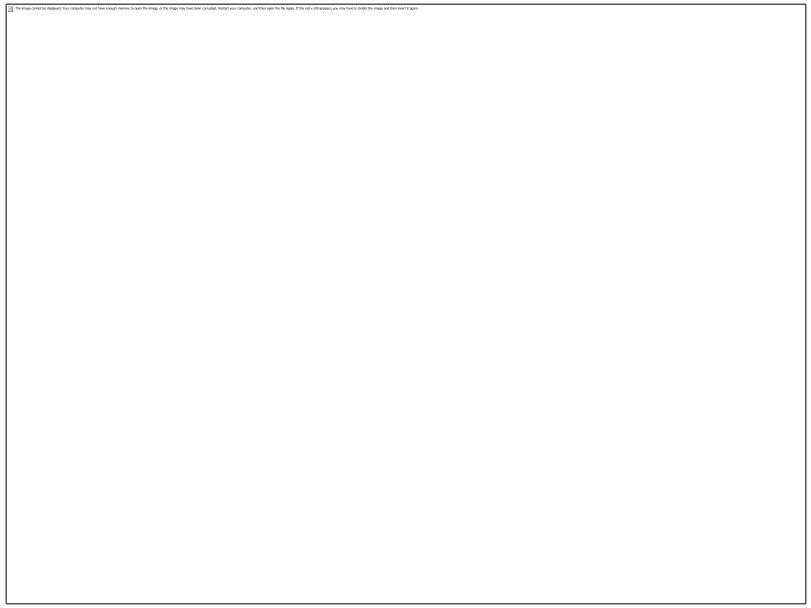
Dynamic Visibility

- **Autonomous navigation can be improved by visibility algorithms**
- **Visibility can be computed from image, DEM, or fused sources**
- **Visibility method is extremely fast, enabling dynamic visibility and flythrough capabilities**



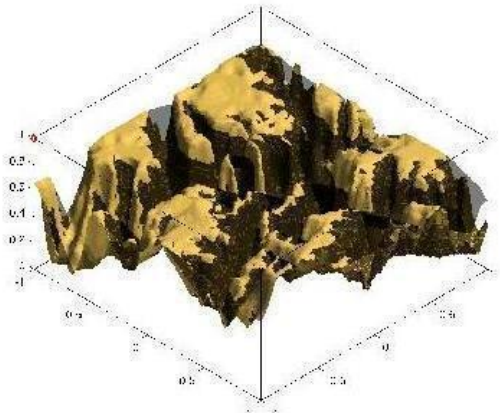
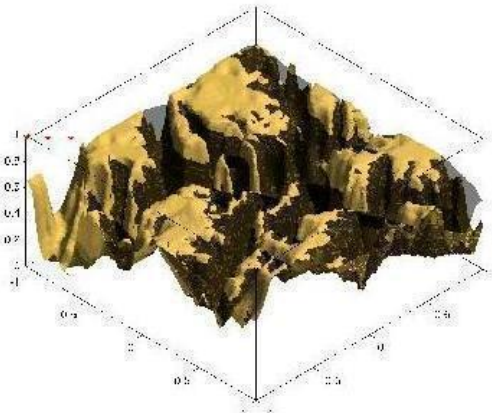
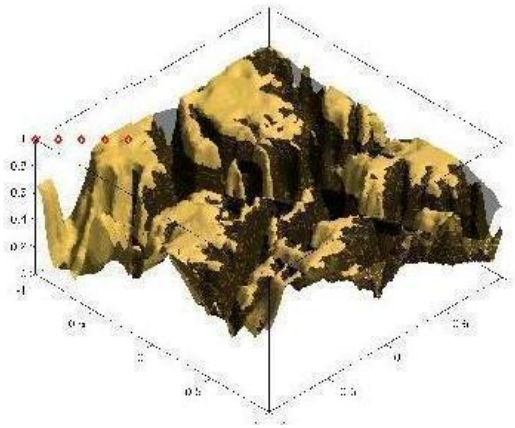
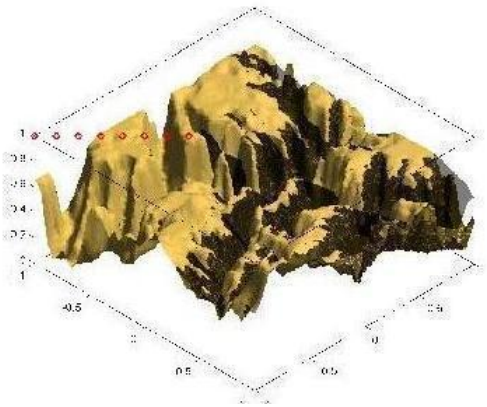
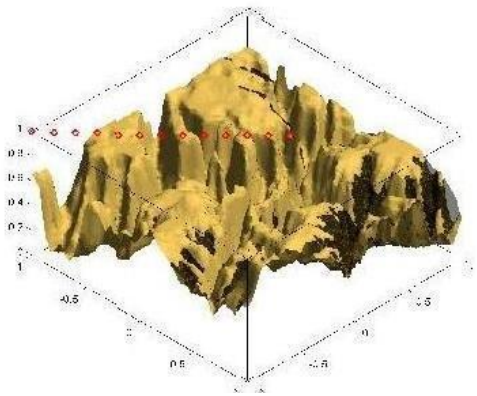
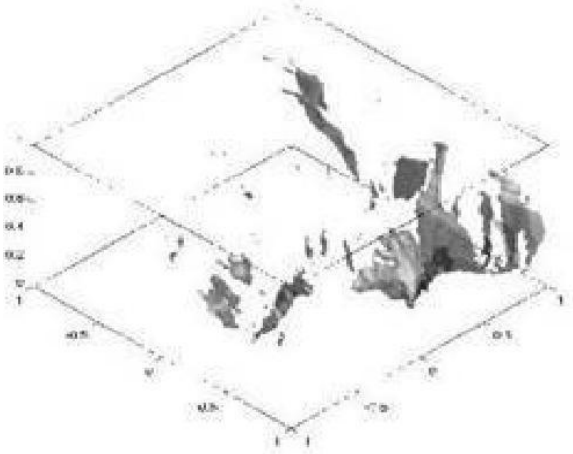
- Regions of visibility with respect to the center point are shaded in.
- Visibility comes from DEM data

