Progressive Image Compression Using Binary Trees

Computer Graphics Group,
Mathematics Dept.
Moscow State University

Authors: *Denis V. Ivanov*
Eugene P. Kuzmin
Sergey V. Burtsev

Compression Types

- Lossless (PCX,GIF,PING)
  - » No lose of any data
  - » Relatively low compression ratios
- Lossy (JPEG,Wavelets)
  - » May lose significant data
  - » High compression ratios
- Progressive = Lossy + Lossless
  - » Construct image sketches from incomplete data
  - » Enhance quality while receiving next portions of data
  - » Reconstruct the original having received the whole data

Progressive Transmission

- GIF, PING
  - » Image reconstruction on uniform grid basis
  - » Each cell is represented by top-left pixel (not average)
- Non-linear transforms
  - – S+P – transforms (similar to Haar wavelets)
    - » Reconstruction on block basis
    - » Each cell is represented by average value
  - – S+P + set partitioning
    - » Reconstruction ordering judging from MSE
    - » Computationally complex

Advantages of Our Technique

- Lossless compression ratios are among the best
  - » Better then PCX, GIF, PING, …
- Progressive decompression
  - » Decompression may be implemented in parallel to data extraction
- Fast and simple compression/decompression
  - » Parallel operations, MMX
- MSE estimation
  - » MSE of intermediate sketches may be obtained without any additional computations

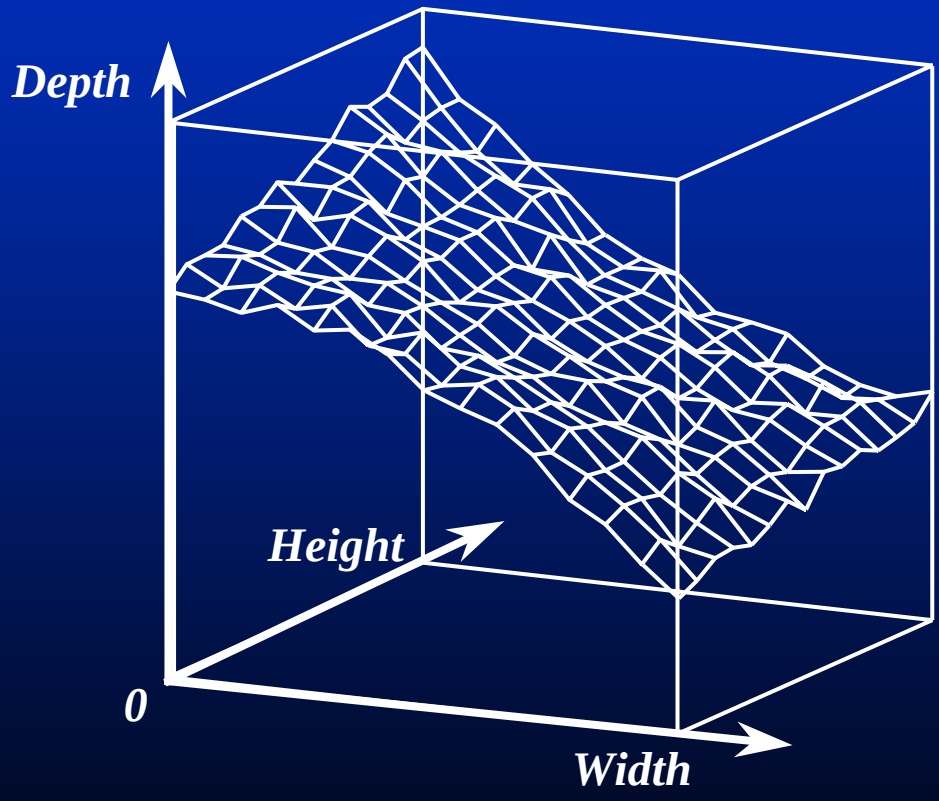
Compression Stages

- Binary tree representation
  - » Bitmap is represented by special binary tree structure
- Nodes sorting
  - » Nodes are sorted in the order of their appearance in the compressed data stream
- Entropy coding
  - » Nodes are encoded judging from their frequencies, which are generally the same for all images

