Composite Rigid Body Construction for Fast and Compact Dynamic Data Compression

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Abstract—**Compression of 3D dynamic datasets in remote visualization still remains two challenges. One is low time performance due to the grown data and complex computation of compression algorithm. Another is small compression factor because of dynamic scenes without known equations of their motions. In this paper, we propose a fast and compact compression for 3D dynamic datasets. It accelerates compression with KD-tree construction and node-grid mapping for the dynamic data, which allow parallel rigid body decomposition and merging with disjoint union method. To increase the compression factor, composite rigid body is introduced with consideration of temporary motion consistency among rigid bodies. The results of the experiments show that our algorithm can compress dynamic datasets quickly and obtain high compression factor to reduce limitation of bandwidth.**

Keywords-dynamic datasets compression; rigid body decomposition; disjoint union; composite rigid body construction

I. INTRODUCTION

With the advent of internet era, as well as the computation enhancement of mobile computing platform such as laptops, tablets, and smartphones, remote visualization becomes a new trend in visualization. It can make full use of data in internet, but the amount of data obtained through observations and simulations increases much faster than the growth of network bandwidth. How to realize fast and compact compression is a big challenge in remote visualization.

In interactive remote visualization, conventional algorithms [1,2] are to send the visualization parameters from the client interested in the visualization to the server who stores the dataset of interest, to compute the desired visualization frame on the server, and to send the frame to the client where it is displayed. These approaches require no storage, computing, or visualization capabilities at the client and therefore scale well with the number of clients. However, these approaches suffer from long latency for frequent single frame transmission in one second, especially with huge clients, which reduce the interaction of server and client greatly. Also because of limitation of bandwidth, few datasets transmitted to client result in low quality display. Rosen [3] obtains high compression factor by merging vertices with similar trajectory as a rigid body and computing its transformations applied to vertex initial position to replace other positions for transmission. But this method compresses very slowly and compression factor need to be improved for without considering temporal consistency of vertex trajectory.

In this paper, we propose composite rigid body construction (CRBC) to provide a solution for both problems above. CRBC can process all kinds of time-varying datasets handled by RBD. The first technique is rigid body decomposition based on disjoint union (DU-RBD). It avoids the serial searching, comparing and merging of RBD with parallel generation of small rigid bodies (SRBs) and a fast SRB combination based on disjoint union. DU-RBD accelerates the process of RBD. The second technique takes advantage of temporary motion consistency for a period, and merges the rigid bodies (RBs) outputted from DU-RBD into composite rigid bodies (CRBs) according to their transformations. The use of CRBs reduces transformation matrixes need to be transmitted and makes the compression more compact.

II. ALGORITHM

The composite rigid body is constructed in two major steps (Figure 1). First, disjoint-union based rigid body decomposition is introduced to create the rigid bodies of the scene. We organize the nodes into a kd-tree structure with considering of their initial 3D position, and use RBD to generate a small rigid body for each leaf parallel. The leafs of the tree are mapped to the cell of a 3D uniform grid, thus the small rigid body is related to the cell. We create the initial singletons for disjoint sets with small rigid bodies related to cells, and use find and union operations to accelerate the generation of the rigid bodies for the scene. Second, a cell division algorithm is proposed to generate the composite rigid bodies with considering of period motion correspondences among the rigid bodies. All rigid bodies are initialized as one parent cell at the first state. For a given state i, we check whether all rigid bodies in the same cell of state i-1 can still maintain the rigid body motion. If not, this cell will be divided into a few of children cells at state i. Each cell in this process has its own lifetime from state i to j. These cells give us partitions of RB, and their lifetimes define the start and ending attributes of composite rigid bodies.

