SELECTIVE DECOMPRESSION FOR THE VISUALIZATION IN NETWORKS

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ABSTRACT: This paper describes the use of a special multidimensional compression method in a process of visualization of a large volume of multidimensional scientific data in a network area.

For compression a special compression method can be used which 3D-Dithering can be called. 3D-Dithering is a special lossy method for voxel model data compression. It is highly recommended for the medical data, because 3D-Dithering has very low level of degradation, and we can successfully apply any method (segmentation) to Undithered data.

Another feature of this method is the fact that in the compressed data volume is a full structural information. This feature can be used for fast visualization preview because for this preview we need not decompress data volume. And in the case of necessity it is possible to selectively decompress an important part of the previewed model.

KEYWORDS: data compression, dithering, visualization, network, selective decompression

1. Introduction

The problem of the visualization in a network area is that the large data volume is stored in a server station but it's necessary to work with the data volume (visualization, processing etc.) at a client station. Without special algorithms any process on client station is time-consuming because of network communication reasons.

This problem can be solved by many common compression algorithms (Huffman coding, LZW, LZArit etc. [1]) or specialized (3DCT, Wavelets or 3D-Dithering [8]).

This work contains an alternative approach to the problem of visualizing the large volume of multidimensional scientific data via using a special lossy compression method. In the first part of this paper will be explained a special lossy compression method. In the second part will be discussed the problem of visualizing of the large volume of the multidimensional scientific data in a network area – especially from the point of view of the interaction between client and server.

2. Dithering as a compression method

Originally dithering has been developed for color reduction in two-dimensional images. A typical application was to reduce image-containing pixels in several gray shade levels into image that contains black and white pixels only. There are several methods that can be used (Ordered Dithering, Stochastic Dithering etc.). The most popular is Floyd - Steinberg method where error caused by substitution of a gray pixel by the black or white one is distributed to other part of the image.

This process reduces the number of bits necessary for the representation of a pixel. That means that the dithering can be considered as an image compression method [3]. A very important fact is that the dithered image can be “undithered” by an inverse method. This process corresponds to decompression. As the original image can not be fully restored this compression method is a lossy one.

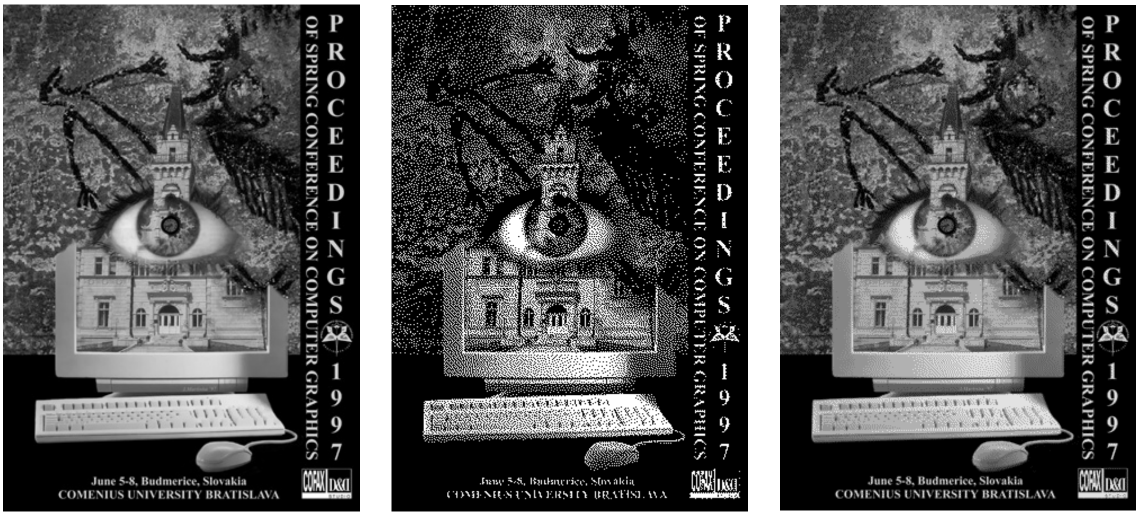

Fig. 1 - Original (8 bpp), Dithered (2bits bpp) and UnDithered (8bits bpp) rastered images.

