International Journal of Applied Mathematics and Computing Science. Volume 4, Issue 2, (2015) 103-108
http://www.cayley-nielson.com/ijamcs

Advance Research of lossless compression method for Large-scale Volume Data

Xiangyan Meng[1*], Yumiao Ren[2]
[1,2] Xi'an Technological University, Xi'an, China
[*1]Corresponding author
E-mail: [1]*wulizu@126.com,* [2] *2520910 @qq.com*

Abstract

Numerous biomedical applications produce extremely large data sets through numeric simulations or physical data acquisition. Data compression has been an important research issue in the area of visualization. With the rapidly increasing of dimensions, resolutions and variables, the amount of volume data is growing exponentially, which makes compression become even more significant today. In this paper, we examine various lossless compression methods for their applicability for volume data. In the end, we discuss the future research on this topic.

Keywords: volume data, lossless compression, lossy compression

1. Introduction

It has been widely used in many fields of science and engineering, but the problem of large amount of data influences the development of visualization technology. With the rapid increase of volume data resolution, the emergence of time-varying and multi variable body data is widely used in science and engineering. Both efficient storage and efficient transmission of large medical data sets request efficient compression techniques. Although the computer hardware conditions continue to improve, such as the use of graphics hardware GPU accelerated the visualization of the process, but the development of hardware technology is still not up to catch up with the volume of bulk data. At present, the data compression technology is still an effective method to solve the large scale volume data interactive visualization. A variety of data compression techniques have been proposed to reduce the storage and transmission cost.

2. Lossless compression method for volume data

Lossless compression technology of volume data borrows the method of file and image compression technology, and the volume data is regarded as a collection of multiple two-dimensional data sheets (slice). For efficient storage and transmission of such data, compression algorithms are imperative. However, most volumetric datasets are used in biomedicine and other scientific applications where lossy compression is unacceptable. Compression methods reduce redundancy in volume data to provide a significantly more compact representation [1].

2.1 Run-length encoding compression

Run-length encoding (RLE) is a very simple form of data compression in which runs of data (that is, sequences in which the same data value occurs in many consecutive data elements) are stored as a single data value and count, rather than as the original run. This is most useful on data that contains many such runs. Consider, for example, simple graphic images such as icons, line drawings, and animations. It is not useful with files that don't have many runs as it could greatly increase the file size. This technique is first

* Fund support:Shaanxi Province education department special scientific research plan, 14JK1341.

ISSN 2333-2425 /
September, 2015

applied to the SLC file format in VolVis system [2]. S Forstmann[3] presented an algorithm for the visualization of large opaque volume data. And they showed that large run-length-encoded volume data can efficiently be visualized using CUDA. Because the probability of the same data value in the body space is big, so the RLE is better than the one by using RLE in the volume space, but the data difference can not improve the compression rate of RLE.

2.2 Entropy encoding compression

Entropy encoding is a more common type of lossless compression method. The general idea of an entropy encoder is to represent frequent voxel values with a short code, and infrequent voxel values with a longer code. Huffman coding[4], Shannon-Fano and Arithmetic coding[5] are some of the few well known entropy encoding techniques, many variations of which are extensively used in lossless data compression solutions. Huffman and Shannon-Fano coding are better suited for the two-pass (static) coding, while arithmetic coding lends itself better to single-pass (adaptive) coding. When applied to data sheet data, the compression effect is better. Fowler[6] proposed a new algorithm based on a combination of differential pulse-code modulation, DPCM and Huffman coding and results in compression of around 50% for a set of volume data files. Ibarria [7] presented a simple method for compressing very large and regularly sampled scalar fields. A new Lorenzo predictor was proposed, which estimates the value of the scalar field at each sample from the values at processed neighbors. And the residuals (differences between the actual and predicted values) are encoded using arithmetic coding.

2.3 Variable Bit Length Encoding compression

Not all voxel values require the same number of bits. Low intensity 8bit voxels (0..15) for example require a significantly smaller number of bits than high intensity voxel values (128-255) [8,9]. Consequently, we can save bits per voxels for low intensity voxel values, but need to invest bits to represent the code size for the voxels. Instead of storing that information for every voxel, we generate a run-length-encoded representation of segments of the same bit length. This is a reasonable assumption for scanned volumetric data, since most of background voxels will have low intensity noise voxel values that require a smaller number of bits than the actual voxels of the scanned object.

