Volume Rendering Based on Distribution Data

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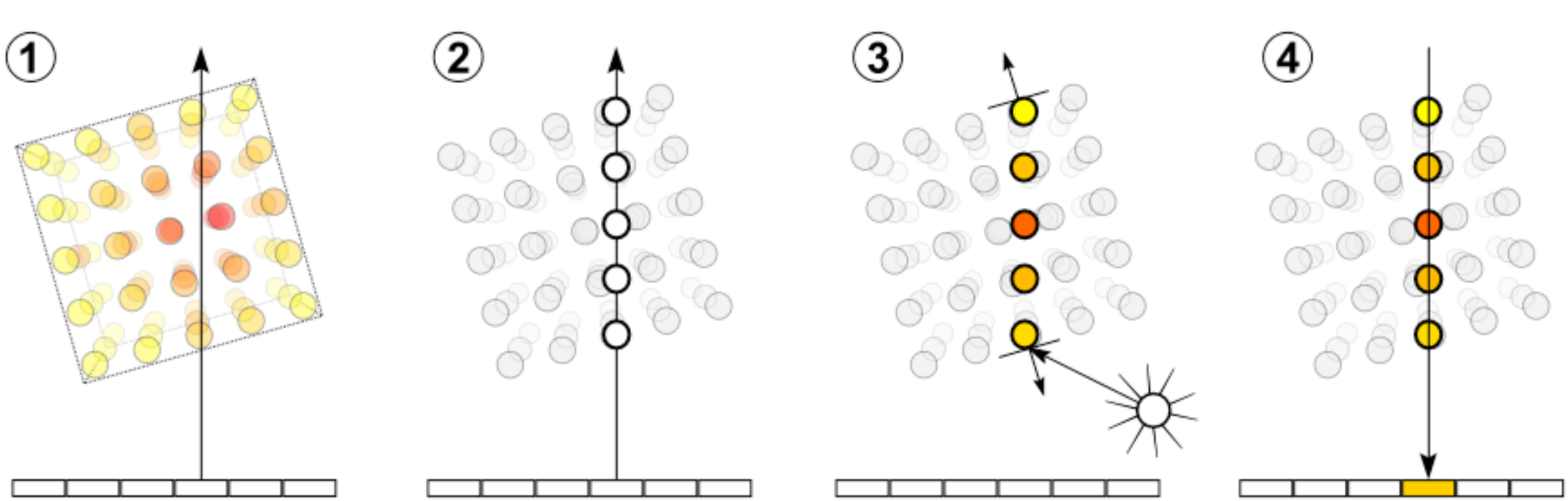
Introduction

- We implemented a way of interactively querying and visualizing large scale dataset
- Our query and visualization is based on histograms of the block regions of the raw data
- We can render distribution data by statistic measures, such as mean, variance, entropy
- We applied similarity-based coding algorithm to reduce the data size

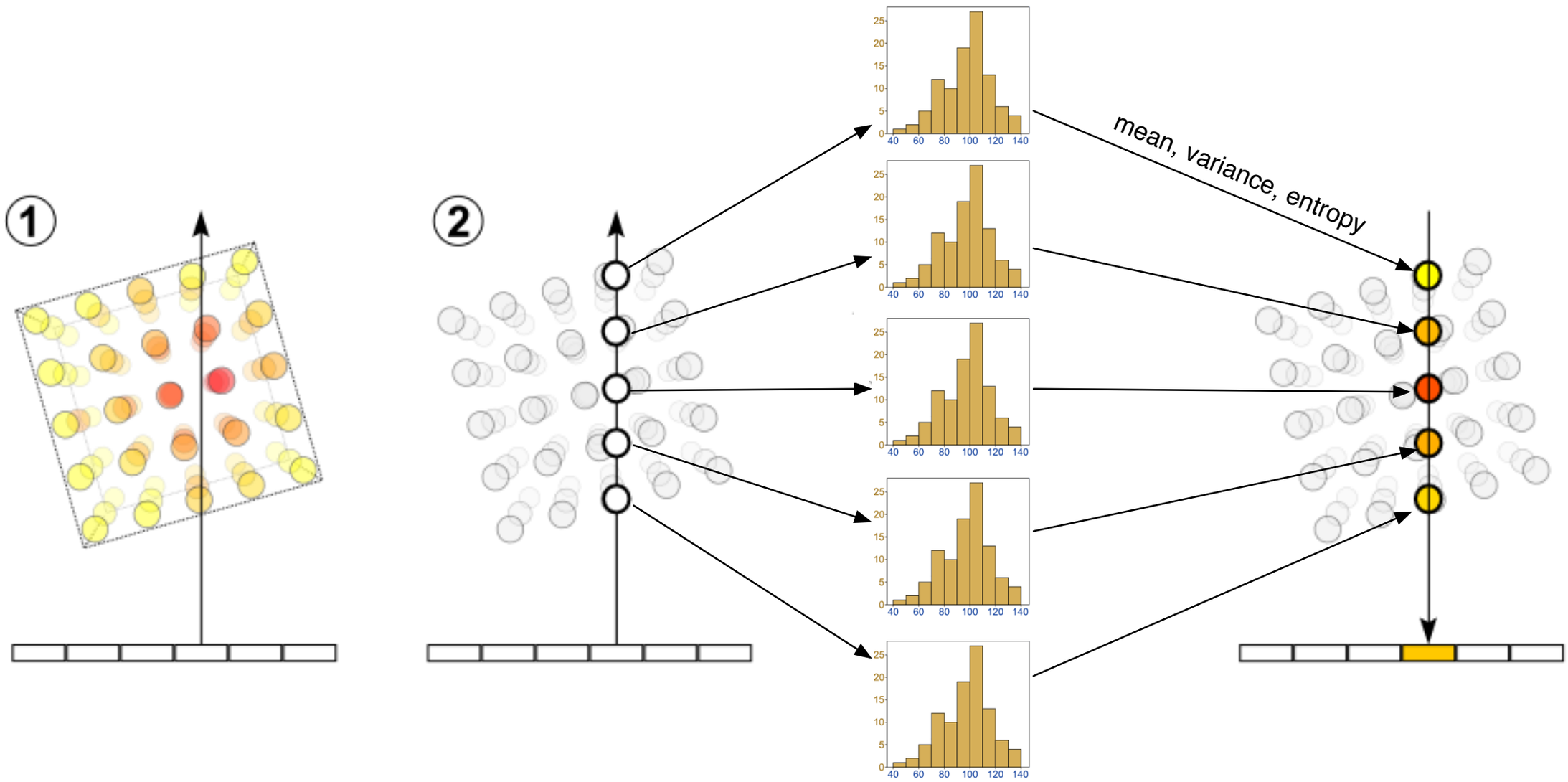
Background

- GPU based volume rendering
  - Direct volume ray casting with 3D texture



Background

- GPU based volume rendering <u>with histogram</u>



Background

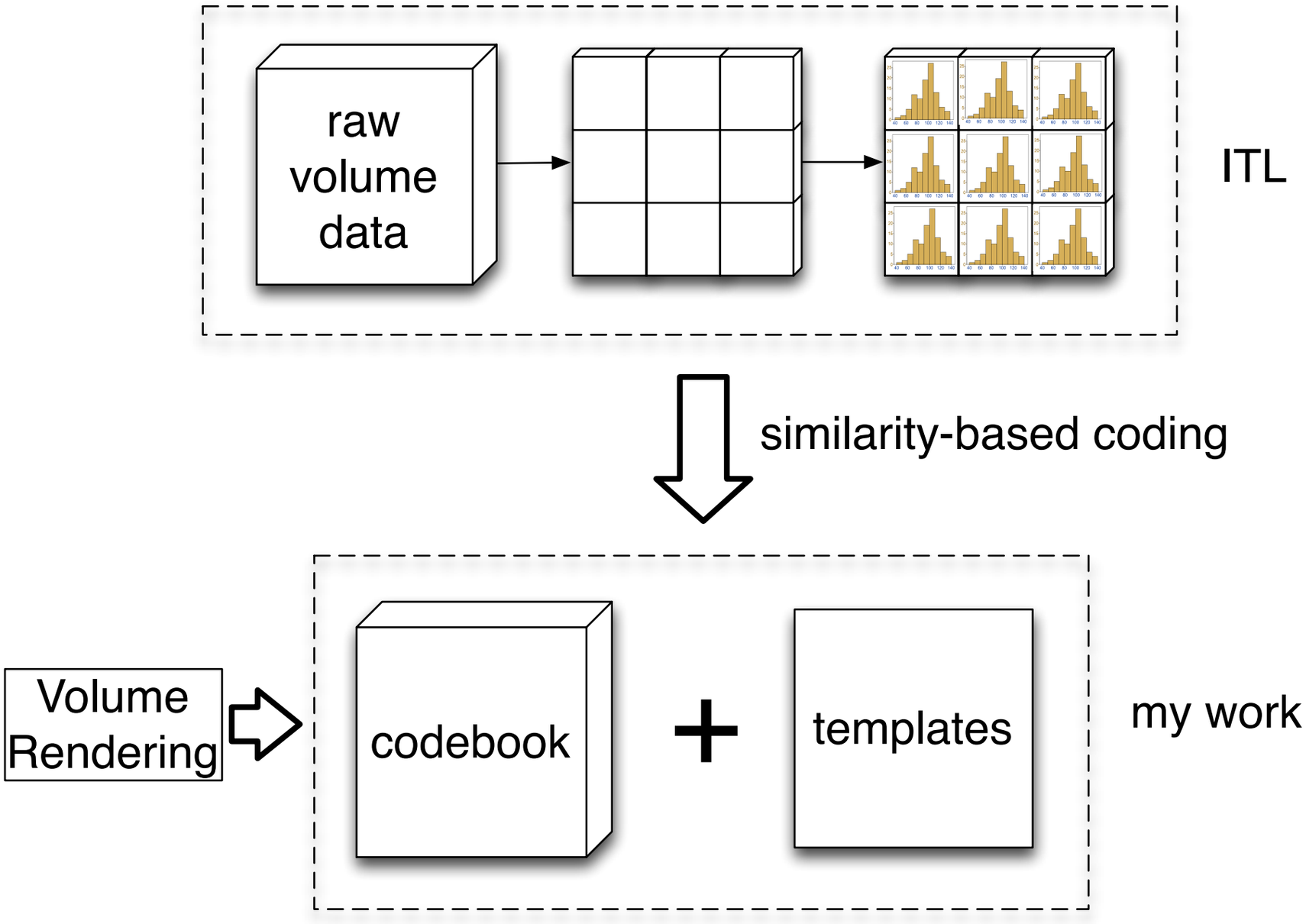
- Measures of distribution data
  - Mean: $$H(x) = -\sum_{i=1}^{n} p_i \times \log(p_i)$$
  - Variance: $$Var(x) = \sum_{i=1}^{n} p_i \times (x_i - \mu)^2$$
  - Entropy: $$H(x) = -\sum_{i=1}^{n} p_i \times \log(p_i)$$

Background

- Similarity-based coding algorithm
  - The idea is from fractal image compression
  - Based on the fact of self-similarity
  - Encode the volume data into templates with transformations

Background

- Input data:



