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Time-Varying Volume Compression in Spatio-Temporal Domain

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Abstract. Data compression is always required in large-scale time-varying volume visualization. In some recent application cases, the compression method is also required to include a low-cost decompression process. In this paper, we propose a compression scheme for large-scale time-varying volume data using spatio-temporal features. With this compression scheme, we can provide a proper compression ratio to satisfy many system environments by setting proper compression parameters. After the compression, we can also provide a low-cost and fast decompression process for the compressed data. Furthermore, we also achieve an accelerated rendering process for the decompressed data.

Keywords: Compression, Time-varying, Volume data, Visualization

1. Introduction

Time-dependent simulations can be found in many scientific fields (e.g., computational fluid dynamics, electromagnetic field simulation or ocean prediction). A good visualization result for these time-dependent simulations is always required to clearly show changes and variations over time [4, 7, 8, 9]. Because the time-varying volume data from these simulations are always highly complex and have a large-scale structure, effectively visualizing them is extremely difficult. As a result, a good compression method is always required to decrease the size of the time-varying volume data.

In some recent visualization cases, except for the efficient compression of large-scale time-varying data, a low-cost decompression and visualization process for the compressed data is also required because some visualization applications may have to perform the decompression and visualization process with a low-spec terminal. For example, “smart fishing” [12] is a case where the decompression and visualization must be performed with a low-spec terminal. “Smart fishing” refers to efficient fishing (e.g., rapid search for fishery grounds) using an ocean prediction dataset. It must transfer the large-scale ocean prediction dataset to

the on-board fisherman and visualize the data to complete an interactive analysis for fishery grounds. Because the wireless communication speed on the ocean (mainly through satellite) is slow, the large-scale time-varying ocean data must be compressed. Moreover, the visualization and decompression process should be very low-cost and fast to satisfy the low-spec hardware (e.g., tablet or notebook PC, which fisherman may hold).

In previous studies, many volume compression methods have been proposed [3, 5, 6, 10, 11, 13, 14] to achieve the time-varying volume compression. However, these compression approaches require costly decompression or generate a large decompression size, which are not appropriate for applications that require low-cost decompression (e.g., "smart fishing").

To solve this problem, we propose a volume compression scheme based on the spatio-temporal features of the time-varying volume data. In our proposed compression scheme, there are two compression processes to separately use the spatial and temporal features of large-scale time-varying data. In our previous work [1], we proposed a compression scheme using spatial features. In the present work, we add temporal domain compression to the previous method to achieve a higher compression ratio. Specifically, to use the temporal feature, we calculate the temporal coherence between every two consecutive time steps and subsequently delete the vertices that share coherence with the previous time step to compress the volume. The compressed volume data are stored in a vertex table, which records the coherence information for each vertex, and a compressed-value array. This simple structure can allow a fast decompression process (see details in section 3.2). Additionally, we provide two parameters: block size and tolerance rate, to control the compression precision and compression ratio. As a result, our compression scheme can provide a proper compression ratio and a low-cost decompression process. Moreover, we implement a special method for particle-based volume rendering (PBVR) [2] to render the decompressed volume data. Thus, the temporal features can be used to compress the volume data and to accelerate the PBVR process.

The main achievements of our proposed system are listed as follows:

1. Proper compression ratio for large-scale time-varying volume data to satisfy many system environments (even a low-spec environment) by setting the proper compression parameters.
2. Low-cost and fast decompression process.
3. Accelerated volume-rendering process (PBVR).

To verify the efficiency of our proposed compression scheme, we conduct an experiment to test the compression results using the spatio-temporal features. The experimental results show the efficiency of our proposed method.

2. Related Work

Large-scale time-varying volume data make visualization a challenging problem. Because of the large data size, many volume compression techniques have been proposed so that the rendering process can be more easily performed.

Jens Schneider et al. [5] proposed a vector-quantization-based compression scheme for both static and time-varying volume data. With vector quantization, this compression scheme can achieve a high compression ratio. However, it requires a costly decompression process, which can lead to a low frame-rate rendering result. Chaoli Wang et al. [14] used a wave-