In total, we need three data buffers that contain the segment lengths (segments of more than 28 elements are split in two segments), the number of bits required for the voxel values of the segments, and finally the actual voxel value stream, encoded in variable bit length. In order to further reduce the space requirements, each of the data buffers is encoded with an entropy encoder.

VBL allowed the best compression rates if the image data was provided through a difference buffer and in some cases if the whole data volume was compressed. VBLE is more suitable for the application of body data compression, but it is usually necessary to combine RLE to store the number of individual elements of encoding. A new compression method was proposed by Klajnsek[10] and the results proved that data coherence is exploited more sufficiently using proposed quadtree approach. This paper introduces a new method for the compression of volumetric datasets. It is based on quadtree encoding.

2.4 Dictionary-based encoding compression

Dictionary-based encoding schemes are among the most popular schemes in data compression, where the encoded data is represented by codes that represent sequences that occur in the dataset. LZ77, LZ78 and LZW are 3 kinds of basic encoding algorithm based on the dictionary structure of encoding method. LZV is improved algorithm of LZ77, and it is applied to medical MRI body data compression by Chow[11]. The advantage of the LZ77 and LZW approaches lies in the implicitly stored dictionaries, that do not require space for an explicitly stored one. Typical examples for LZ77 compression schemes are gzip (combined with Huffman coding) [12] and ZIP. Unix's compress uses LZW. All dictionary-based compression algorithms clearly benefited, if the dataset was compressed as a whole volume and if a difference buffer was used for compression.

2.5 Burrows–Wheeler transform compression

The Burrows–Wheeler transform(BWT, also called block-sorting compression)[13,14], is an algorithm used in data compression techniques such as bzip2. It was invented by Michael Burrows and David Wheeler in 1994 while working at DEC Systems Research Center in Palo Alto, California. It is based on a previously unpublished transformation discovered by Wheeler in 1983.

When a character string is transformed by the BWT, none of its characters change value. The transformation permutes the order of the characters. If the original string had several substrings that occurred often, then the transformed string will have several places where a single character is repeated multiple times in a row. This is useful for compression, since it tends to be easy to compress a string that has runs of repeated characters by techniques such as move-to-front transform and run-length encoding. The BZIP2 algorithm has better compression effect on the body space and the differential data compression. For the popular BZIP2 compression algorithm, the BWT is combined with a Huffman coding, which encodes the permuted input block. Similar to the previous approaches, BZIP2's compression rate increased if the whole volume was compressed instead of single image slices. In this case, it also benefited from a difference buffer.

2.6 Wavelet transform compression

Wavelet transformations are the basis for many the state-of-the-art compression algorithms, including the JPEG-2000 standard. And wavelet method is often used in the lossless compression of medical data. The 3D medical data (such as CT, MRI) is stored in the form of multiple 2D images. So in most medical data compression, they are considered as a collection of multi-dimensional gray images. Ridgelet and Curvelet are the latest research in recent years. Sanchez [13] proposed a symmetry-based scalable lossless compression method for 3D medical images using the 2D integer wavelet transform and the embedded block coder with optimized truncation (EBCOT). A new inter-slice DPCM prediction method exploits the correlation between slices. Performance evaluations on real 3D medical images show an average improvement of up to 17 % in lossless compression ratios when compared to the state-of-the-art compression methods including 3D-JPEG2000, JPEG2000 and H.264 intra-coding. Krishnan [14] presented a scheme that uses JPEG2000 and JPIP (JPEG2000 Interactive Protocol) to transmit data in a multi-resolution and progressive fashion. And then they presented a prioritization that enables the client to progressively visualize scene content from a compressed file. In our specific example, the client is able to make requests to progressively receive data corresponding to any tissue type. The resulting system is ideally suited for client-server applications with the server maintaining the compressed volume data, to be browsed by a client with a low bandwidth constraint. Compression method [15,16]based on 3D wavelet decomposition is applied to medical data lossless compression. A major criterion for the compression quality is the type of wavelet base-functions that are used. Typical examples are the Haar-wavelets (usually only used for description of the principle)[17] or B-Spline functions. Li Zongjian[18,19] studied the cubic data compression algorithm based on ridgelet transform. And the result indicated that the ridgelet, as a new analytic tool，has the good performance for describing the signals which have super-plane singularities in high dimensions. Yuancheng Li [20]proposed a novel scheme for image compression by means of the second generation curvelet transform and support vector machine (SVM) regression. Compression is achieved by using SVM regression to approximate curvelet coefficients with the predefined error. Compared with image compression method based on wavelet transform, experimental results showed that the compression performance of this method gains much improvement. Moreover, the algorithm works fairly well for declining block effect at higher compression ratios.