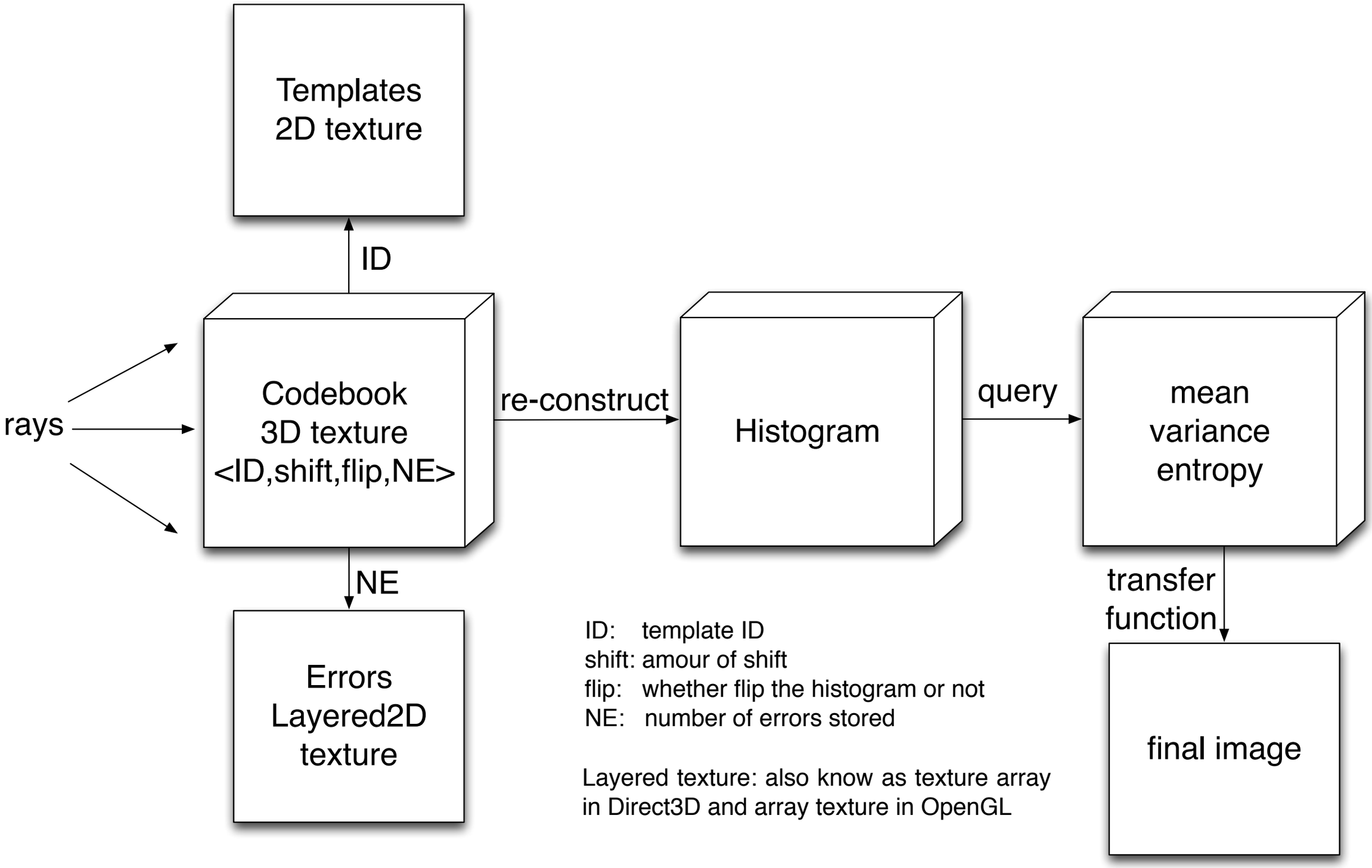
Background

- CUDA 5.0
  - Parallel computing
    - cuda_kernel<<<nBlock, nThreads>>>();
- Graphics features
  - volume rendering

Similarity-based Coding Algorithm

- **histogram → template + transformation**
- A template is a histogram.
  - number of histograms >> number of templates
- Transformation: circular shift and flip.
  - right shift each bin
  - flip the histogram if necessary
  - number of histogram bins >> (tempateID, shift, flip)
- Error control (optional): error information of histograms

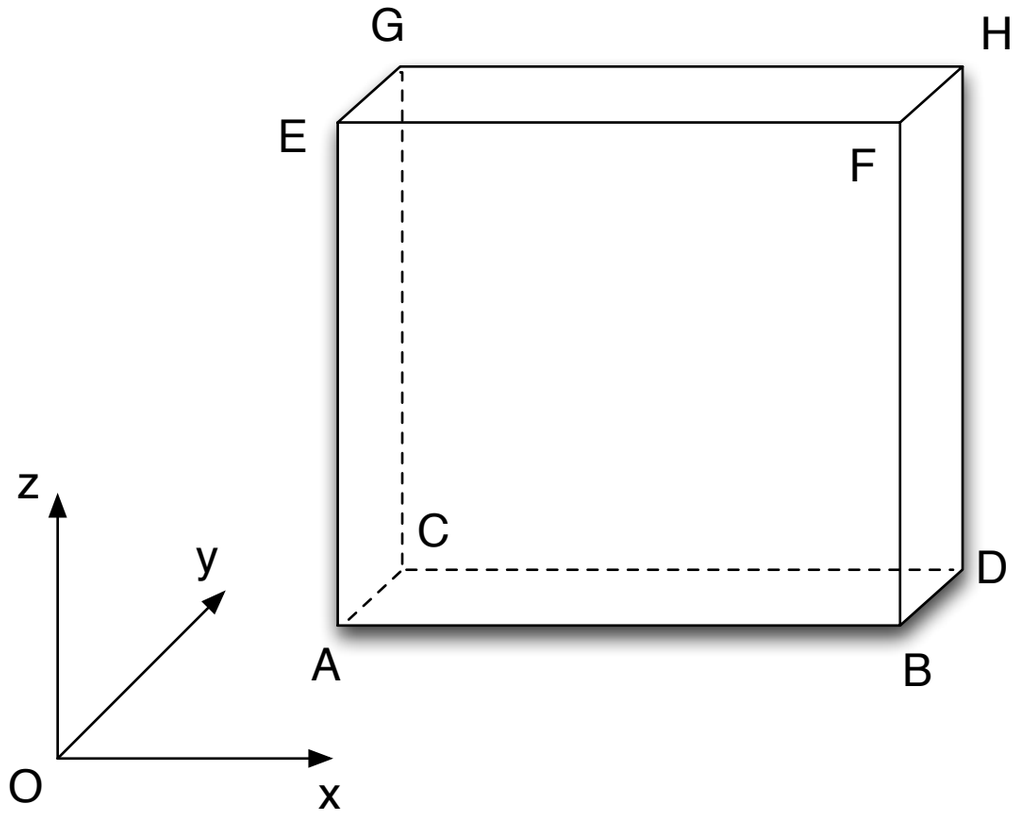
Pipeline of Volume Rendering Based on Distribution Data



Query Flexible Block Size Distribution

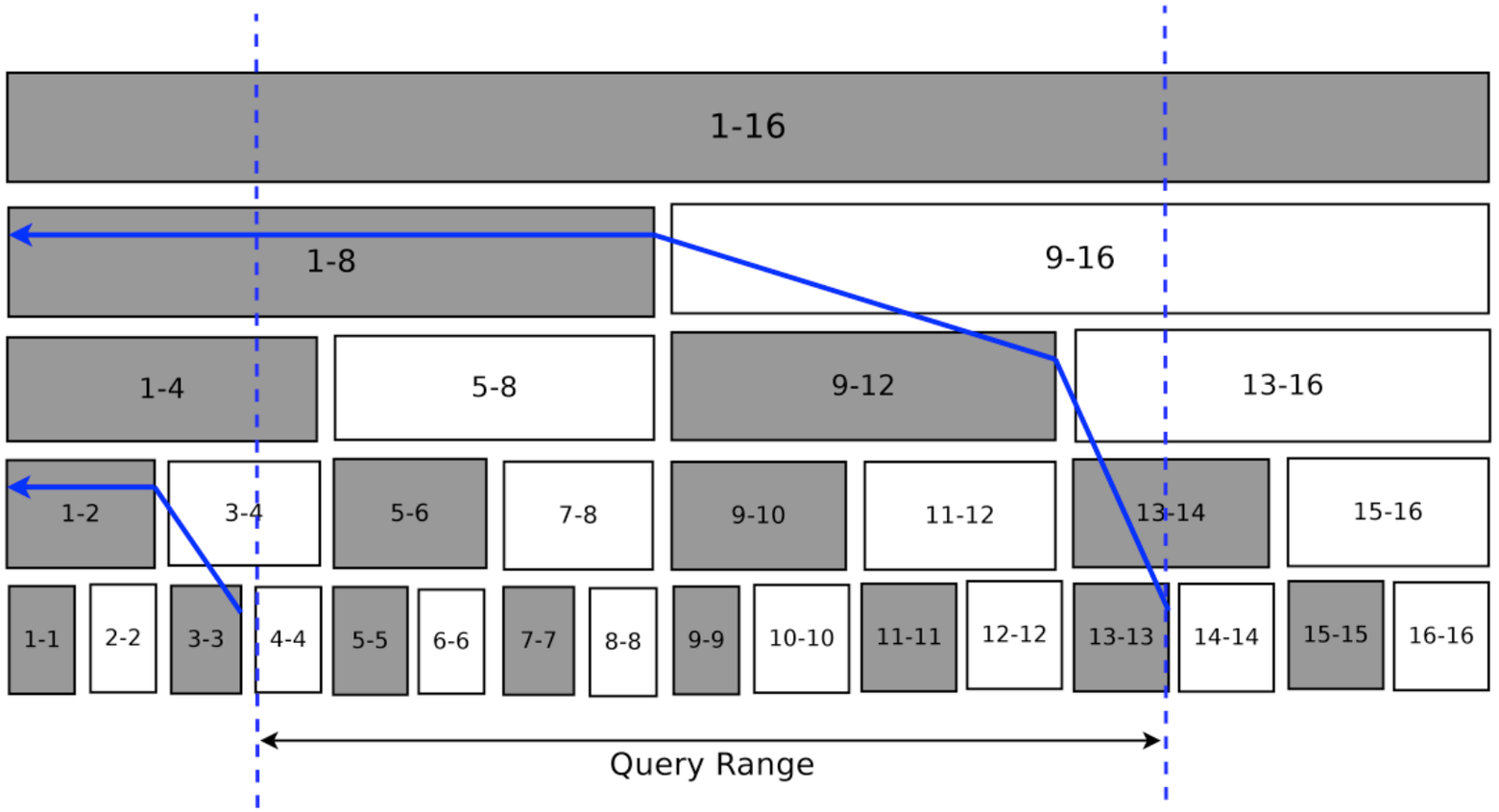
- If we allow user to query distribution of arbitrary block size, things become much more complex
  - Integral Distribution: the distribution from origin to each data point (similar to summed area table)
  - Reconstruct integral distribution from a hierarchy of block-level distributions (reducing storage cost)