2.1. Basic principles

Basic Principles of Dithering Compression Method can be summarized as follows:

- In the first phase a volume of information of every volume element (to one half, one quarter etc.) must be decreased. This process can be named Dithering. As a dithering algorithm a modified Floyd – Steinberg algorithm can be used.
- After Dithering it is possible to compress dithered model with lossless compression method (like Huffman coding, LZW, LZArit, LZHuff etc. [1]). This step improves compress ratio significantly.
- The first step of decompression is decoding compressed data with used lossless compression method.
- Last step is a reconstruction of dithered picture. This process is named UnDithering.

It is also possible to control this lossy compression method. The base of loss level controlling is a decision how many bits we want to leave in the dithered data volume. The most common case is halving number of bits in the dithered data (from 8bpp[1] to 4bpp or 16bpv[2] to 8bpv). In this case we obtain a loss of information in compressed data volume and good compression ratio but it is also possible to make some experiments with the controlling of a loss of information.

2.2. 3D-Dithering

3D-Dithering is a method, which is derived from the normal Floyd-Steinberg Dithering. 3D-Dithering is only an extension of Floyd-Steinberg algorithm to the third dimension. Merely we must work in three dimensions and instead of working with colors (for pixel) it is necessary to work with densities (for voxels).

The most important thing of this method is that an error is distributed via diagonal and theoretically an error from the first processed voxel change an intensity of the last processed voxel. This feature minimized a level of the degradation an information of reductive intensity [8].

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[1] Bits per pixel
[2] Bits per voxel

2.2.1. 3D-UnDithering

3D-Undithering is an inverse process for 3D-Dithering. This process is based on the convolution [2], [3]. There are two basic ways – with the static convolutory matrix (only one static matrix is used for all voxel model) or with the dynamic convolutory matrix (for each voxel is computed its own convolutory matrix).

2.2.1.1. Static convolutory matrix

A is the convolutory matrix with size (m,n,o). But m and n are odd integers and o is integer. Undithered intensity $I_{ud}(x,y,z)$ we can describe from dithered intensity $I(x,y,z)$ as:

$$I_{ud}(x_0,y_0,z_0) = \frac{1}{\sum_{i=0}^{i<m}\sum_{j=0}^{j<n}\sum_{k=0}^{k<o} A(i,j,k)} \sum_{i=0}^{i<m}\sum_{j=0}^{j<n}\sum_{k=0}^{k<o} I(x_0 - m \bmod 2 + i, y_0 - n \bmod 2 + j, z_k) A(i,j,k)$$

As convolutory matrixes one from these matrixes can be used:

$$A(x_i,y_i,0) = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 3 & 2 \\ 1 & 2 & 1 \end{bmatrix}; \qquad A(x_i,y_i,1) = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 2 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

$$A(x_i,y_i,0) = \begin{bmatrix} 0 & 4 & 0 \\ 4 & 16 & 4 \\ 0 & 4 & 0 \end{bmatrix}; \qquad A(x_i,y_i,1) = \begin{bmatrix} 0 & 2 & 0 \\ 2 & 8 & 2 \\ 0 & 2 & 0 \end{bmatrix}$$