Dynamic Visibility

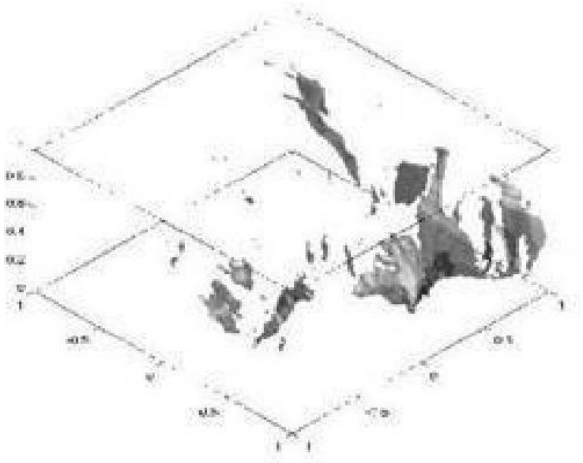


•Regions of visibility with respect to a point (red) moving through space with fixed parameters, obtained using LSS software. Shaded regions are areas of non visibility.

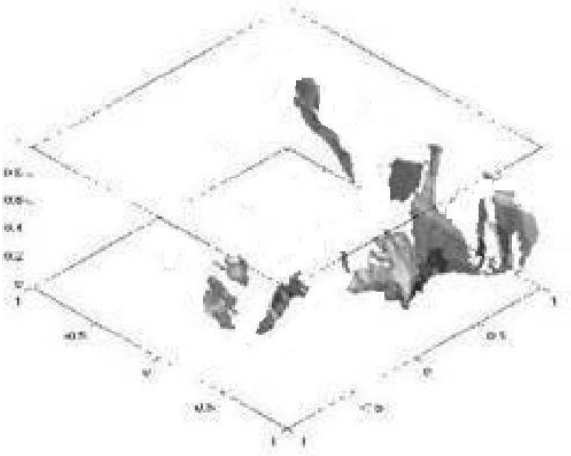
Dynamic Visibility

Dynamic Visibility



Uncompressed data



Compressed data

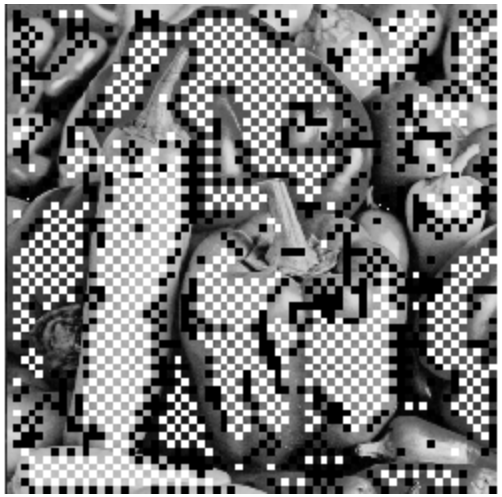
- **Visibility is robust under data compression**
- **With a compression ratio of 20:1, errors in visibility are 5%**
- **Compression and fast visibility algorithm allows for change detection and identification of moving targets**

Automatic image inpainting/interpolation for compression and wireless transmission