Integral Distribution



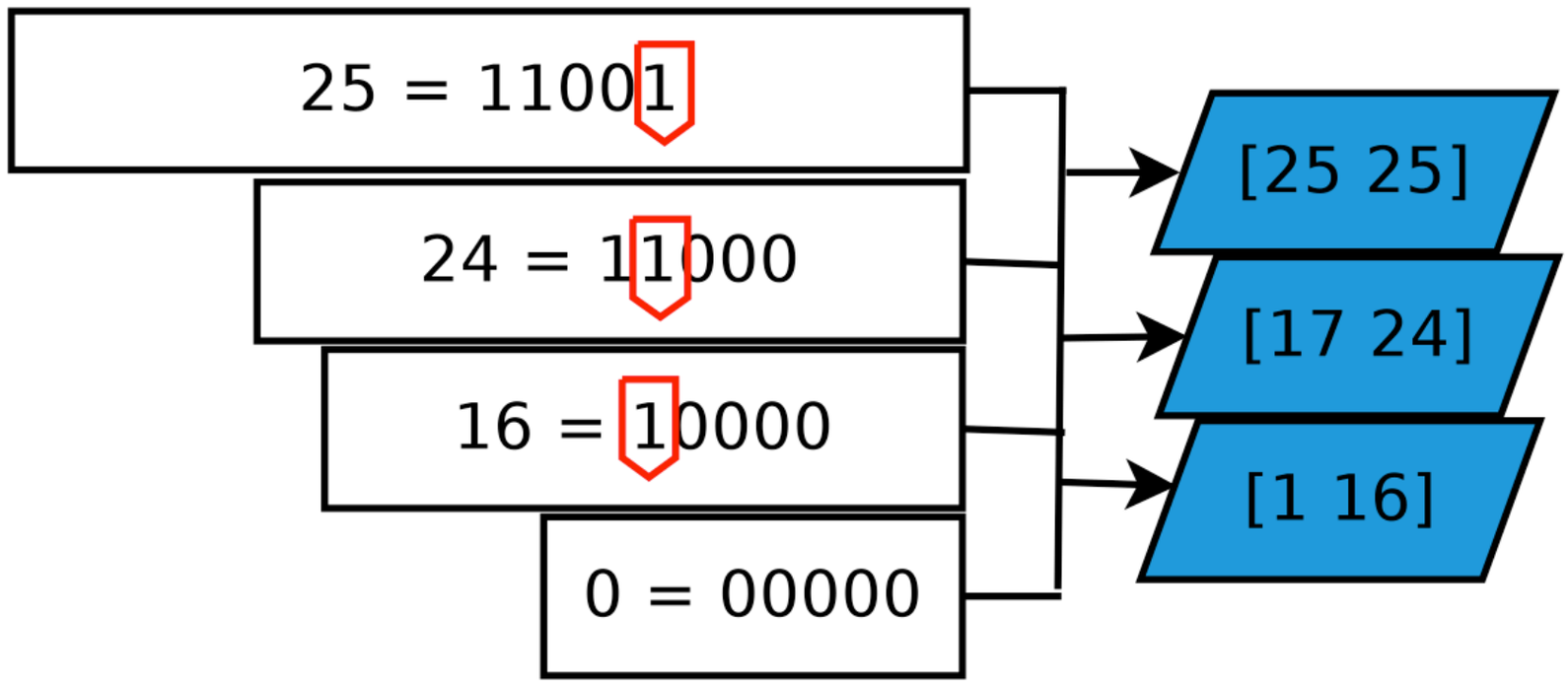
$$H(ABCDEFGH) = H(A) + H(D) + H(E) + H(H)$$
$$- H(B) - H(C) - H(F) - H(G)$$

a Hierarchy of Block Level Distribution



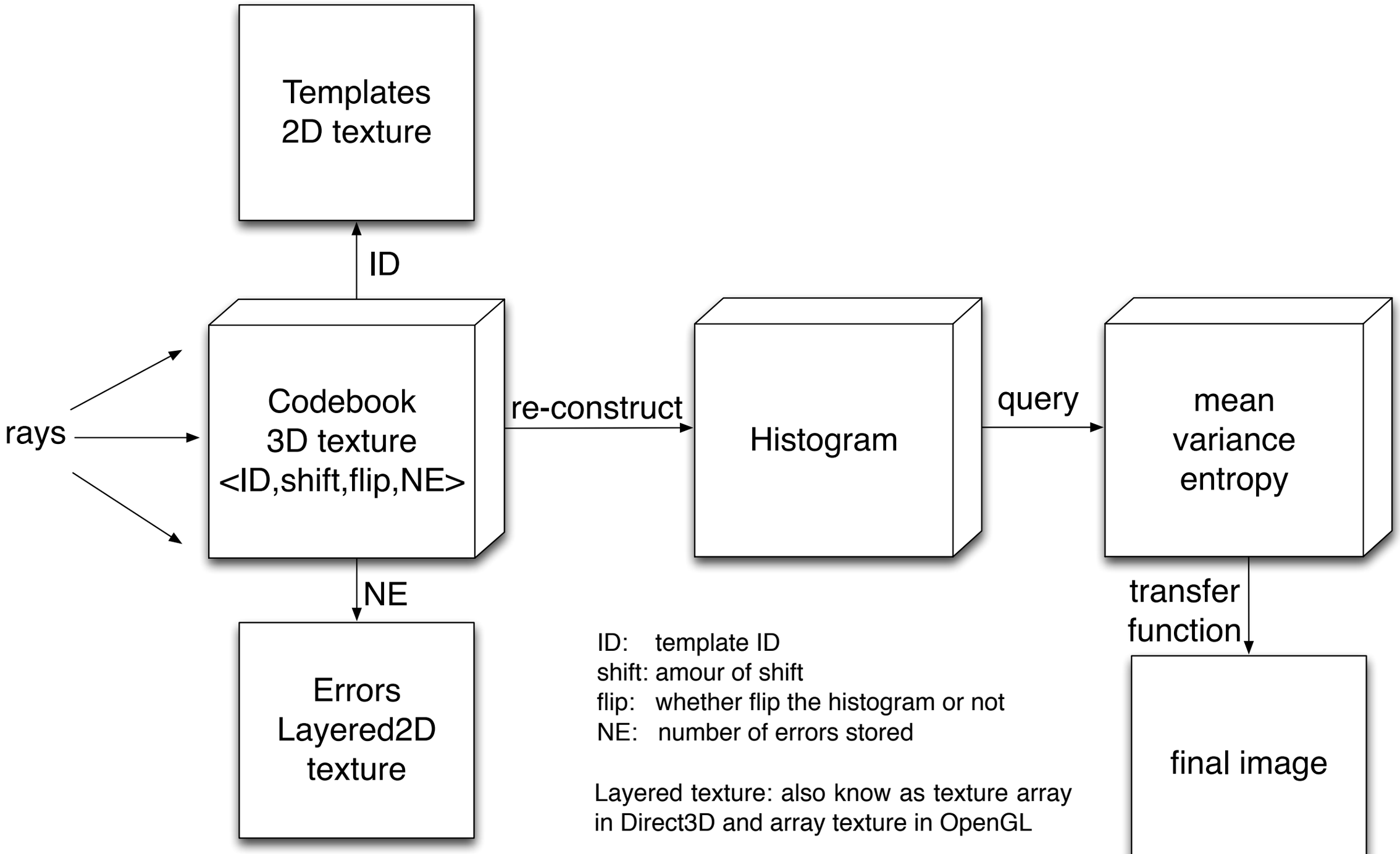
- An octree of distributions
- Each block has size power-of-two

Decompose a block into sub-blocks

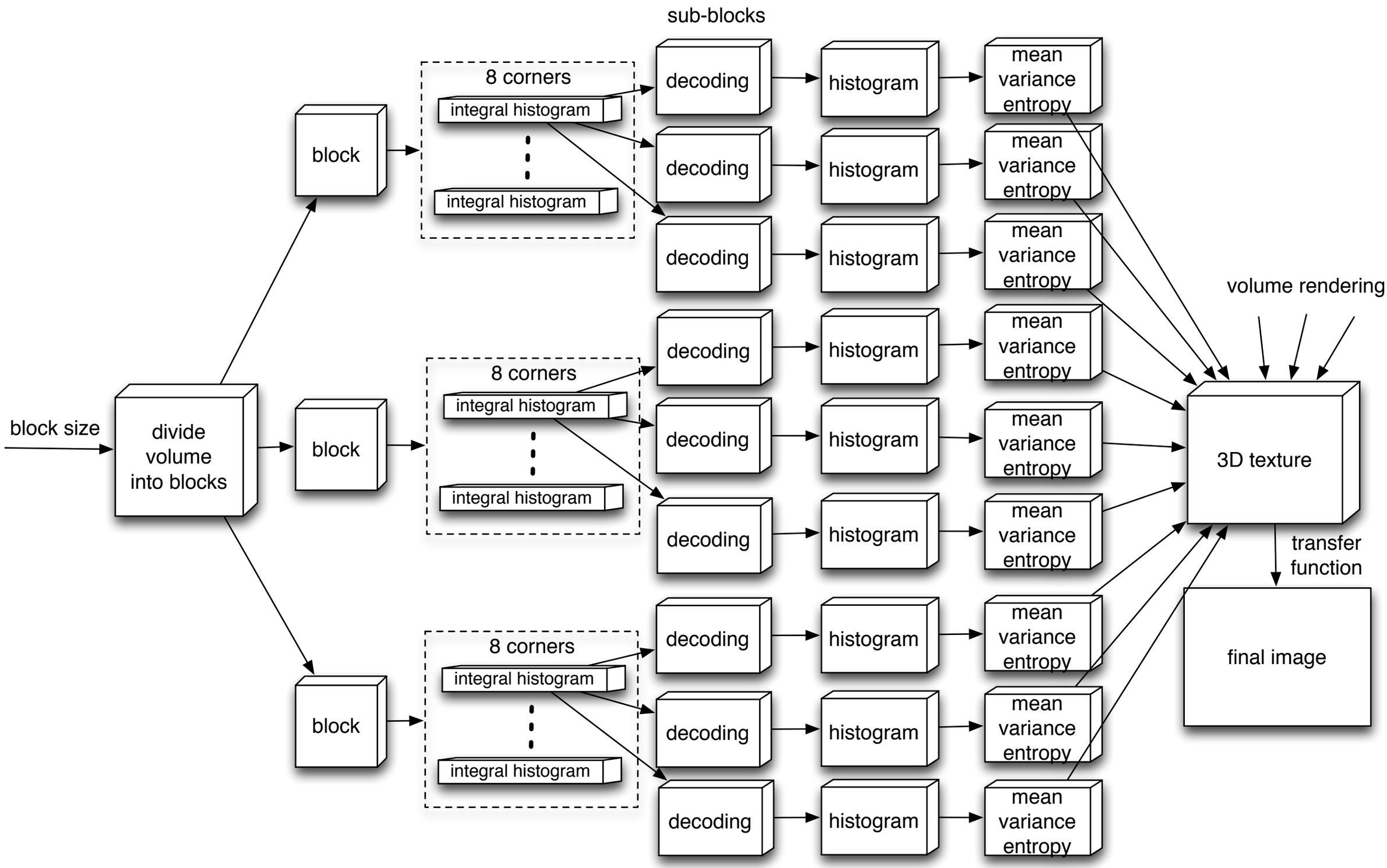


- Use bitwise operation to decompose query range into power-of-two sub-range
- Assume each dimension has N sub-ranges, then the block has N*N*N sub-ranges

Pipeline of Volume Rendering Based on Distribution Data



Pipeline of Volume Rendering Based on Distribution Data With **Flexible Block Size**