These 3 stages are executed simultaneously

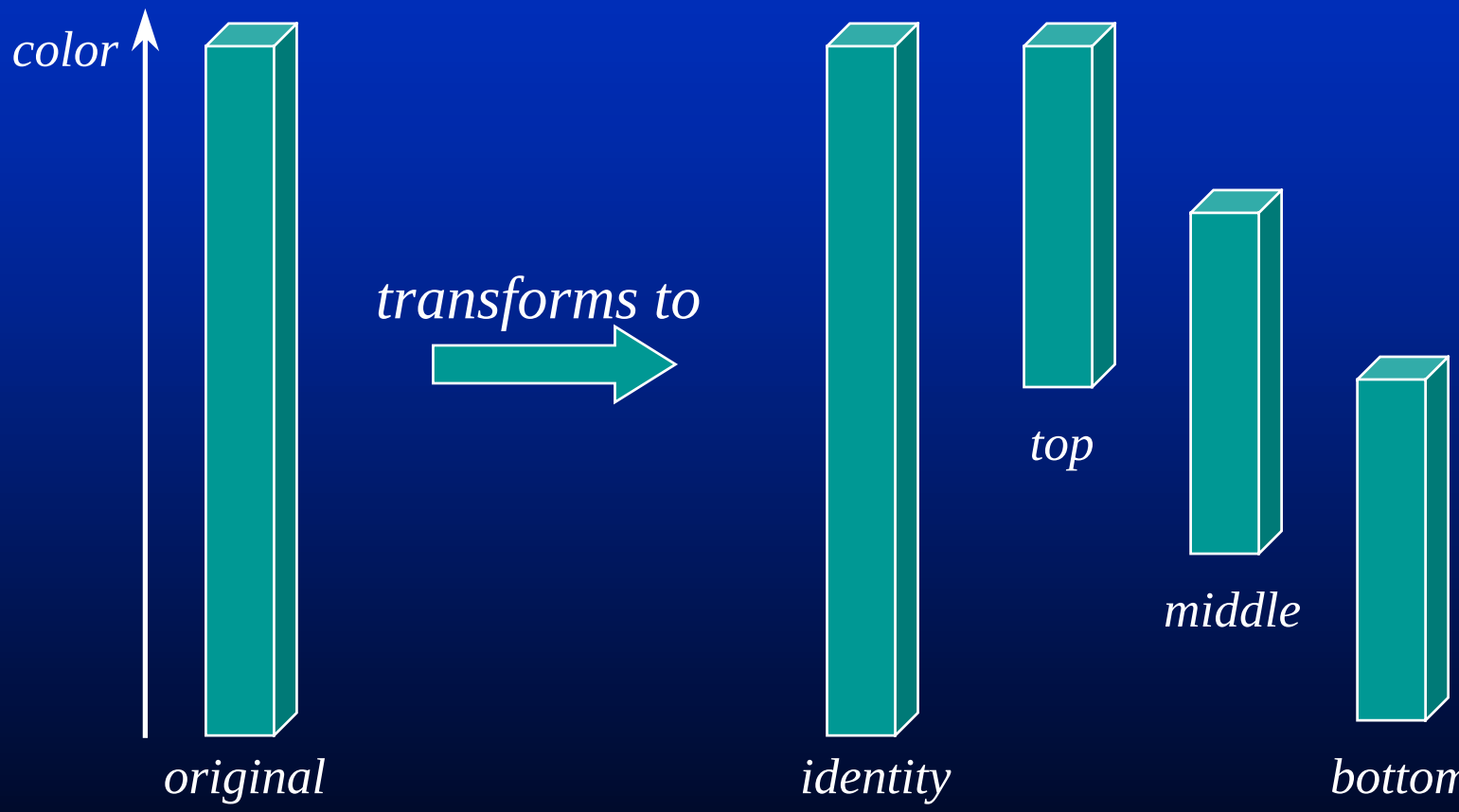
Binary Tree Representation (1)