(Rane-Sapiro-Bertalmio) JPEG and/or JPEG-2000 compatible

Do not send blocks that can be inpainted
Average savings of 20-25%

Transmitted



Automatic reconstruction

Compression Preprocessing
Image Quantization

Original image

Standard quantization

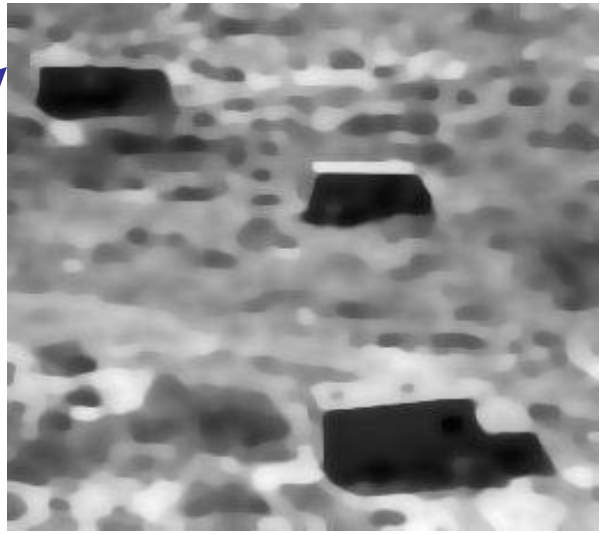
LSS quantization

Quantization preserves key terrain features

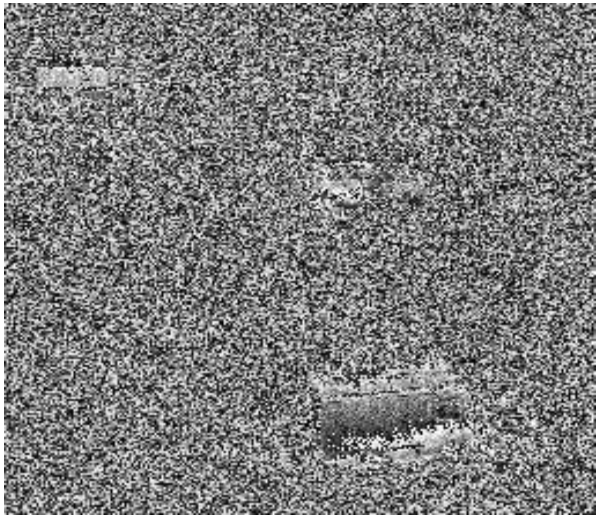
Compression Preprocessing

Texture Extraction

nontextured component



texture component

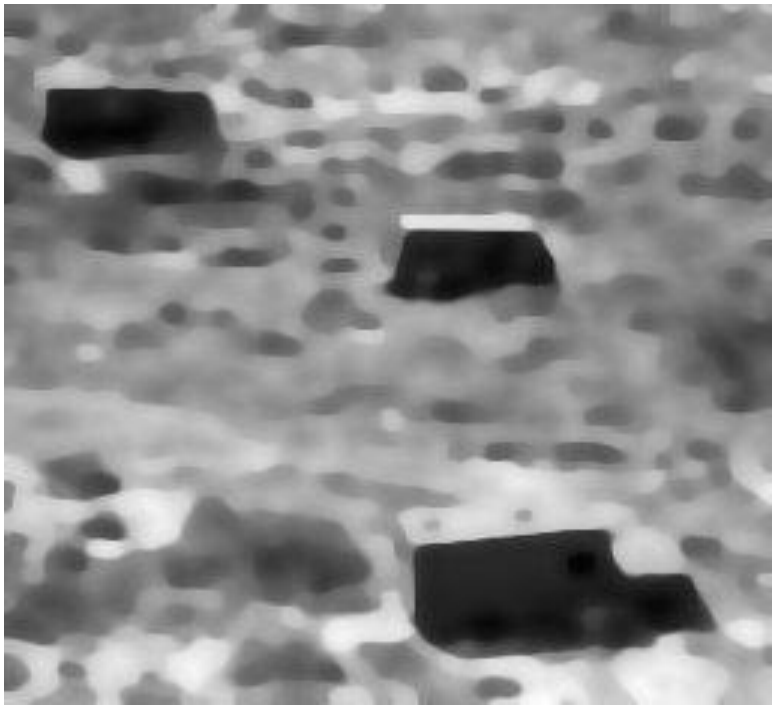


An original image can be decomposed into two components for improved identification and compression.

Compression Preprocessing

Texture Extraction

Original image