Platform

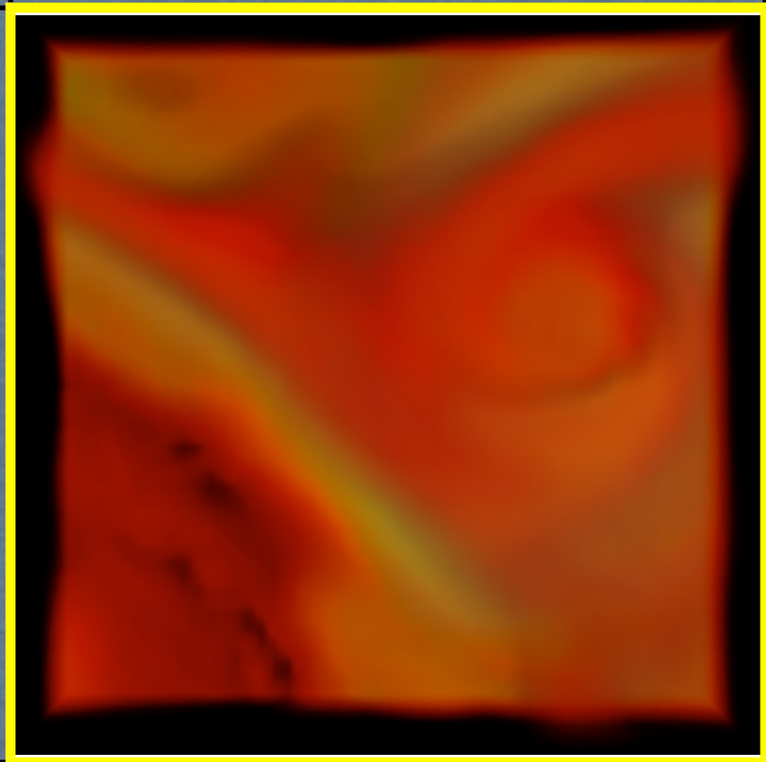
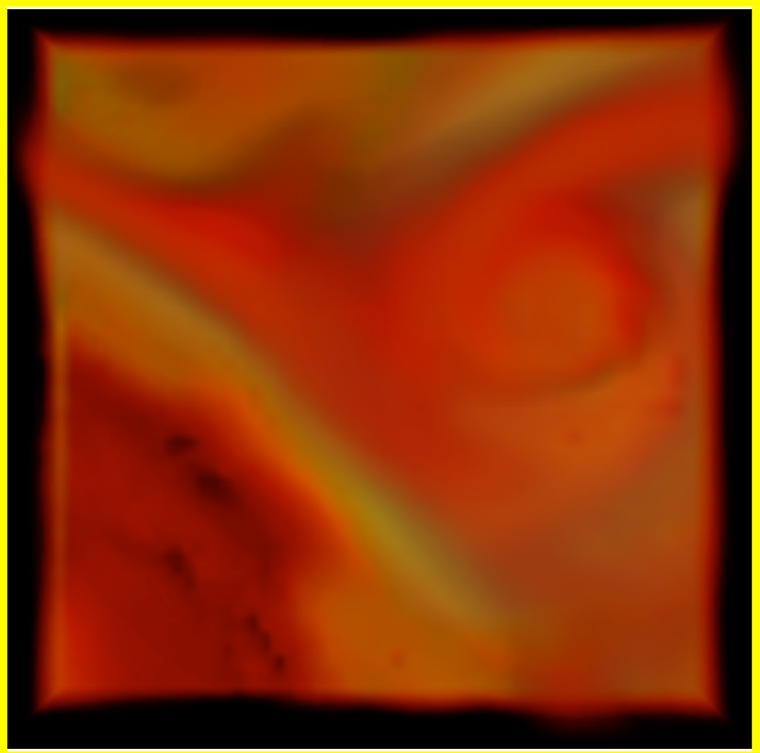
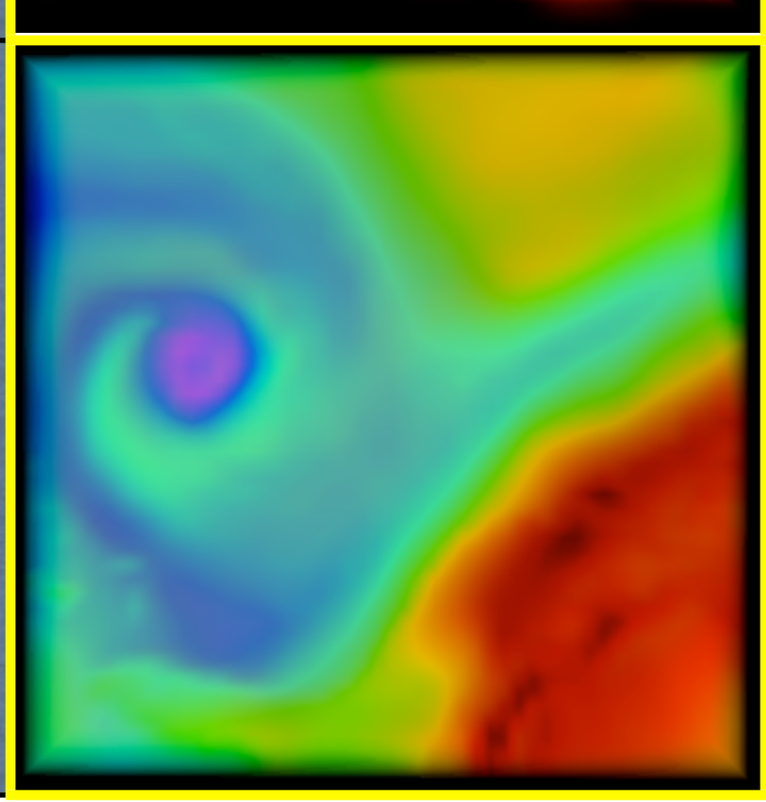
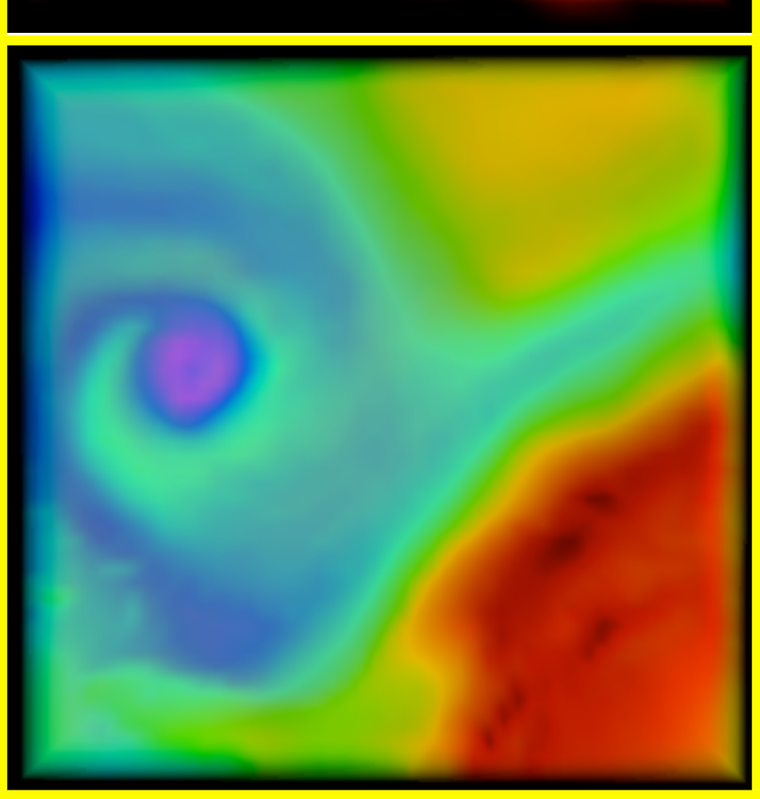
- Windows 7 64 bit
- Intel i7-3770 3.40 GHz CPU
- 16.0 GB RAM
- Nvidia Quadro K5000 Graphics Card
- Visual Studio 2010
- CUDA 5.0
- OpenGL and GLUT

Result and Comparison

	raw data	block histogram	encoded block histogram
data size	100MB	3.2MB	1.5MB (codebook) + 189 KB (templates)
resolution	500x500x100	50x50x10, 32bins	50x50x10, 32bins

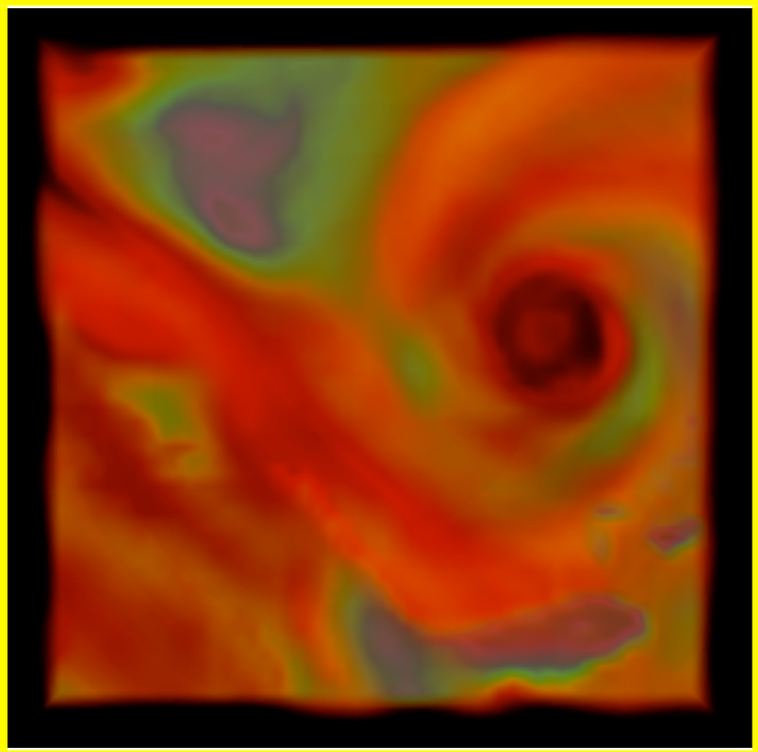
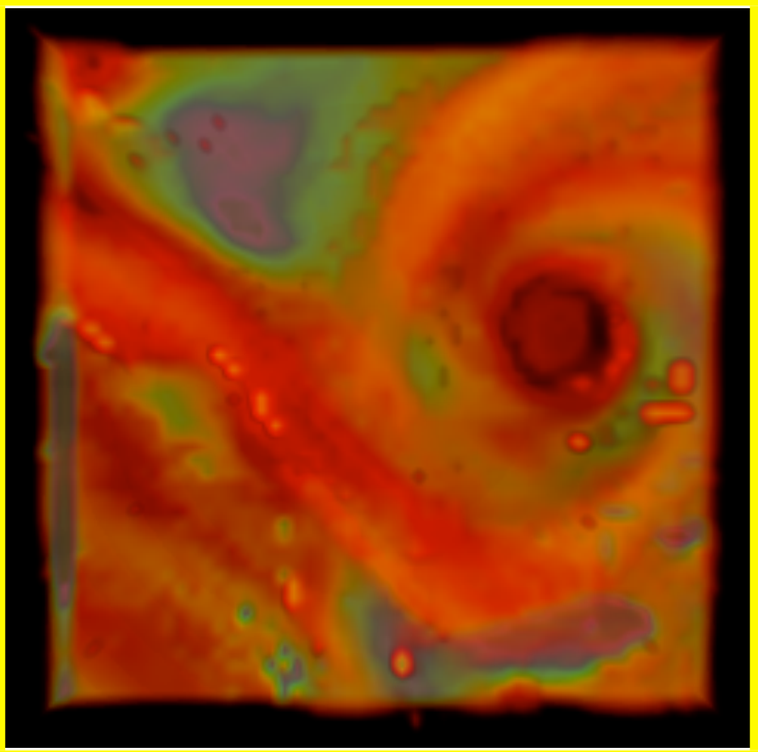
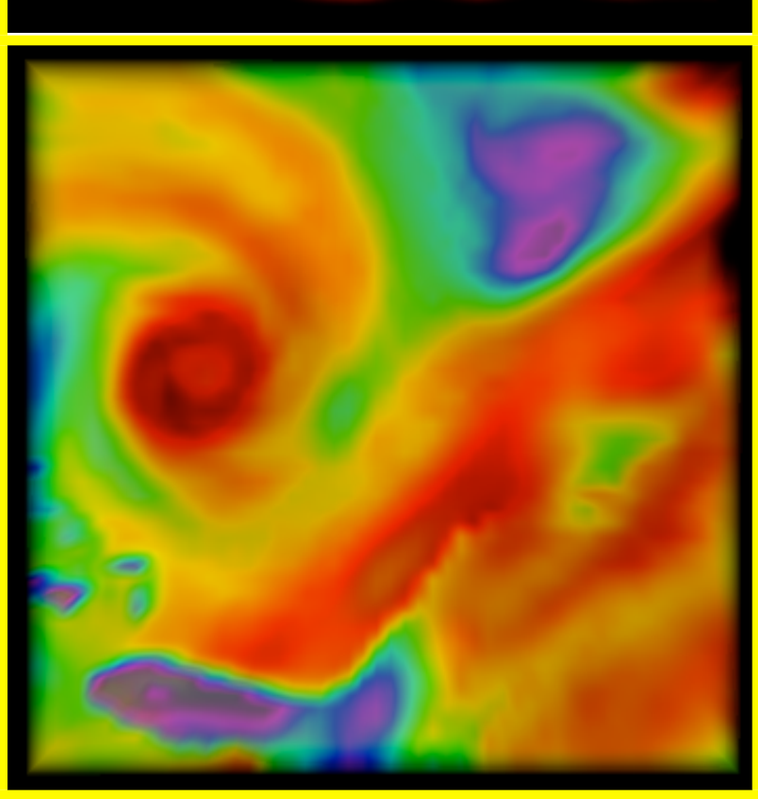
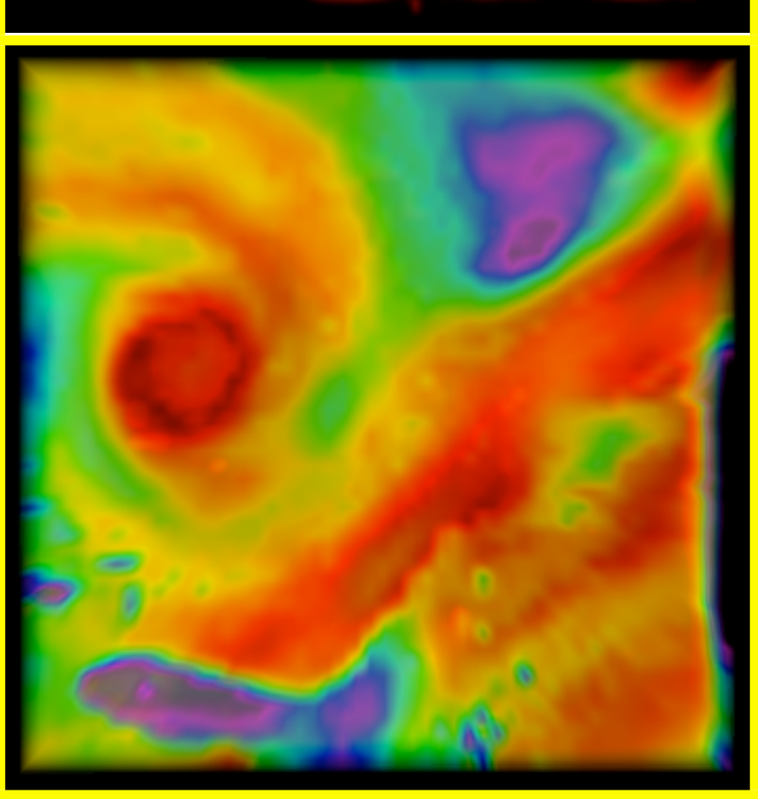
- Isabel Hurricane Dataset
- Histogram is a good choice for data reduction, flexible to change number of bins
- Similarity-based coding algorithm is effective to compress histogram data
- Frame rate: 60 fps