- The root corresponds to 3D cube holding the whole image surface



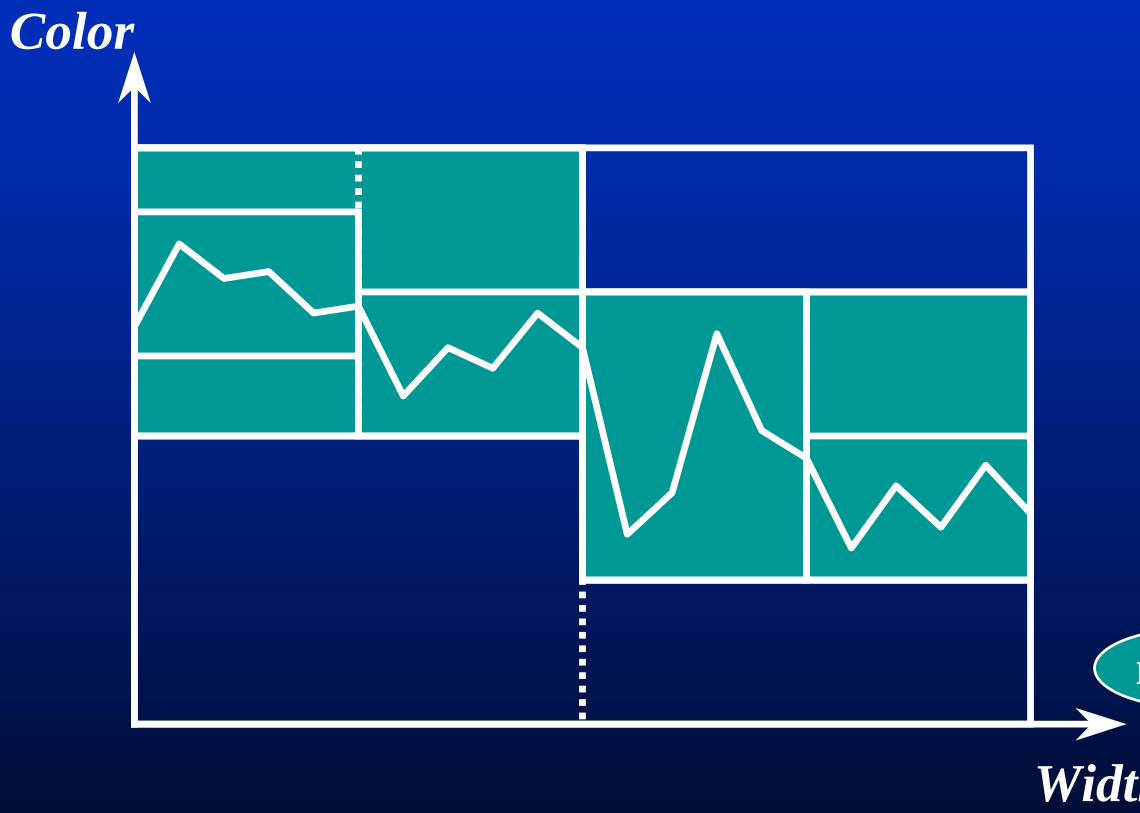
Binary Tree Representation (2)

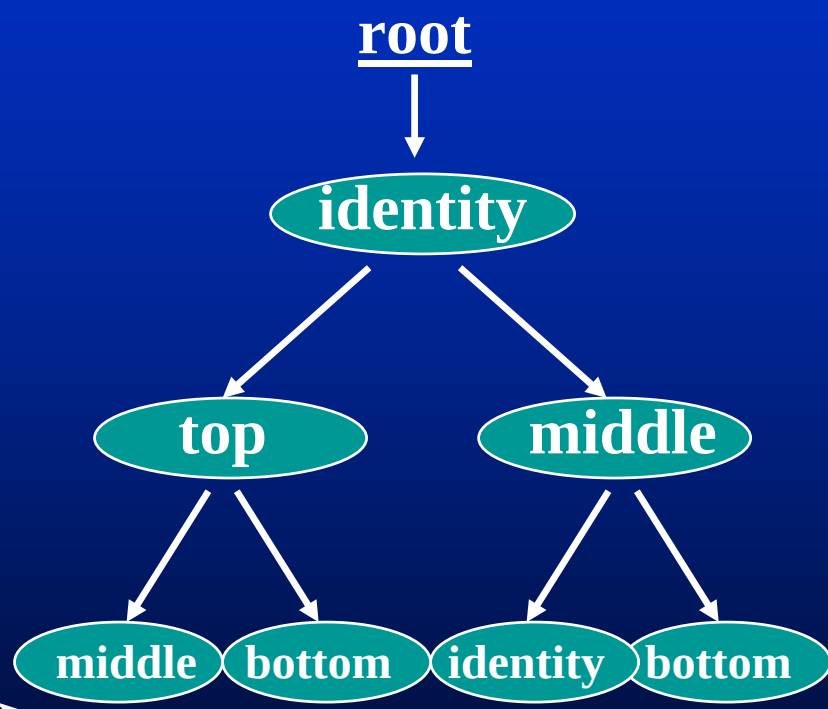
- Each tree node represents one of the contractions in color dimension