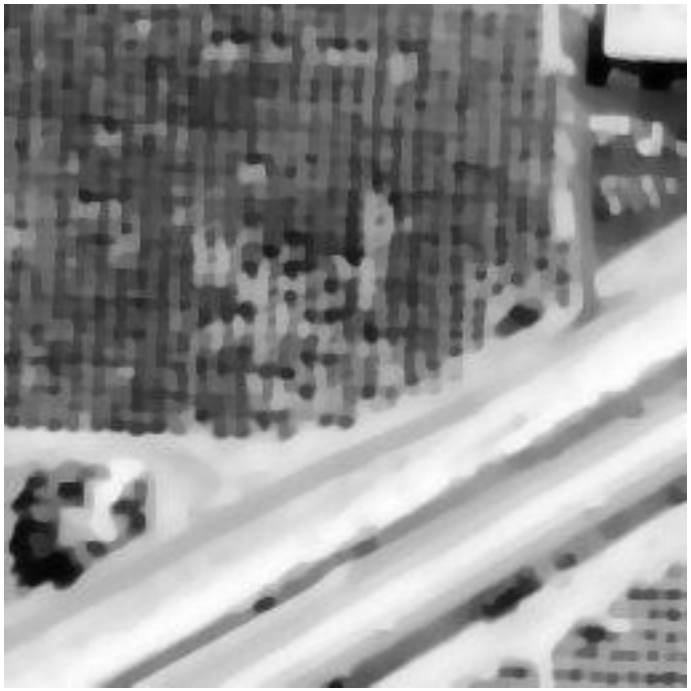
Main structure

Texture removal improves compression ratios of the preserved main structure.

Compression Preprocessing

Texture Extraction

Original image



Main structure

Texture removal improves compression ratios of the preserved main structure.

Compression Preprocessing

Texture Decomposition

CR : 15:1

Original image

Sketch component

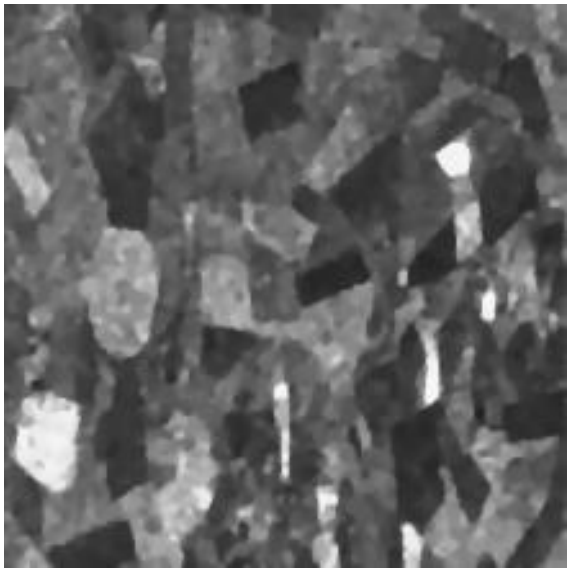
CR = 20:1

Texture component

In some cases, the texture component is more important. Compression ratios of textured component are larger than compression ratios of original data. Texture component can be kept for better compression and improved identification