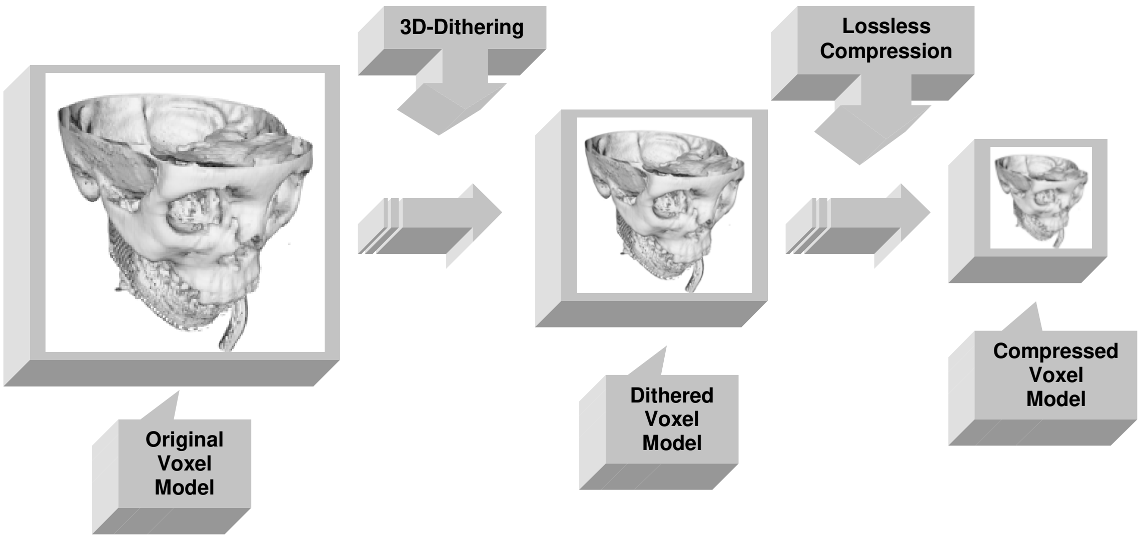

Fig. 2 - Basic principles of 3D-Dithering Compression method.

2.2.1.2. Dynamic convolutory matrix

In the first step it is necessary to define the term Inverse Gradient at the point (x_0, y_0, z_0) regarding to the point (x_i, y_i, z_i):

$$\delta(x_i, y_i, z_i, x_0, y_0, z_0) = \frac{1}{\left|I(x_0, y_0, z_0) - I(x_i, y_i, z_i)\right|}\ ;\ \mathit{for}\ I(x_0, y_0, z_0) \neq I(x_i, y_i, z_i)$$

$$\delta(x_i, y_i, z_i, x_0, y_0, z_0) = 2\ ;\ \mathit{for}\ I(x_0, y_0, z_0) = I(x_i, y_i, z_i)$$

Now can be defined 3D-Convolutory matrix *A* in a point (x_0, y_0, z_0) with members (x_i, y_i, z_i) and with the order (m, n, o). But *m* and *n* are odd integers; *o* is an integer:

$$A(x_i, y_i, z_i, x_0, y_0, z_0) = \frac{1}{2}\frac{\delta(x_i, y_i, z_i, x_0, y_0, z_0)}{\sum_{i=0}^{i<m}\sum_{j'=0}^{j<n}\sum_{k=0}^{k<o} I(x_i - m \bmod 2 + i, y_j - j \bmod 2 + j, z_k, x_0, y_0, z_0)}$$

Undithered intensity I_{ud} at the point (x_0, y_0, z_0) can be described from the dithered intensity I as:

$$I_{ud}(x_0, y_0, z_0) = \frac{1}{\sum_{i=0}^{i<m}\sum_{j=0}^{j<n}\sum_{k=0}^{k<o} A(i, j, k)} \sum_{i=0}^{i<m}\sum_{j=0}^{j<n}\sum_{k=0}^{k<o} I(x_0 - m \bmod 2 + i, y_0 - n \bmod 2 + j, z_k) A(i, j, k)$$