Binary Tree Representation (3)

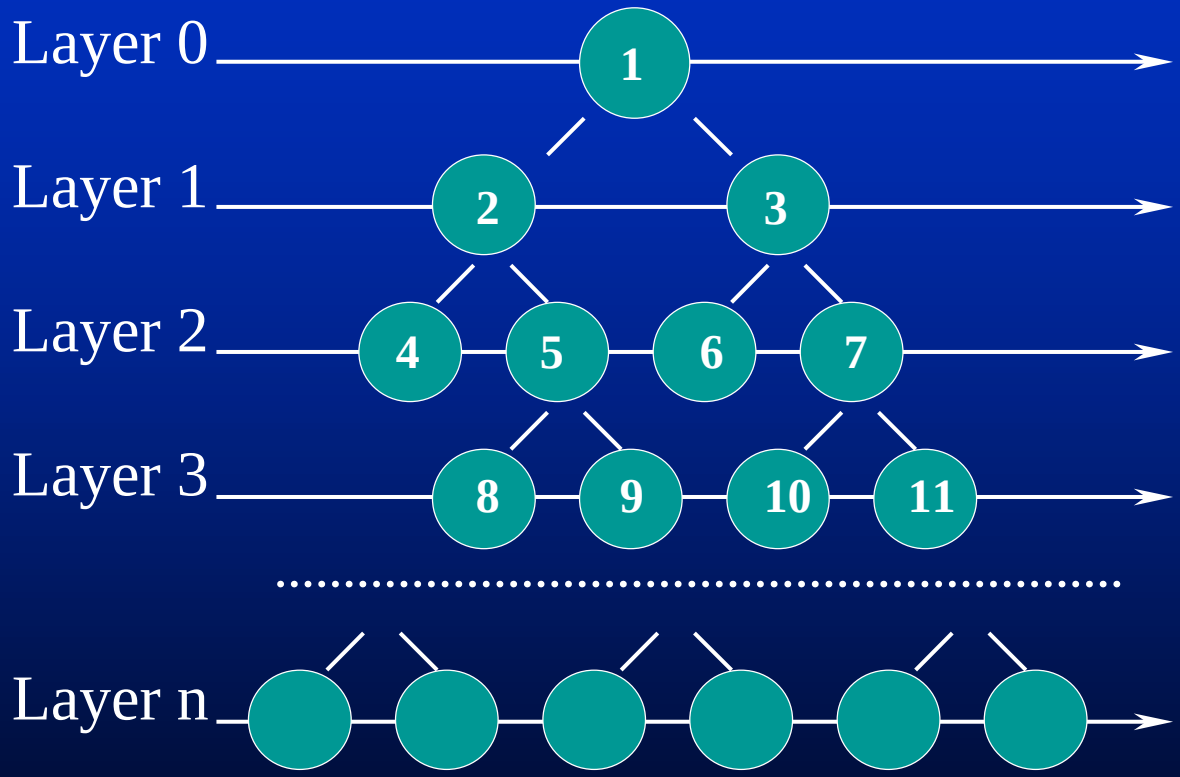
- The tree building is implemented as follows