Image Enhancement

Speckled SAR image



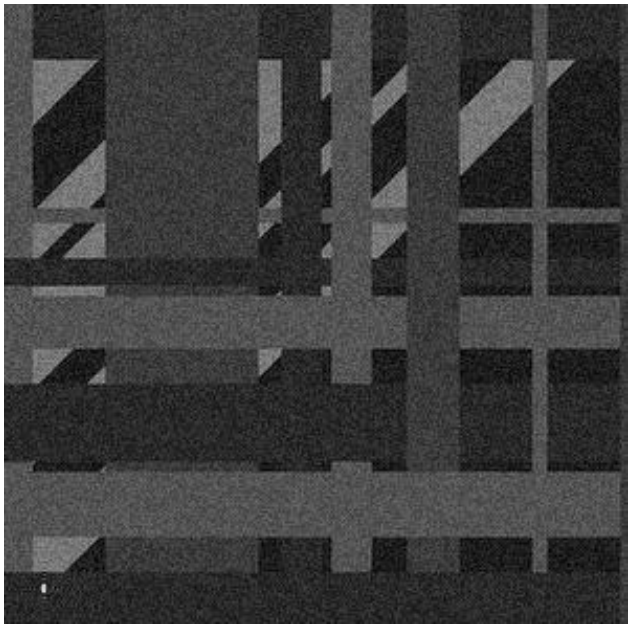
Despeckled image

Speckle SAR images can be enhanced and denoised for improved identification.

Original image extracted from “Filtrage d’images SAR” (Armand Lopes and Roger Fjortoft, sponsored by CESBIO and CNES)

Image Enhancement

Speckled SAR Image



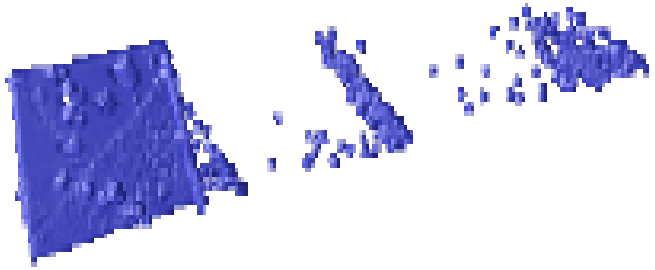
Despeckled image

Speckle SAR images can be enhanced and denoised for improved identification.

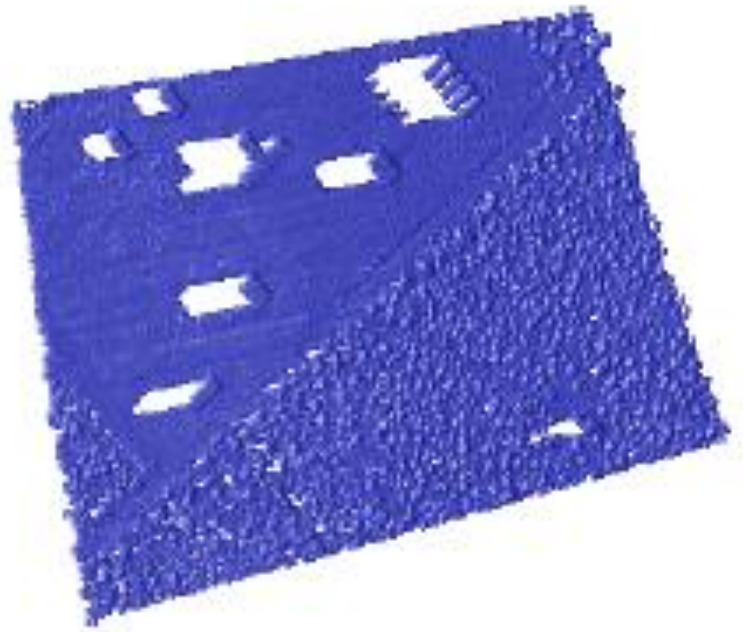
Original image extracted from “Filtrage d’images SAR” (Armand Lopes and Roger Fjortoft, sponsored by CESBIO and CNES)

Data Reconstruction

3-d data can be restored and reconstructed after removal of data outliers for improved identification