Comparing Mean Query

	block histogram	encoded block histogram
front side		
back side		

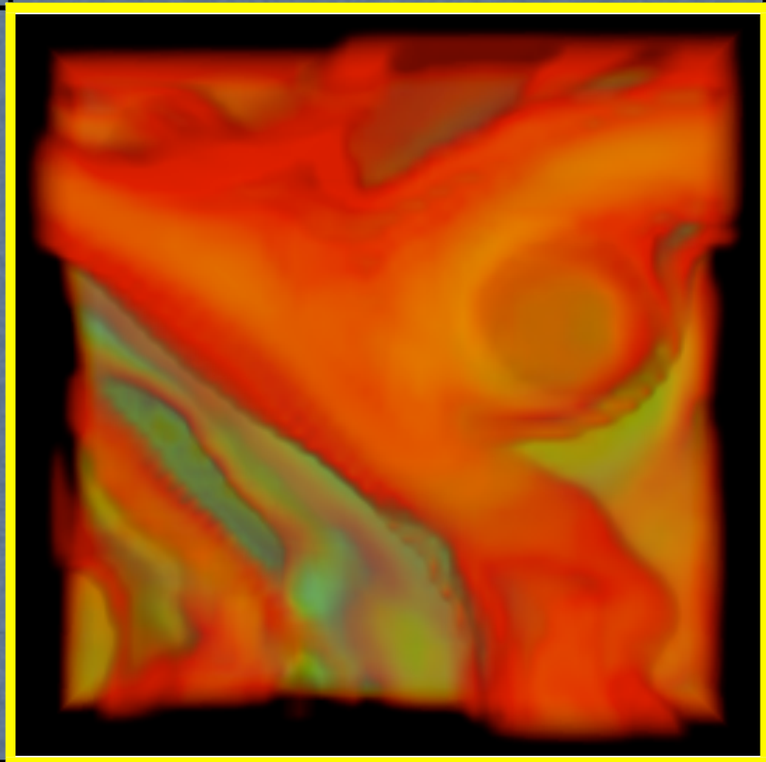
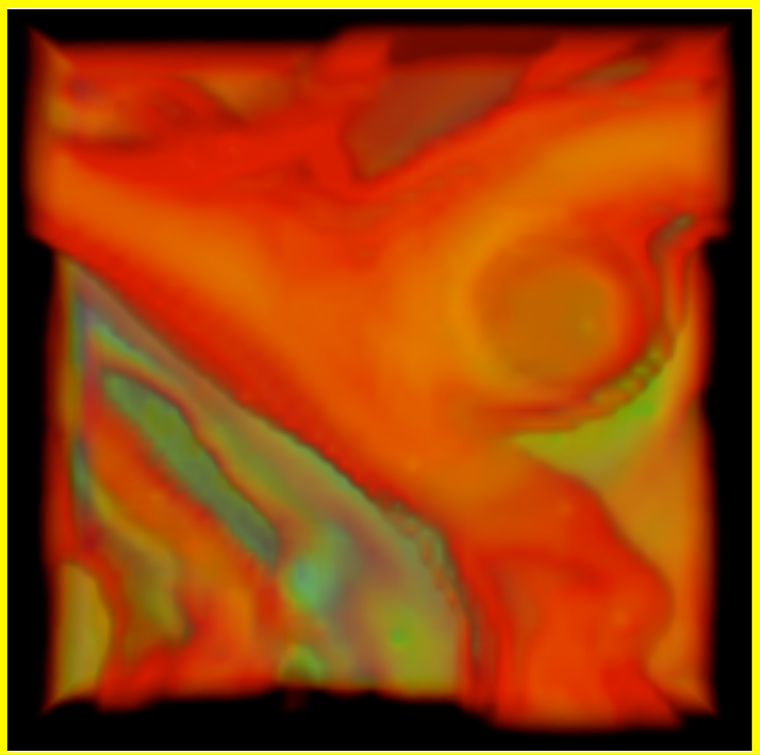
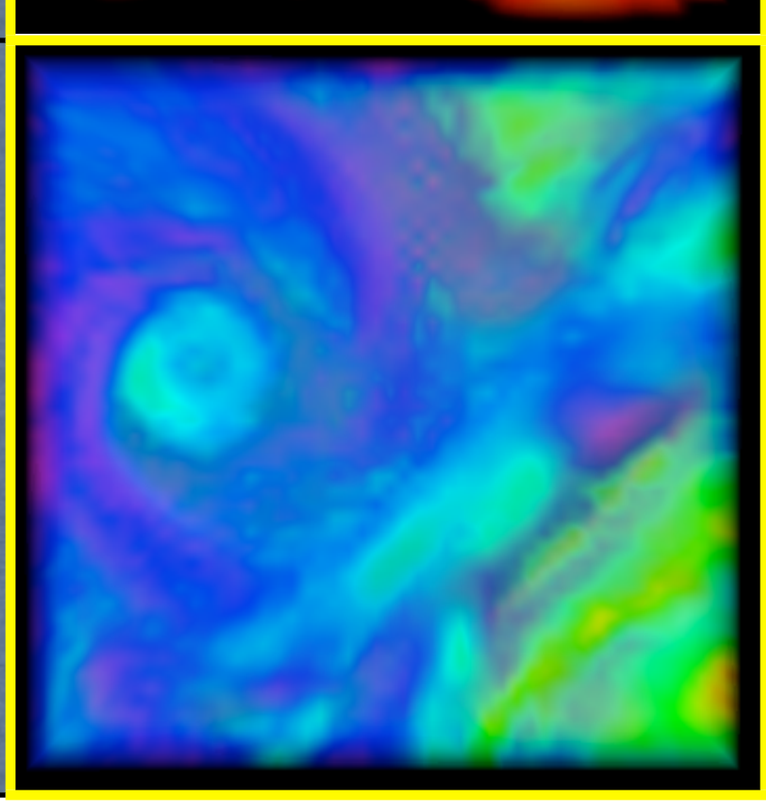
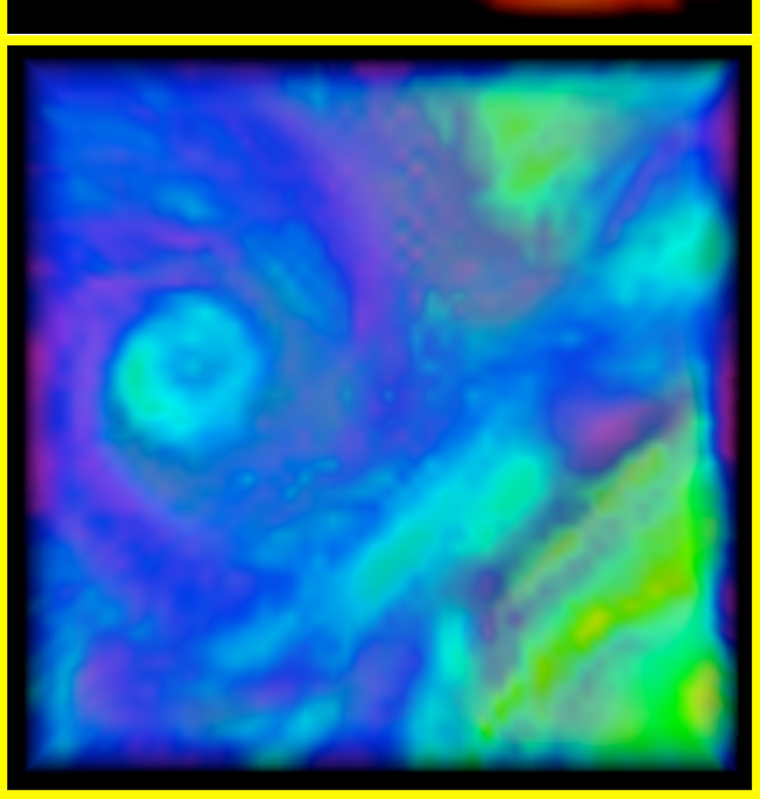
color map: 