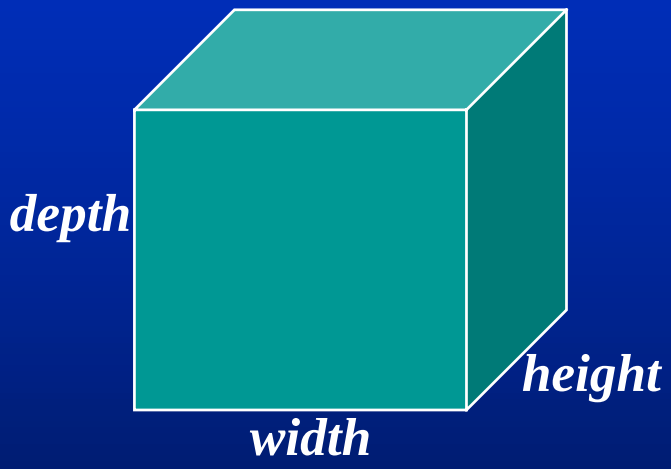
Nodes Sorting (1)

- Layer-by-Layer



Nodes Sorting (2)

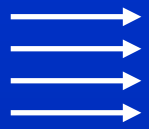
- Volume based



- ✓ Select the node with the largest volume
- ✓ Generate contraction and bisect it in X or Y direction

Volume = Width * Height * Depth

Nodes Sorting (3)



Layer-by-Layer

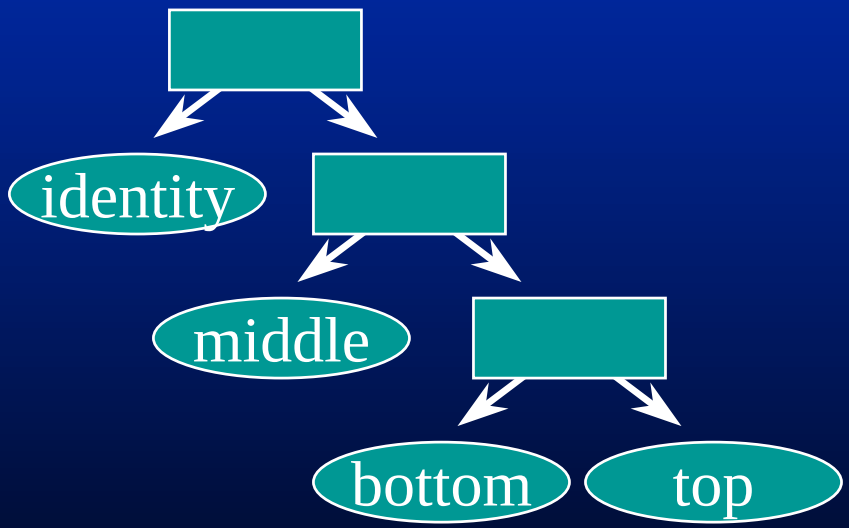
- *Construction*
  - Nodes ordering is simple and natural
- *Reconstruction*
  - MSE is not taken into consideration
  - Reconstruction is made on the uniform grid basis (like in S+P)

Volume based

- *Construction*
  - Nodes ordering procedure is a little bit more complex
- *Reconstruction*
  - MSE is considered locally to perform reconstruction
  - Areas with higher variance are updated at first order

Entropy coding

- Tree nodes (contraction operators) are coded judging from their frequencies
- Frequency histograms are much alike for all image types



Huffman tree for node values

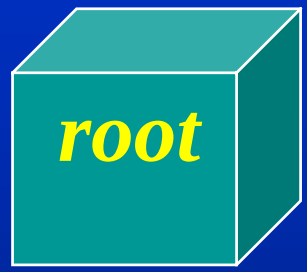
Contraction operator	Code
identity	0
middle	10
bottom	110
top	111