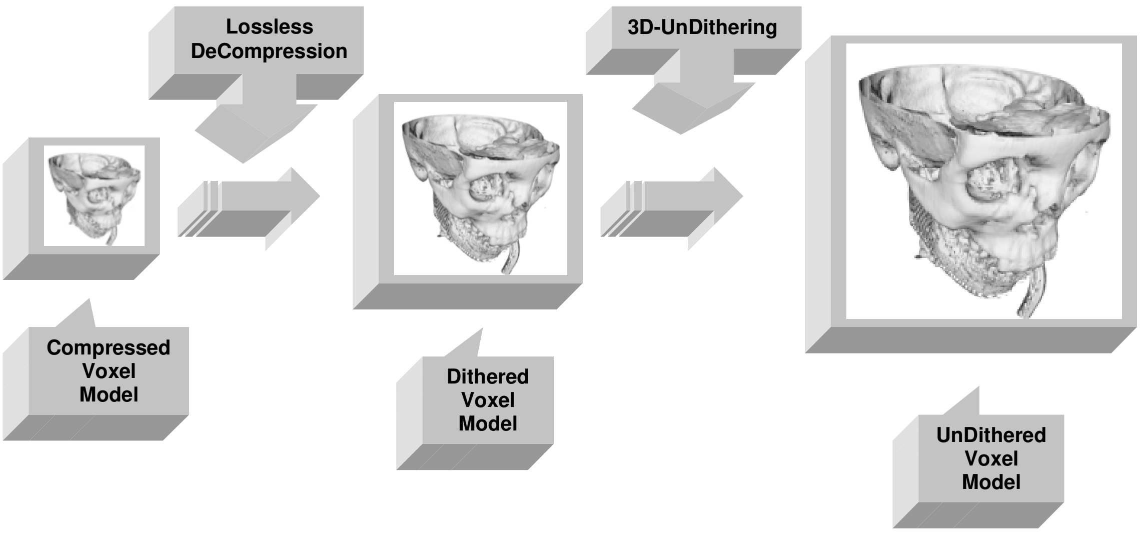

Fig. 3 - Basic principles of 3D-UnDithering.

2.2.2. 3D-Dithering compression method – summary

3D-Undithering with the static convolutory matrix are more faster but it antialiases edges. 3D-Undithering with a dynamic convolutory takes a care of the edges but it’s more time consuming because it’s necessary to compute for each voxel its own three dimensional convolutory matrix.

The computation of convolution matrix in the dynamical case is based on searching of edges in the surroundings of the voxel. This feature saves almost all edges in the undithered model. Sometimes it can be said that undithered model is from the subjective point of view more informative than original one.

For the explanation it was used the three dimensional case but it is possible to extend this method to the any dimension (from two dimensional pictures to n-dimensional tensor array). That means that this method could be used e.g. for CFD applications.

2.3. Evaluation

Undithering is the process which is based on filter methods. This reason makes that in the undithered data voxels (three-dimensional case) which have an intensity never seen in the original data can be found. These new voxels cause higher value MSE (see the table Tab. 1[3]). Now it is necessary to decide if in the dithered model is enough information.

	STATICAL CONVOLUTORY MATRIX	DYNAMICAL CONVOLUTORY MATRIX
MSE	2.1e+02	2.3e+02
MAE	4,4	3,4
SDAE	2.3e+02	2e+02
MNAE[4]	5.1e+01	4e+01

Tab. 1 - Average levels of loss (Compression from 8bpv to 4bpv and back).

Because an undithering has some characteristics of filter processing we were searching another method of comparison than the global methods like MSE. It can be said that the most important information for the operator are information about the edges (for example the segmentation of the medical data). For the test of edges in the voxel models any algorithm for edge detection can be used (Canny) [4]. This algorithm can be used on dithered and original data volume and the end of this process can be easily compared all edges which has been founded in both models. After processing this "edge test" we can say that more than 95% of the edge information is conserved in the udithered data volume.