Comparing Variance Query

	block histogram	encoded block histogram
front side		
back side		

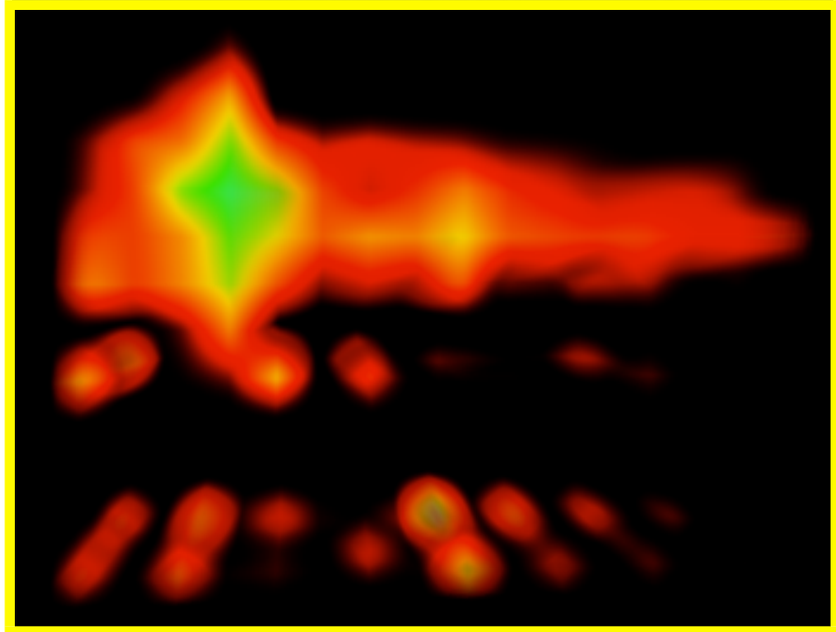
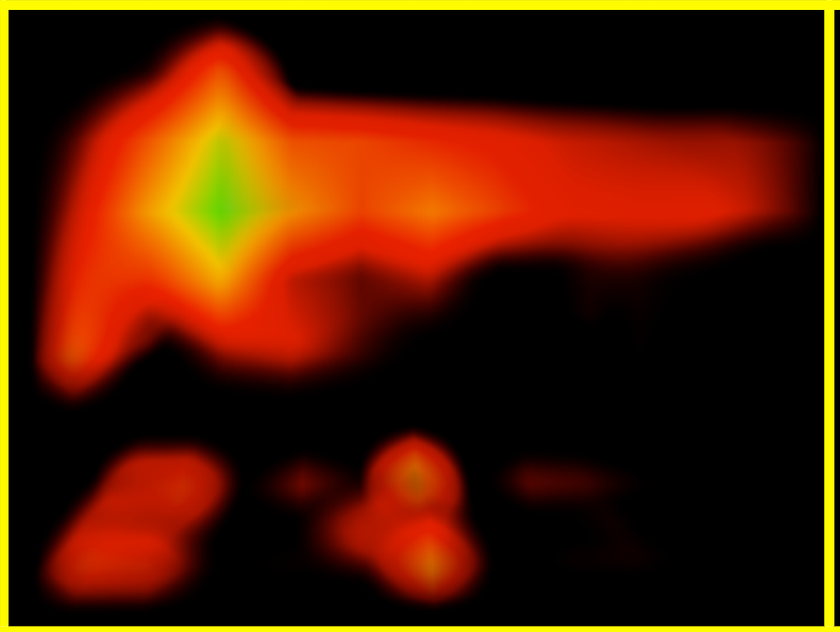
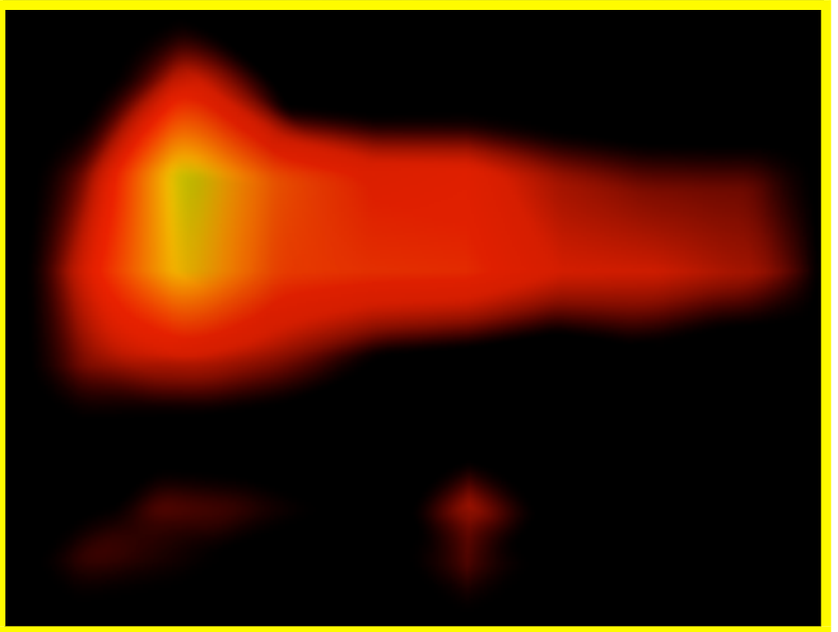
color map: 

Comparing Entropy Query

	block histogram	encoded block histogram
front side		
back side		

color map: 

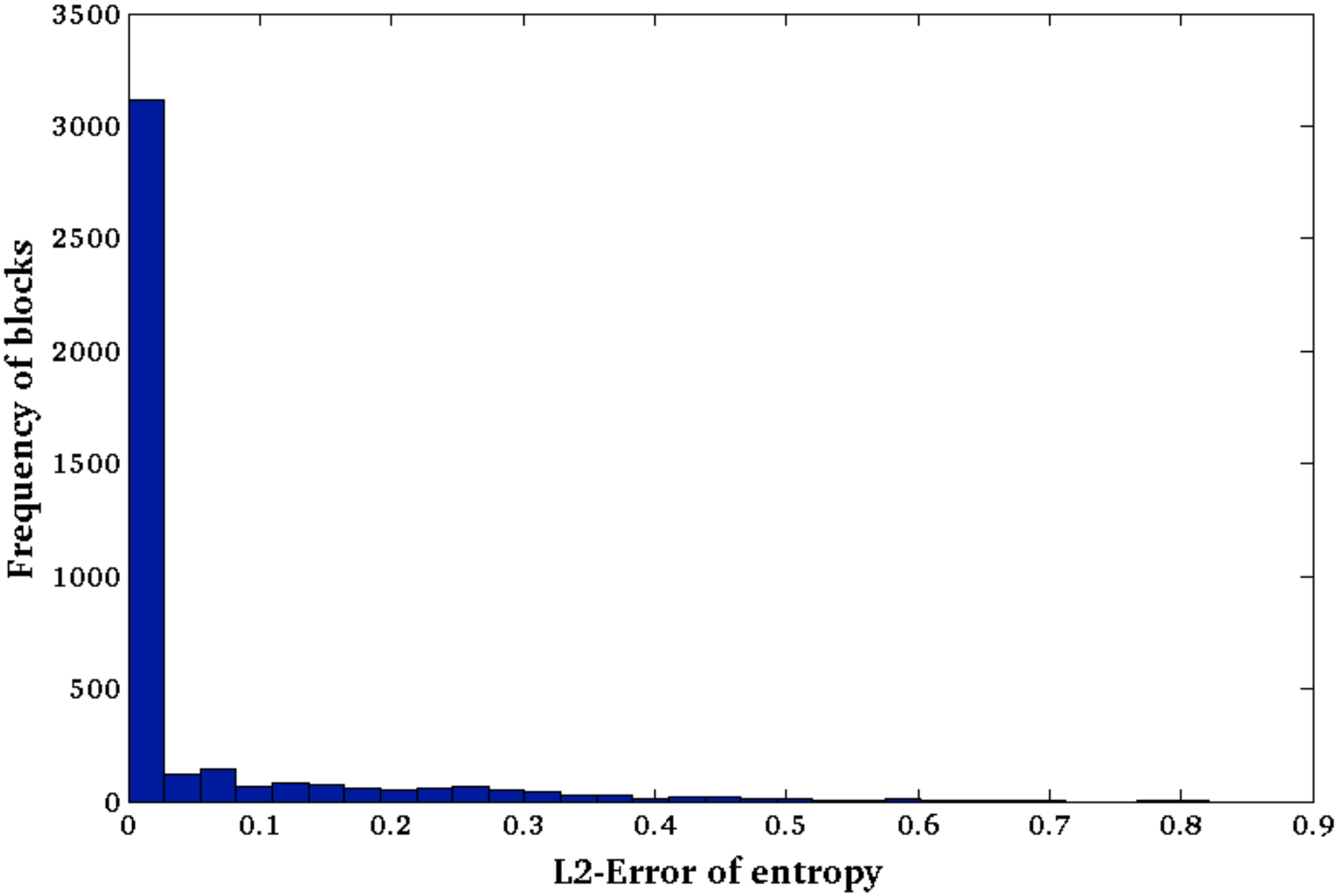
Flexible Block Size of Fuel Dataset

block size 4	block size 6	block size 8
		

- This is entropy query
- Raw data resolution: 64*64*64

color map: 

Analysis



- Only a few blocks has high errors
- Error is prominent in blank area

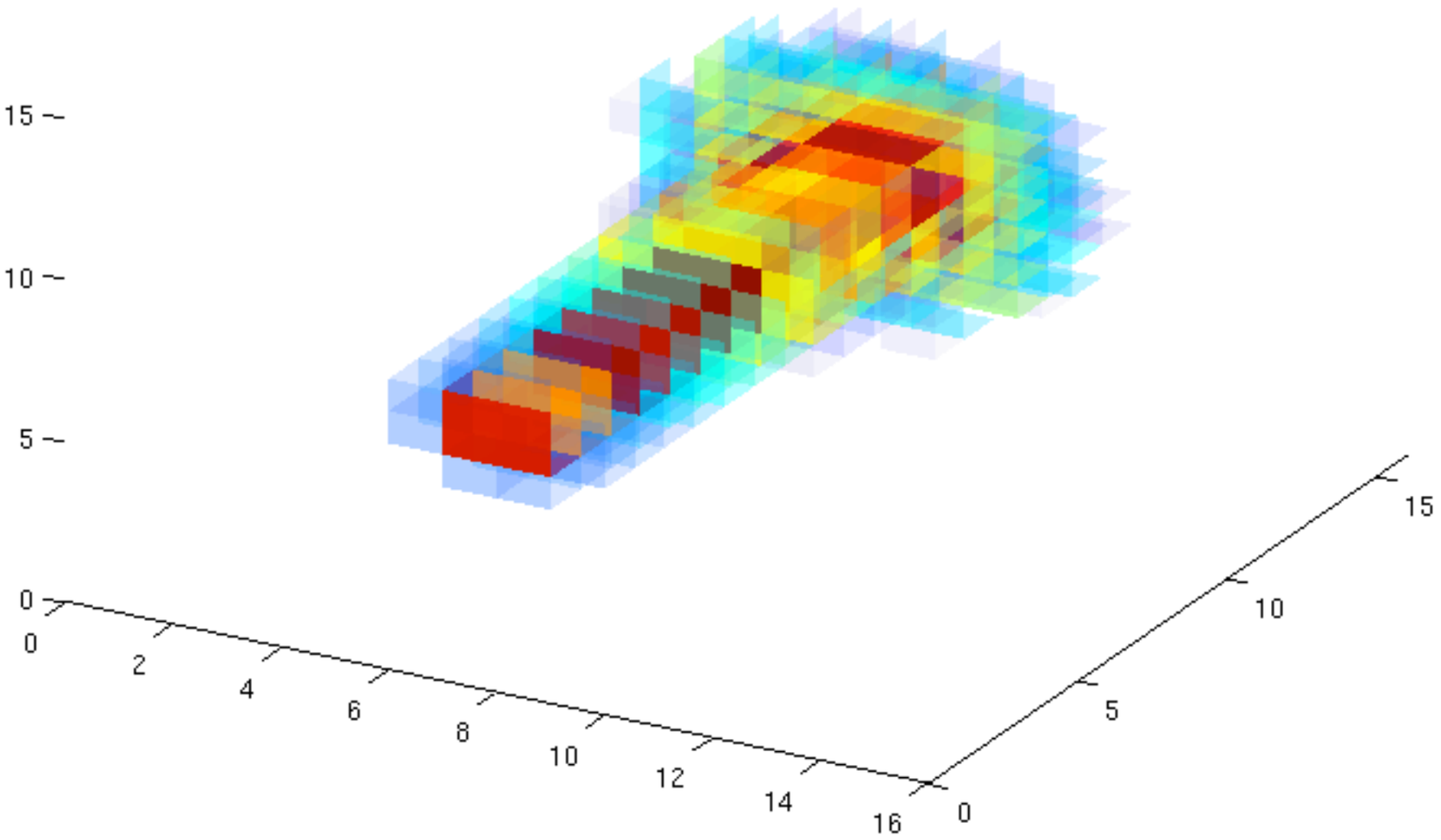
Future Work

- Optimize program
  - currently it is not fully parallel
- Reduce error
  - some errors will affect the blank area