Image Reconstruction

Input

Bit stream: 1010010010110101O…

Decoder



= Width x Height x Depth

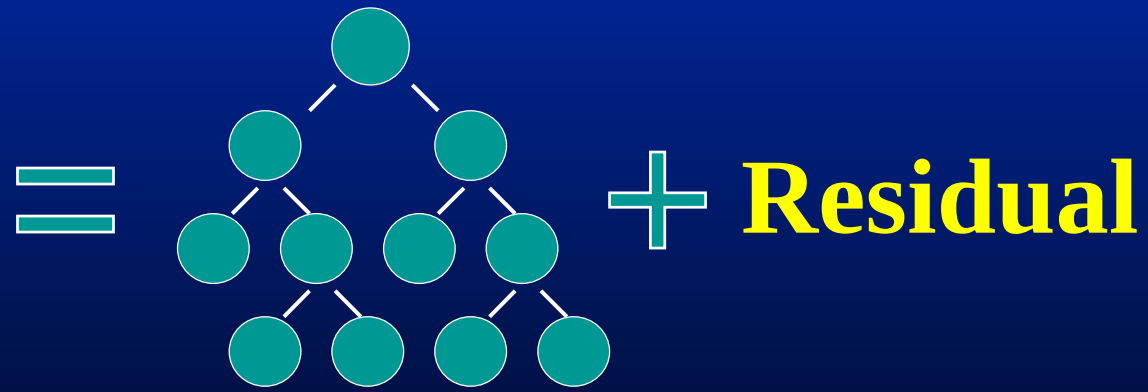
1. Get next code (Huffman)
2. Select the corresponding node
3. Apply the corresponding contraction in color dimension
4. Form children = Bisect parallelepiped in X or Y dimension
5. Goto 1

Tree Truncation (1)

- Our research showed that it is better to construct the tree up to the certain level, such as

Layer = 7 or Volume = 32 or Area = 4

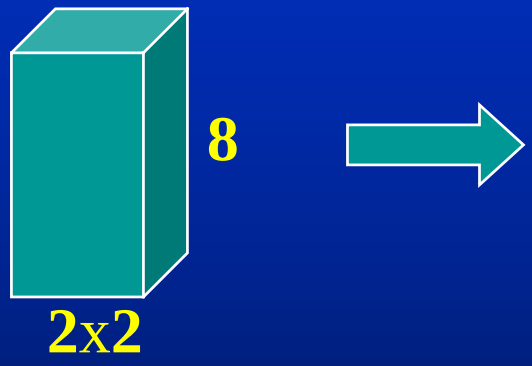
Original image



Tree Truncation (2)

- Residual storage

Volume (*Node*) = 32



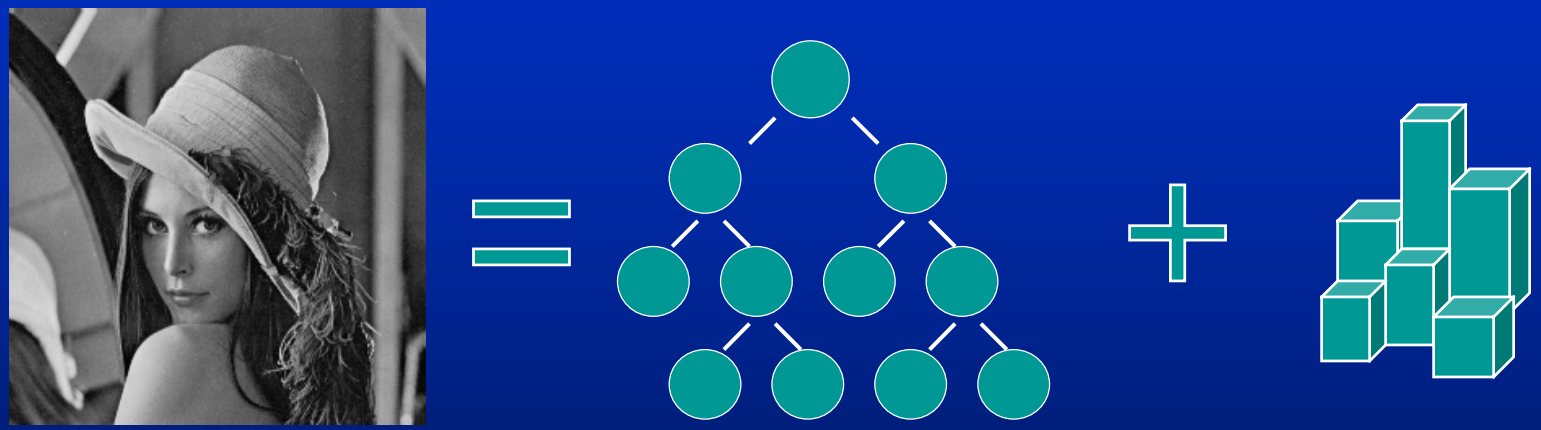
4 *pixels* * **3** *bits/pixel* = **12** *bits*