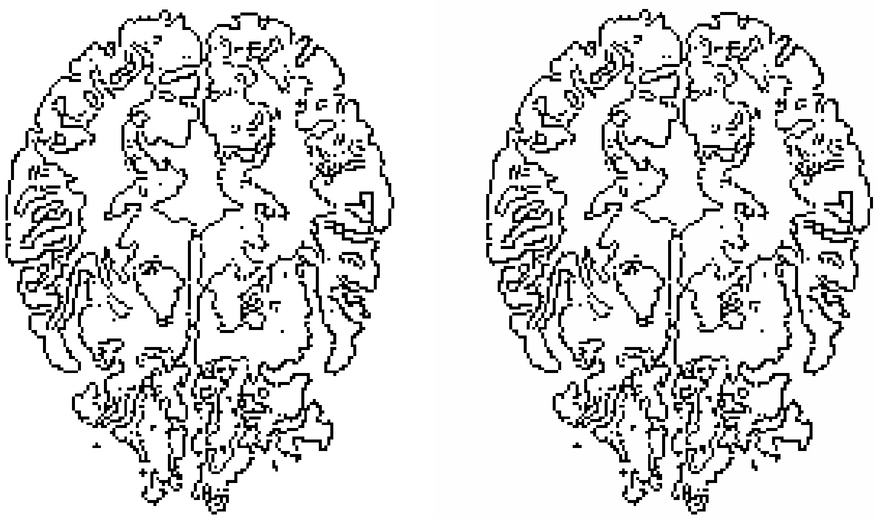

Fig. 4 – On the left side are edges in the original model and on the right side are edges in dynamically undithered one.

[3] For tests was used a volume of eight voxel models, which have complete size 150 MB. All these models have a medical character and they have been took from *ftp://carlos.wustl.edu/dist/imagelib* (for an example of tested data see the figure Fig. 8).

[4] Maximal Normal Absolute Error

Compression ratio test has been made on large data volume[5] and in the case of minimized level of the degradation of undithered information. For details see the table Tab. 2.

COMPRESSION METHOD	COMPRESSION RATIO
Original data	100%
LZSS	23,5%
Huffman coding	21,4%
LZARIT	12,9%
ARJ	11,4%
PKZIP	11,3%
3D-Dithering+LZSS	10,0%
3D-Dithering+Huffman coding	9,4%
MPEG	8,8%
3D-Dithering+LZARIT	5,8%
3D-Dithering+LZHuff	4,7%

Tab. 2 - Average compression ratios in case of minimised level of loss (Compression 8bpv to 4bpv and back).

If the loss of information in the uncompressed data volume causes this data unsuitable for use it is possible to upgrade this information by sending differences[6] between the original data and the undithered one.

3D-Dithering has several time aspects - fast compression, fast preview decoding and slow decompression (compression time 58sec, fast preview decompression time 5,9sec, and decompression time 540sec[7]). In case of usable compression ratio and the lowest level of degradation of undithered data the disadvantage of slow decompression can be eliminated by using the preview and the following selective decompression.