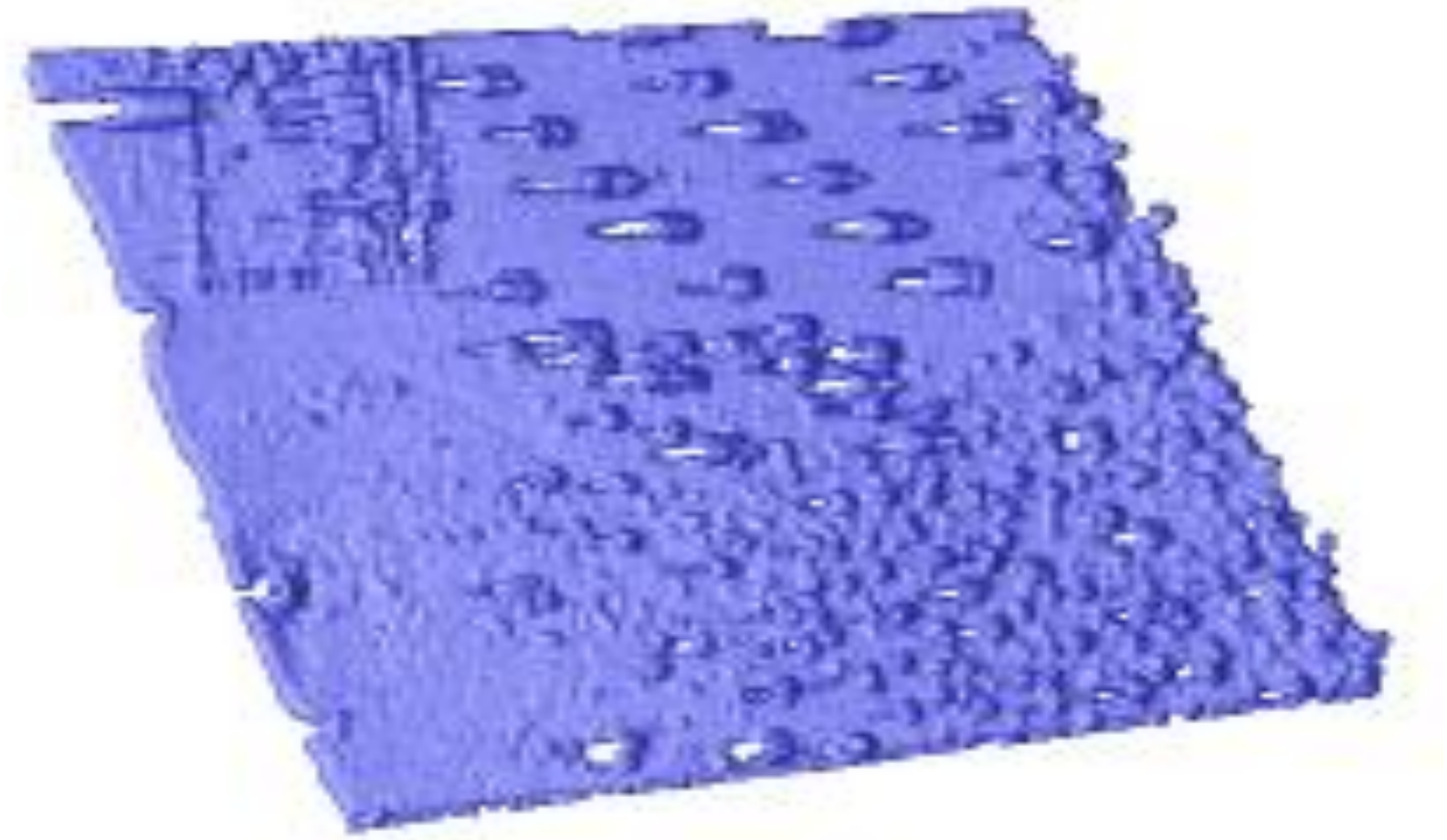


Raw terrain data



Terrain after reconstruction

Technical Approach
Data Reconstruction



Visualization of tanks after reconstruction

LSS Relationships

- LSS collaborates with various consultants from industry and academia
- LSS has history of collaborating with researchers at ONR and China Lake
- LSS compression and image processing software is completely compatible with other level set based techniques, e.g. level set based registration (A. Van Nevel, G. Hewer of China Lake and L. Rudin of Cognitech)