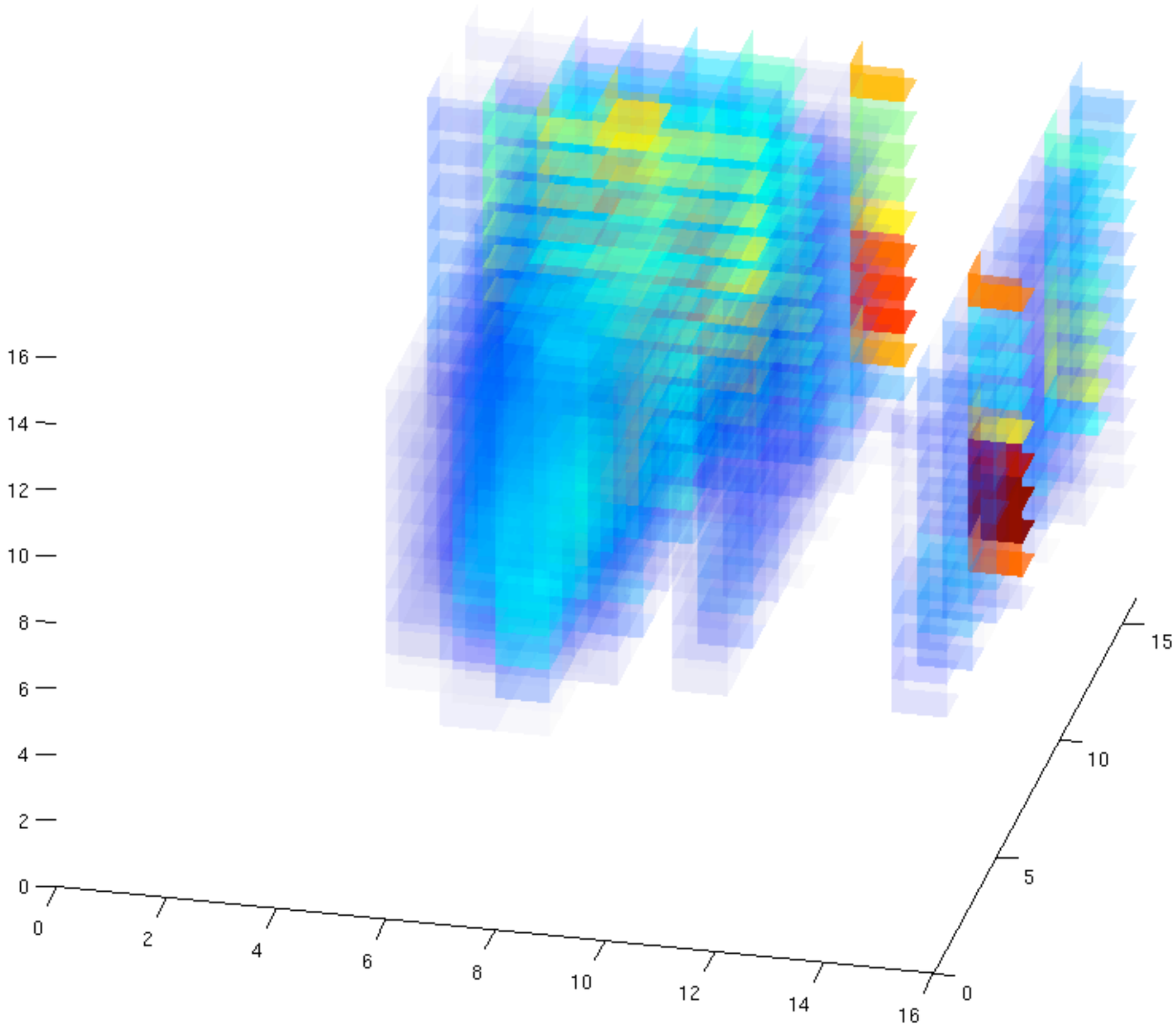
Acknowledgement

- Professor Han-Wei Shen and Professor Huamin Wang
- Abon
- All group members

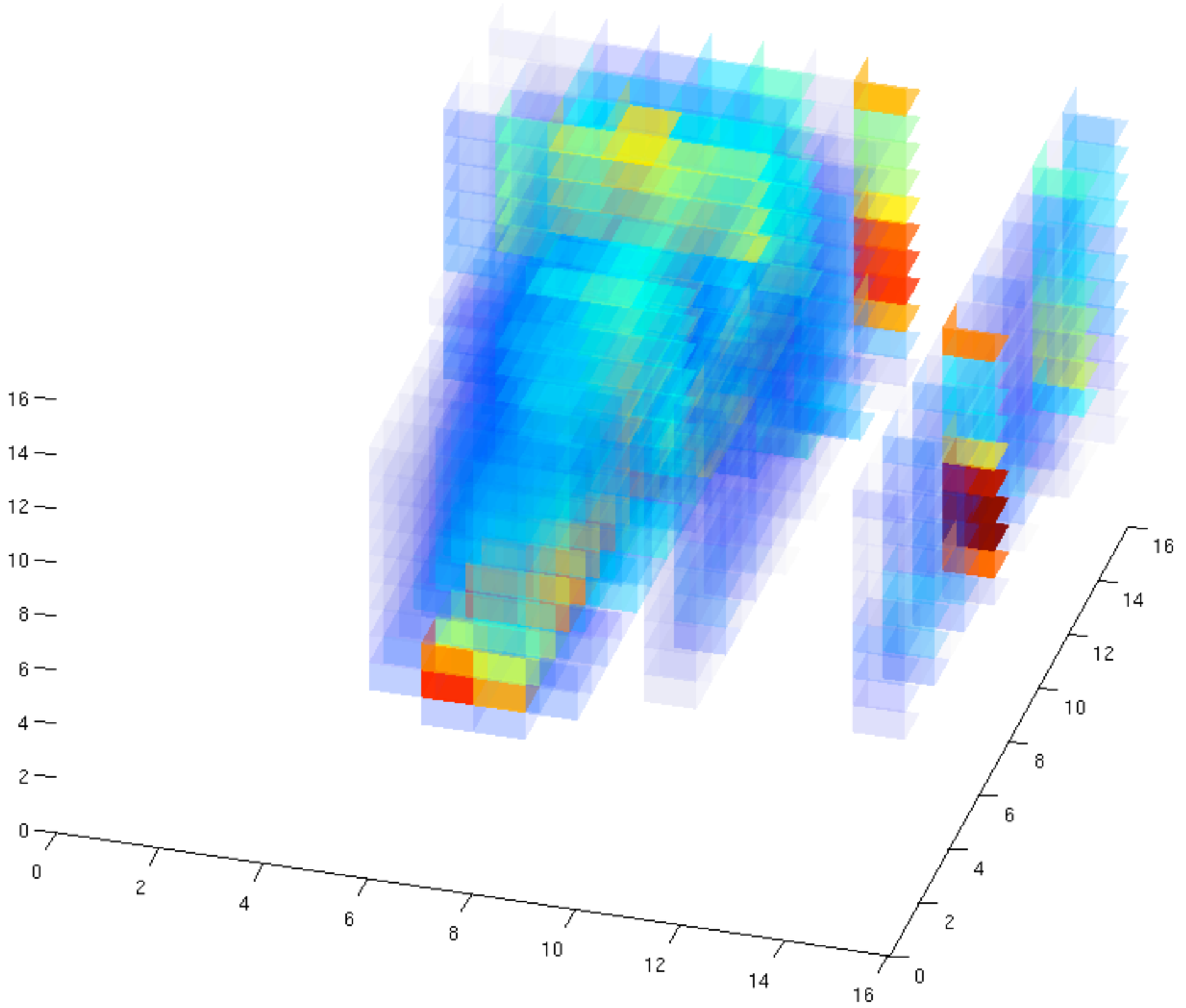
Actual Blockwise Entropies

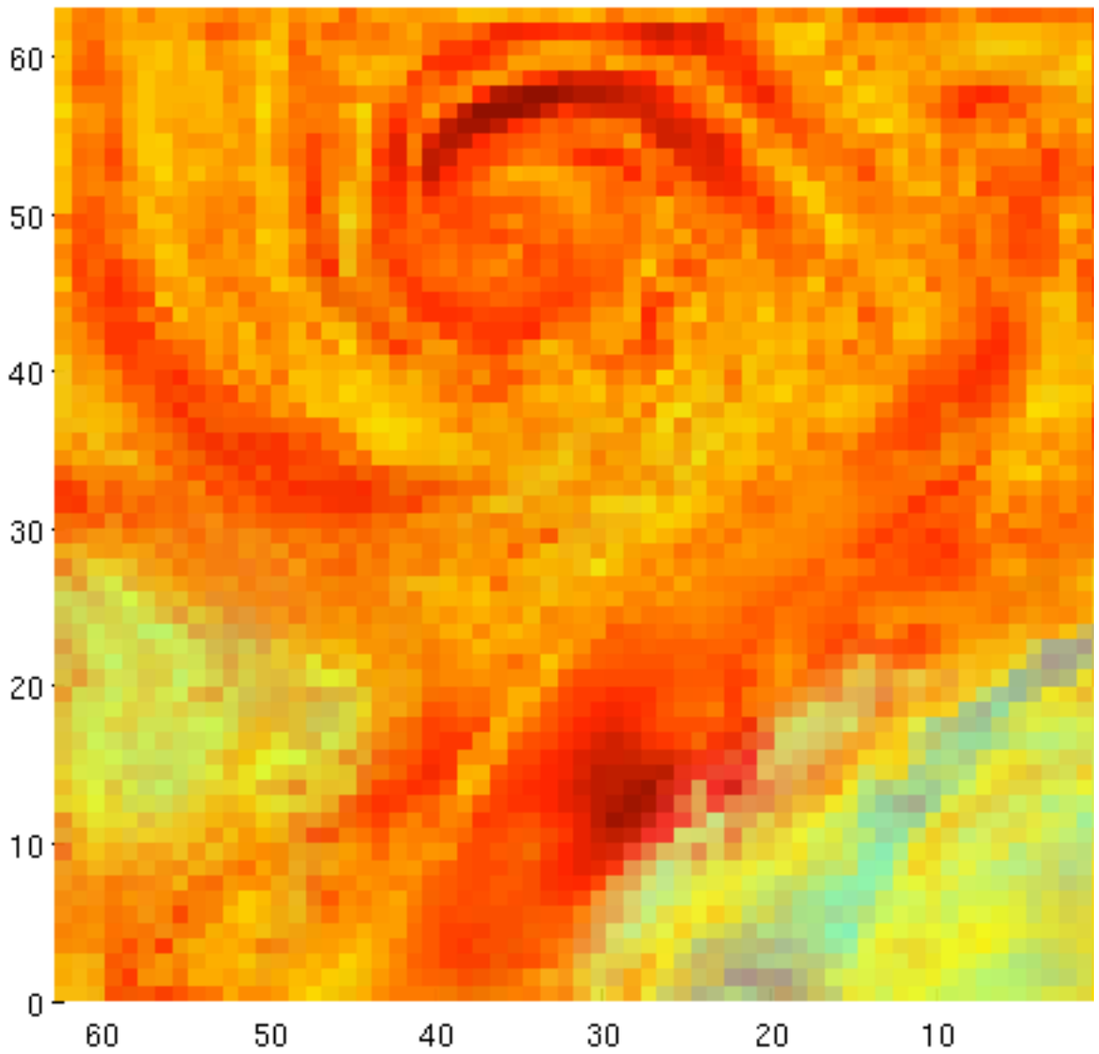


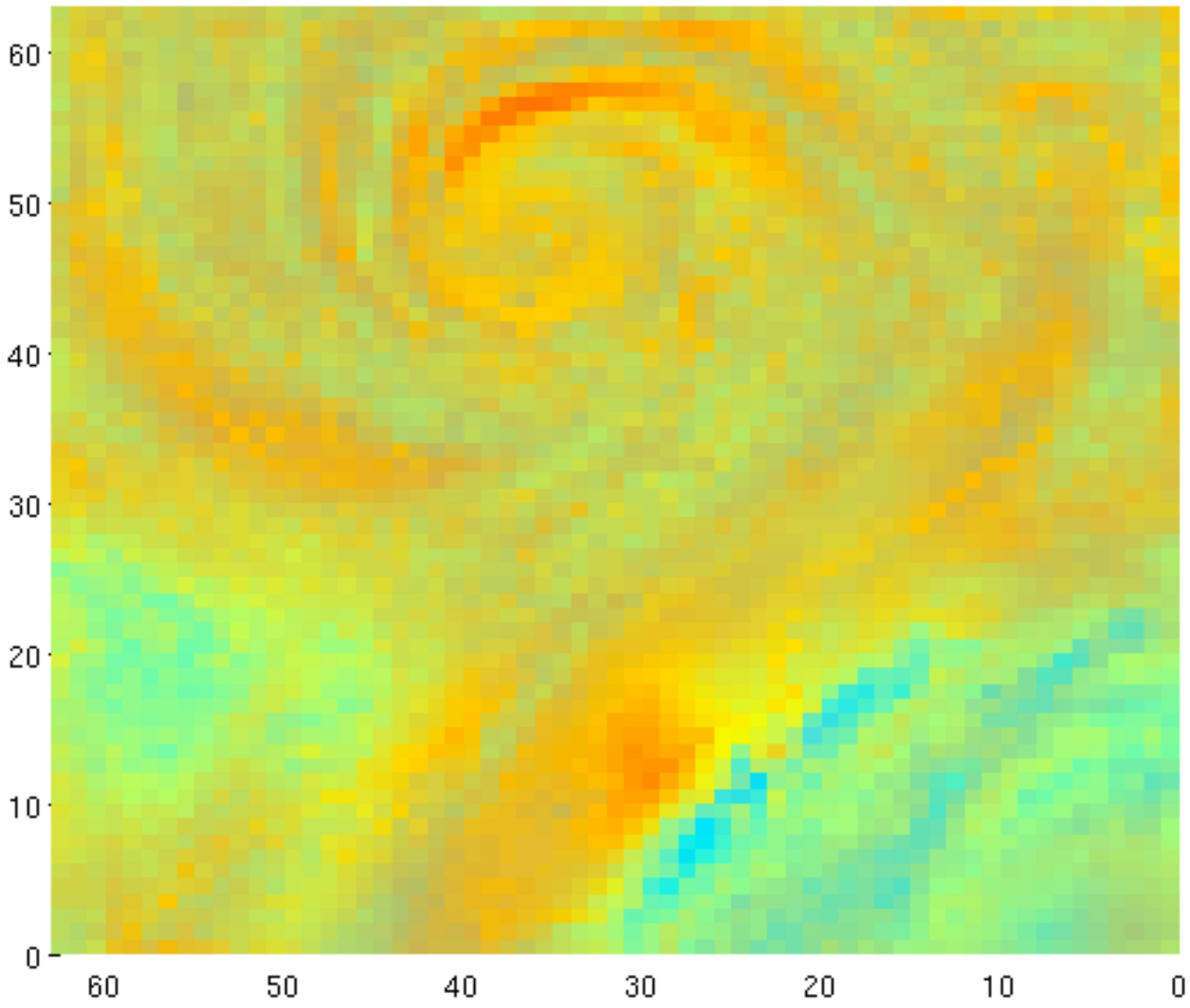
Approximate (Decoded) Blockwise Entropies