- We state: *For some tree limit (depending on image) the residual can not be efficiently coded with entropy coding methods.*

Residual = Incompressible Noise

Practical Results (1)

- Compression of *Lena* image



Original image
65536 (100%)

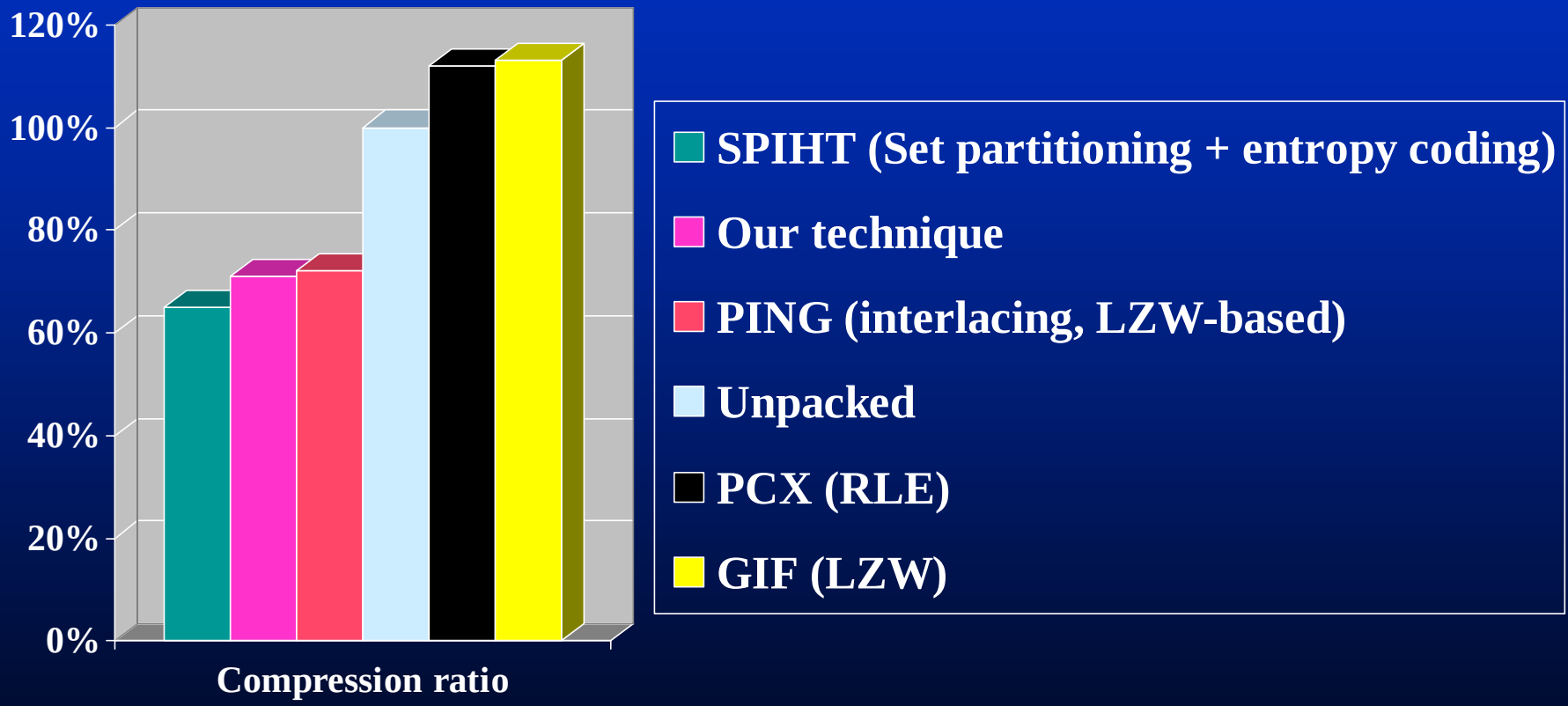
depth = 16 or *area* = 4
7332 (11%)