A. *Rigid body decomposition based on disjoint union*

Small rigid body is a rigid body that only has the nodes in local region of the scene. SRB construction is the process

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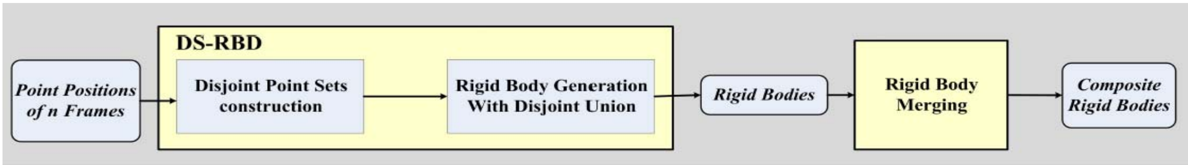

Figure 1 Overview for fast and compact compression of 3D dynamic datasets

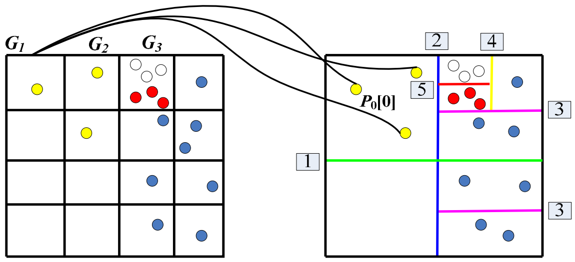

Figure 2 Creation of node-cell mapping

to generate the SRBs for the scene in parallel. In order to relate SRBs to the cells of the grid, the mapping from the leaves of the kd-tree to the grid cells is created (Figure 2). The first node of the SRB inside a leaf is taken as the representative node of the leaf. If there are more than one SRB related to the same cell, the first SRB is kept, and other SRBs are tested to see if they can be merged into the first one. In SRB combination, a fast algorithm based on disjoint union is proposed to combine SRBs into the RBs for the scene quickly. Figure 3 shows a 2D example of SRB combination. The neighbor finding and union operations are executed in row major order for SRBs. For each cell with srb_i, we find its right and bottom cells to see if their srb_j can be combined with srb_i.

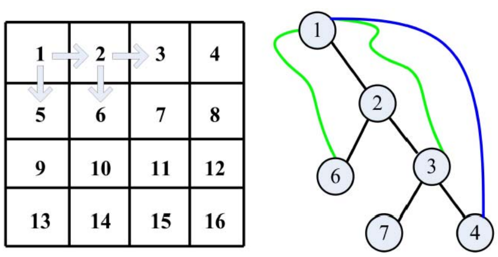

Figure 3 Merge rigid bodies using disjoint union

B. *Composite rigid body generation*

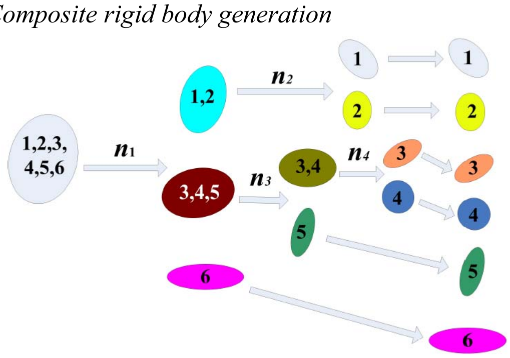

Figure 4 Composite rigid body generation

We propose to construct CRBs to merge RBs with temporary motion consistency. All the merged RBs are first merged into a CRB and CRB keep moving with its first merged rigid bodies' transformations until some vertices position errors under cell's transformations are bigger than error threshold, which results in cell division and also means a CRB's end and another new CRB's begin.

III. RESULT AND DISCUSSION

Table 1 gives the compression factors and time consumed of three datasets with variable error thresholds using our method and Rosen's. From the comparison, we see that our algorithm has faster compression speed and more compact compression factor.

In the future, we will extend our method from nodes in 3D space to samples in the screen space, thus providing solutions to these cases.

TABLE I. TABLE TYPE STYLES

Model	Error threshold [mm]	Compression Factor		Compression Factor	
		Rosen's method	***Our method***	***Rosen's method***	***Our method***
Bunny [998MB]	10	10.2	49.8	769.95	18.38
	50	17.7	95.2	441.53	6.53
	100	47.4	283.6	173.62	2.42
Truck [191MB]	10	11.4	14.3	567.87	17.2
	50	25.1	37.5	375.68	4.38
	100	33.4	56.9	282.91	1.97
Armadillo [177MB]	10	2.9	9.3	986.92	67.24
	50	4.6	15.4	552.17	26.13
	100	8.4	21.5	258.24	9.68

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