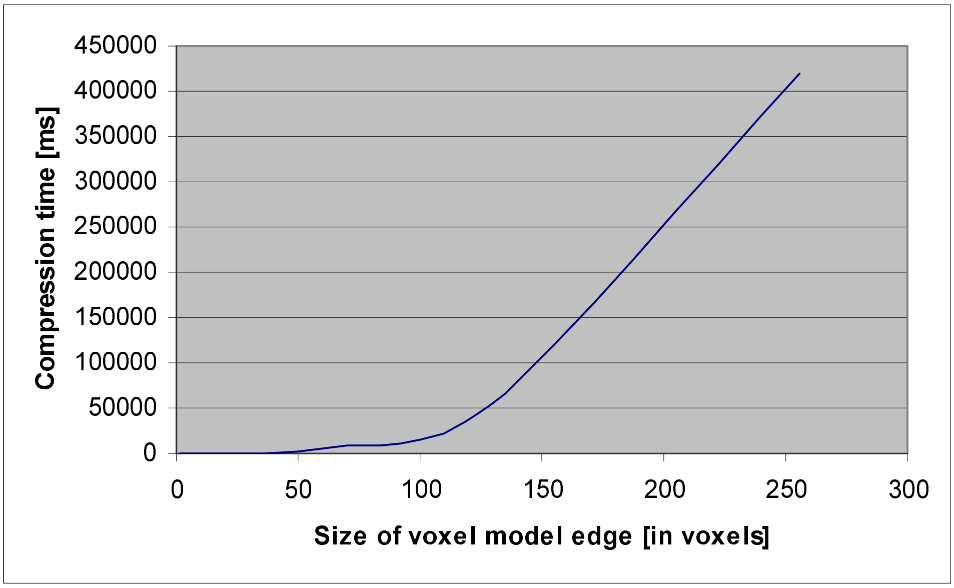

Fig. 5 - The relation between the compression time and the size of voxel model cube.

[5] For tests was used a volume of eight voxel models, which have complete size 150 MB. All these models have a medical character and they have been took from *ftp://carlos.wustl.edu/dist/imagelib* (for an example of tested data see the figure Fig. 8).

[6] Files of differences are called in this paper as chunks.

[7] Time tests has been made on Pentium 133 computer with 128x128x128 voxel model.

3. Visualization of large volume of scientific data in a network area

In the practice we are often faced with the situation when a computationally demanding simulation runs at a large mainframe computer [9]. The user controls the course of simulation from the distant workstation. In order to be able to set parameters of the simulated process properly it is necessary to visualize the data obtained during simulations.

As the volume of the data is usually very large it is necessary to find ways how to reduce time for the data transmission from the server (e.g. the mainframe) to the client. The solution to this problem is data compression. In many cases the user does not require the detailed information (visualization of all data) but he is satisfied with some kind of a preview. In the case of this preview the user can either make his decision about the parameter settings for the new course of simulation or he can require more detailed information (additional data to be visualized). It is also possible to give requests to the server for a new form of data (resample etc.)

Such a scheme of communication was developed for the 3D-Dithering compression method:

- In the first step of the communication the Dithered data are sent to the client station.
- After lossless client decompression an undithering need not be made because a undithered data can be visualized as a fast preview.
- After this step an operator has three ways of processing the data volume:
  - An operator can see the data and can create any requests to the server station.
  - The 3D-Undithering can be processed for the better resolution of the data volume.
  - The client station can demand the server station for chunks which can upgrade an information in the dithered data to the original.
- Now the requests for the server station (process data, resample data etc.) can be made and the cycle can be repeated.

The described method of communication in the network environment substantially speeds up the information exchange between the user with a distant server. The next step for an improvement is the selective decompression.

3.1. Selective decompression

3D-Dithering compression method has the slow decompression (approximately twice slower than Wavelets decompression has) and the fast compression (approximately four times faster than Wavelets compression has). For the really interactive processing in the client-server environment it is necessary to have fast compression and decompression method. The disadvantage of the slow decompression can be compensated by the possibility of the selective decompression[8].

In the first phase of the explanation it is necessary to say that the preview which can be obtained in the phase of 3D-Dithering decompression is fast and it has also a lot of useful information inside – mainly the structural one.

[8] For example: when in the previewed voxel model (128x128x128) an operator wants to undither only smaller area of his interests (64x64x64) thus the process of selective decompression will be eight time faster that decompression of the all voxel model.