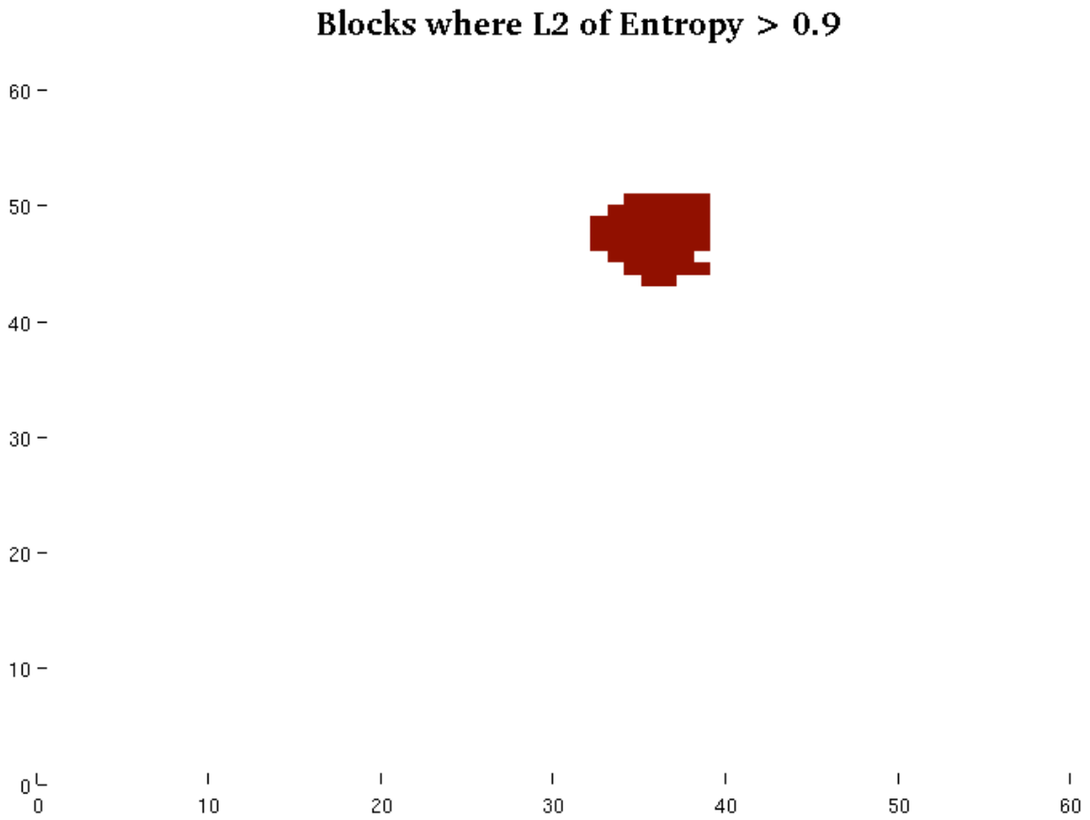


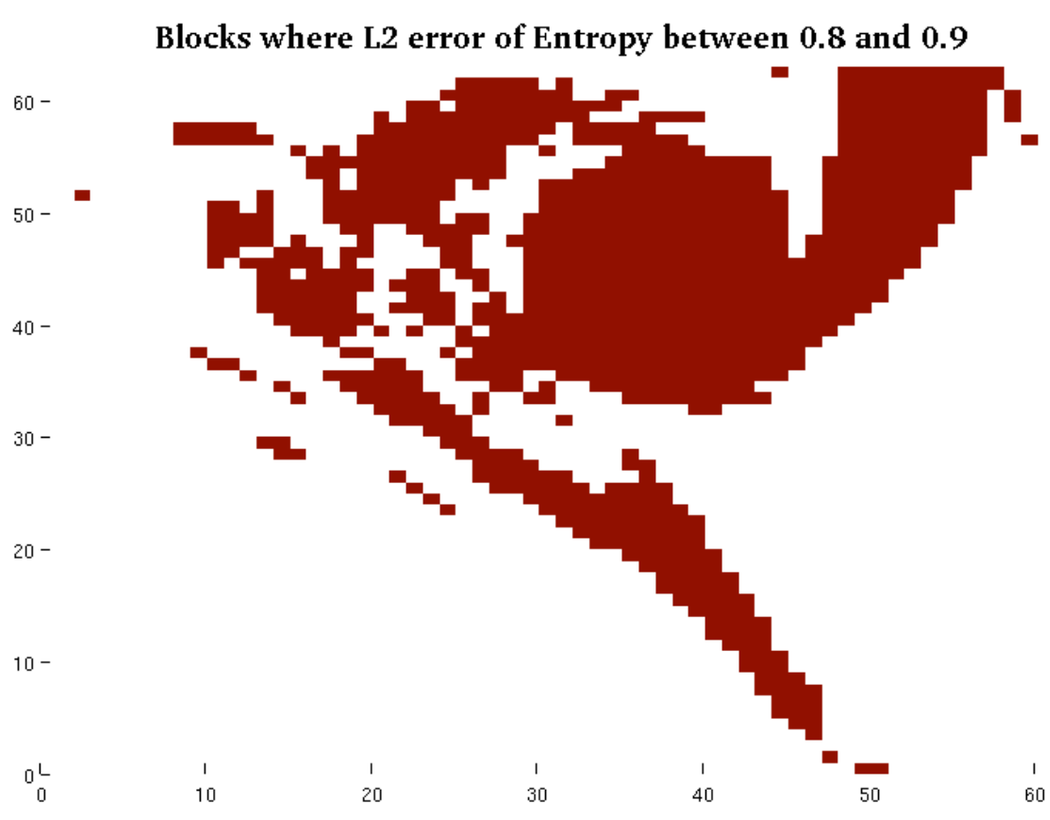
L2-Error of Blockwise Entropies




60
50
40
30
20
10
0
60
50
40
30
20
10


60
50
40
30
20
10
0
60
50
40
30
20
10
0


Blocks where L2 of Entropy > 0.9
60
50
40
30
20
10
0
0
10
20
30
40
50
60


Blocks where L2 error of Entropy between 0.8 and 0.9
60
50
40
30
20
10
0
0
10
20
30
40
50
60