3 Current problems

At present, most of the compression work is based on the integer type, and the research on the data compression of real type is relatively small. Because of the small correlation of the mantissa of real type data, compression process is more difficult. Compressing floating-point time-varying volume data and achieving both high compression rate and near lossless are challenging[21]. Lindstrom [22] proposed a simple scheme for lossless, online compression of floating-point data that transparently integrates into the I/O of many applications. A plug-in scheme for data-dependent prediction makes our scheme applicable to a wide variety of data used in visualization, such as unstructured meshes, point sets, images, and voxel grids. Unlike previous schemes, their method also adapts well to variable-precision floating-point and integer data. Fout [23]proposed two prediction-based compression methods that share a common framework, which consists of a switched prediction scheme wherein the best predictor out of a preset group of linear predictors is selected. The results demonstrated that their polynomial predictor, APE, is comparable to previous approaches in terms of speed but achieves better compression rates on average. ACE, their combined predictor, while somewhat slower, is able to achieve the best compression rate on all datasets, with significantly better rates on most of the datasets. To deal with the performance bottlenecks of hard-disk transfer rate and graphics bus bandwidth, J Mensmann[24] presented a hybrid CPU/GPU scheme for lossless compression and data streaming that combines a temporal prediction model, which allows to exploit coherence between time steps, and variable-length coding with a fast block compression algorithm [25].

Nevertheless, long data transfer times and GPU memory size limitations are often the main limiting factors, especially for massive, time-varying or multi-volume visualization, as well as for networked visualization on the emerging mobile devices. So it is significant for developing flexible and fast decompression algorithm based on GPU completely.

With the development of mobile phones and other mobile platforms, the development of cloud technology, network and mobile body rendering will get more attention, the algorithm used in desktop computing is not necessarily directly applied to these hardware platforms, the need for further research.)

Nowadays, even though the GPU could keep up with the growing amount of volume data by boosting computation performance, the transfer bandwidth between different hardware may become insufficient especially for rendering the high-resolution volume data, which results in an important problem. This problem becomes even more conspicuous for the time-varying volume data.

ACKNOWLEDGMENTS

This subject originates from the subsidization project (14JK1341) of Shaanxi Province education department special scientific research plan.

Reference

[1] Stefan Guthe and Wolfgang Straßer. "Real-Time Decompression and Visualization of Animated Volume Data." *In Proc. of IEEE Visualization*, (2001):1-9

[2] Ricardo S. Avila, Lisa M. Sobierajski, and Arie E. Kaufman. "Towards a comprehensive volume visualization system." *Proceedings of the 3rd Conference on Visualization. Los Alamitos :IEEE Computer Society Press*,(1992):13-20

[3] Sven Forstmann，Jun Ohya. "Visualizing run-length-encoded volume data on modern GPUs". *IEICE technical report*, 107 (2008):355-358

[4] Shrusti Porwal, Yashi Chaudhary, Jitendra Joshi, and Manish Jain, etc. "Data Compression Methodologies

for Lossless Data and Comparison between Algorithms”. *International Journal of Engineering Science and Innovative Technology*, 2 (2) (2013): 142-147

[5] Igor Valeryeich Nesiolovskiy，Artem Igorevich Nesiolovskiy. “Entropy Method of Binary-ternary Lossless Data Coding.” *http://www.freepatentsonline.com/y2013/0222159.html*

[6] Fowler James E., Yagel Roni. “Lossless compression of volume data.”*Proceedings of the Symposium on Volume Visualization’94. New York: ACM*, (1994): 43-50