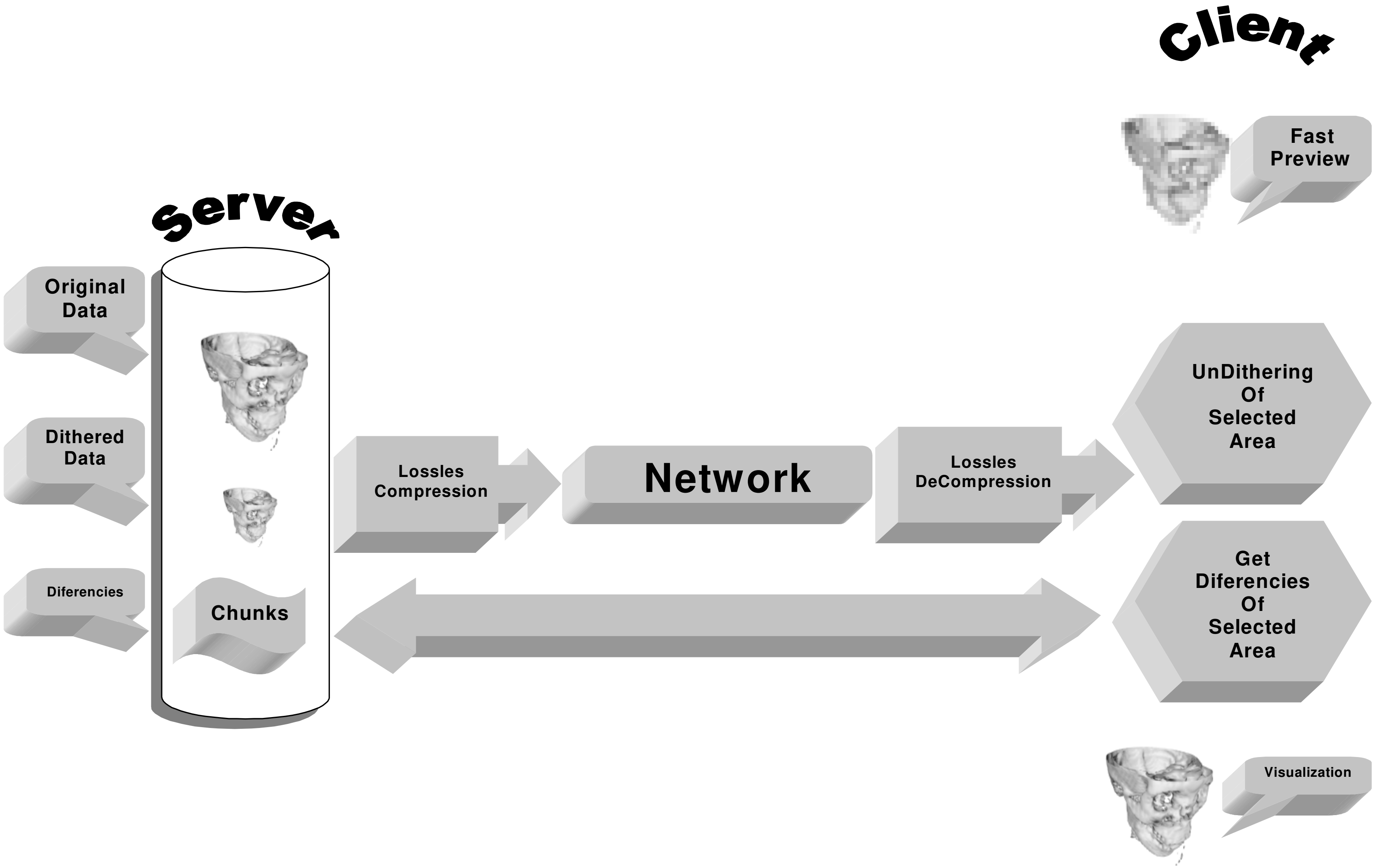

Fig. 6 - Data flow in the process of the visualization in a network area when using selective decompression.