Residual
39515 (71%)

Total: 46847 (71%)

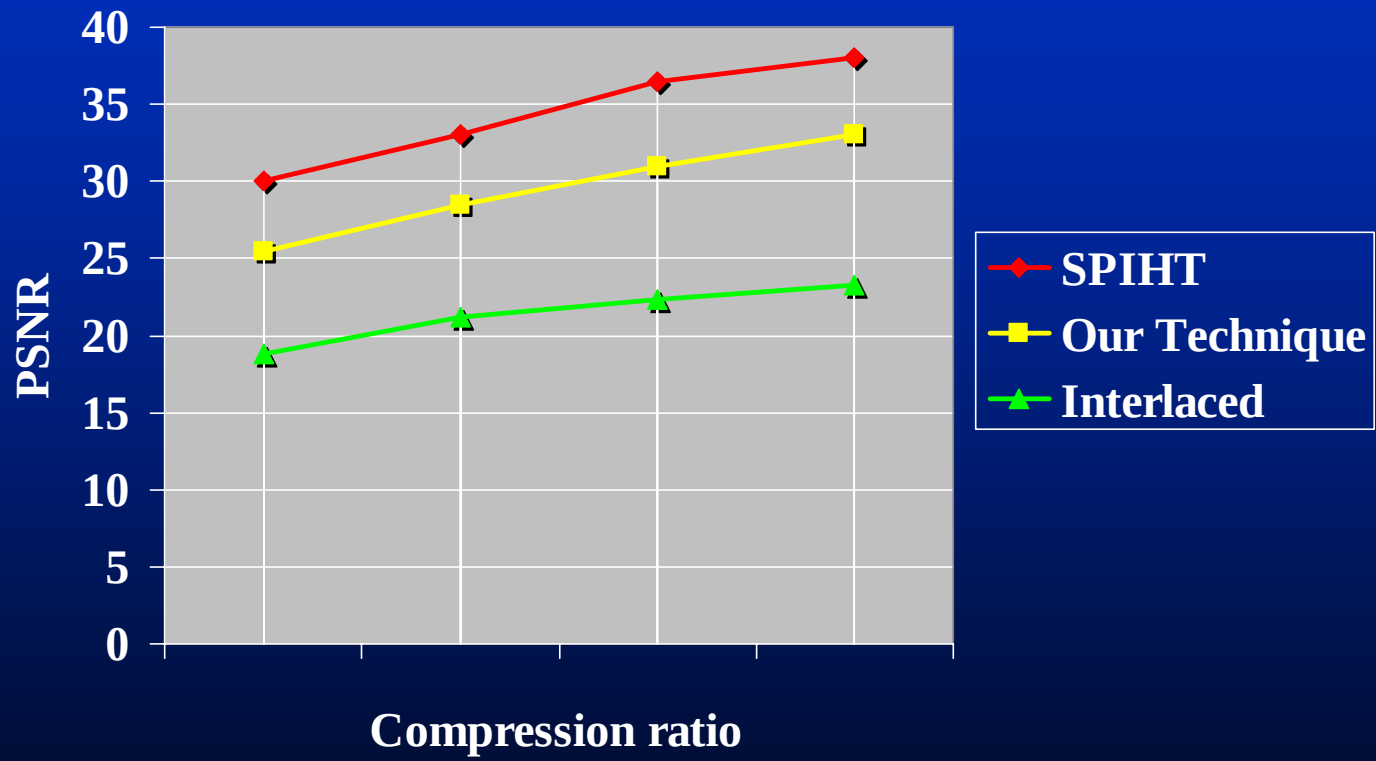
Practical Results (2)

- Compression ratio (*Lena* image)



Practical Results (3)

- Visual quality (*Lena* image)



Practical Results (4)

Lena (*256* x *256* x *256*) - scaled

8 bpp (100%)

Range of Use

- Efficient lossless compression of important data
  - » High compression ratios
- Fast inspection of large image sets via network
  - » Only a short messages should be extracted to reconstruct image sketches
- Hardware implementation
  - » Very simple algorithm
  - » Parallelism

Acknowledgements

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