[7] Ibarria Lawrence, Lindstrom Peter, Rossignac Jarek, and Szymczak Andrzej. “Out-of-core compression and decompression of large *n*-dimensional scalar fields.” *Computer Graphics Forum*, 22 03 (2003):343-348

[8] Wilfried Philips, Steven Van Assche, Dirk De Rycke，and Koen Denecker. “State-of-the-art techniques for lossless compression of 3D medical image sets.” *Computerized Medical Imaging & Graphics*, 25 02 (2001):173-185

[9]B. Vemuri, S. Sahni, F. Chen, C. Kapoor, C. Leonard, and J. Fitzsimmons. “Encyclopedia of Optical Engineering (R. Driggers and E. Lichtenstein (Eds.)), chapter Lossless Image Compression.” *Marcel Drekker Inc.*, 2002.

[10] Klajnsek G, Zalik B. “Progressive lossless compression of volumetric data using small memory load.” *Computerized Medical Imaging and Graphics*, 29 04 (2005):305-312

[11] Chow J, Berger T. “Lossless volume compression using a variation of lempelziv’77.” *Proceedings of IEEE International Symposium on Information Theory. Piscataway: IEEE press*,1997：69

[12] J. Gailly and M. Adler. “The gzip home page.” *http://www.gzip.org*, accessed 2005.

[13] Sanchez V, Abugharbieh R, Nasiopoulos P. “3d scalable lossless compression of medical images based on global and local symmetries.” *Proceedings of the 16th IEEE International Conference on Image Processing. Piscataway: IEEE press*,2009:2525-2528

[14] Krishnan K, Marcellin M W, Bilgin A, *et al*. “Efficient transmission of compressed data for remote volume visualization.” *IEEE Transactions on Medical Imaging*, 25 09 (2006): 1189-1199.

[15] Hashimoto M, Matsuo K, Koike A. “High efficiency loss-less coding method with 3-dimensional wavelet transform for volumetric data.” *Proceedings of Nuclear Science Symposium Conference Record. Los Alamitos :IEEE Computer Society*,2003: 2780-2784

[16]Zixiang Xiong, Xiaolin Wu, and Cheng, S.etc. “Lossy-to-lossless compression of medical volumetric data using three-dimensional integer wavelet transforms.” *Medical Imaging, IEEE Transactions on*, 22 03 (2007):459-470

[17]Philippe Komma, Jan Fischer, Frank Duffner. “Lossless Volume Data Compression Schemes.” *Simvis*, 2007:169-182

[18] Li Zongjian. “Study on Cubic Data Compression Algorithm based on Ridgelet Transform.” *Chongqing: College of Mathematics and Physics Chongqing University*,2007

[19]Z Li, LI Zongjian, Y Zhai, X Zou, and LU Yanping. “Cubic data compression coding method based on ridgelet transform”. 43 21 (2007):193-196

[20] Yuancheng Li , Qiu Yang, Runhai Jiao. “Image compression scheme based on curvelet transform and support vector machine.” *Expert systems with applications*. 37 04 (2010):3063-3069

[21] Zhiyu Ding, Jiangang Tan, Xiangyan Wu, Weifeng Chen, Feiran Wu. “A near lossless compression domain volume rendering algorithm for floating-point time-varying volume data.” *Journal of Visualization*, 18 (2015):147-157

[22] Lindstrom Peter, Isenburg Martin. “Fast and efficient compression of floating point data.” *IEEE Transactions on Visualization and Computer Graphics*, 12 05 (2006):1245-1250

[23] Fout N, Ma K L. “An adaptive prediction-based approach to lossless compression of floating-point volume data.” *IEEE Transactions on Visualization and Computer Graphics*, 18 12 (2012): 2295-2304
[24] Jorg Mensmann, Timo Ropinski, Klaus Hinrichs. “A GPU-Supported Lossless Compression Scheme for Rendering Time-Varying Volume Data.” *The Eurographics Association*, 2012
[25] Rodríguez Marcos Balsa, Gobbetti Enrico, Guitián Jose A Iglesias, etc. “State-of-the-art in compressed GPU-based direct volume rendering.” *Computer Graphics Forum*, 33 06(2014):77-100