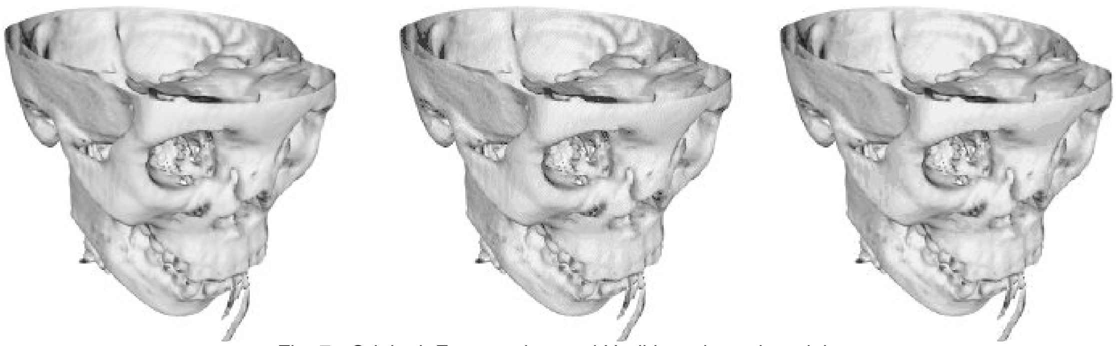

Fig. 7 - Original, Fast preview and Undithered voxel model.

The preview quality to an operator a sufficient volume of information can give for making some requests to the server station. In the case of necessity the operator can selectively decompress only selected areas of his interests and obtain more detailed information in the selected areas. He can also demand updating chunks from the server station only for this selected areas. In our implementation it is necessary to select areas of interests by giving coordinates of selective decompressed areas.

This features of 3D-Dithering compression method can make the process of the interaction more interactive than standard compression method.

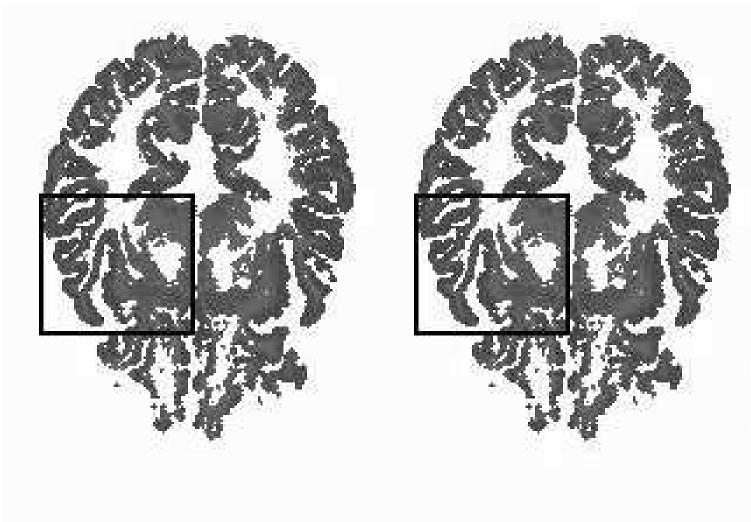

Fig. 8 - An example of selective decompression - on the left is the original slice of voxel model (8bpv), in the middle is the 4bpv fast preview with selectively decompressed data in the square (8bpv) and on the right is the 2bpv fast preview with the selectively decompressed data in the square (8bpv).

4. Future work and preliminary results

For a future work we have two basic aims – to make more faster decompression and to raise the compression ratio. The first aim we want to solve by implementation of new undithering method which is on the edge betwen undithering with static and dynamical method. This “semi-dynamical” method does not compute independent convolutory matrix of each voxel but it computes convolutory matrix for each independent branch in the octree of the voxel model. We assume that this method will have approximately a quality of the undithering with dynamical convolutory matrix and the speed of the undithering with static convolutory matrix.

To raise the compression ratio is more difficult. But we suppose that using an octree structure on dithered data can increase compression ratio. But all these features are in the phase of research.

5. Conclusion

3D-Dithering compression method has several aspects:

- low level of degradation of information
- preview visualization is independent on 3D-UnDithering process
- in dithered data is all structural information of original model
- it is fully multidimensional compression method
- the native support for selective decompression

All these features make this method useful for the interaction work in a network area with the huge multidimensional data volumes.

6. References

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