1. Introduction

Recently, the technological advance of 3D depth sensors such as the Z-Cam[1] has made it possible to acquire a dynamic real object in real time (See Fig 1.(a)). The raw depth image is time consuming to generate connectivity or pre-computed hierarchical data structure from the heavy data set in order to perform graphic and haptic interaction. In this paper, therefore, we propose meshless graphic and haptic rendering algorithm based on the point-based techniques by utilizing graphics hardware for providing efficient visualization and haptic interaction from a depth image acquired in real time.

2. Meshless visual and haptic interaction

2.1 Point based 3D surface representation

Because of the reflectivity or color variation of objects, the original depth image of the object contains noises that directly affect construction of the 3D surface, making the surface jagged as shown in Fig. 1.(b). Therefore, the raw depth data is preceded with noise reduction, smooth, and segmentation. The processed depth image is used for constructing a 3D surface based on the point-based technique that is called the surface splatting, which can directly renders the surface from point datasets without connectivity. The major challenge in the rendering stage is to generate a smooth and continuous point-based surface between discrete points projected on the screen. For rendering a smoothed depth image, we devised a depth image visibility splatting and blending algorithm based on graphics hardware in order to render efficiently and scan convert points as α-texture (See Fig 1.(c)). The α-texture represents the blending kernel Ψ, and we achieve the splat shape. We utilize a e-z-buffer technique to determine visibility and blend multiple points pi, overlapping a pixel (u, v). It allows accumulation and blending of color information from multiple point splats overlapping a given pixel within a small depth-range ε. After visibility splatting and blending, the accumulated per-pixel blending weights generally do not sum up to unity. Therefore, the per-pixel normalization can be performed at the cost of rendering one textured rectangle based on the graphics hardware.

2.2 Depth image based haptic rendering

The haptic rendering performs the collision detection and computation of contact force in order to provide a user with kinesthetic interaction. The collision detection is a process to detect a collision between the actual haptic probe with an object, and is performed by the InteriorQuery whether the haptic probe is inside the depth information or not. The InteriorQuery is directly referring the local depth information from the end of graphic rendering pipeline on the graphics hardware. Once the collision is detected, voxel type’s structure called LOMI [3] is constructed at each haptic iteration loop. Each cell’s type of the LOMI is determined by performing the InteriorQuery. The major challenge in the haptic rendering stage is to acquire local depth information at intersection of the splat point in which depth discontinuity and unwanted topology may occur. To overcome this disadvantage, we have devised the adaptive depth acquisition and bi-linear depth interpolation to reduce a depth quantization error of graphics hardware. A role of the LOMI is determining the proxy which stays on the surface. The contact response force ( F ) then can be computed by the difference vector of the haptic probe and the proxy (See Fig 1.(d)).

3. Conclusion

In this paper, we present meshless visual and haptic interaction from a depth image acquired in real time. To demonstrate effectiveness of the proposed approach, our system is applied to 132,202 point datasets obtained by the Z-Cam. Experimental results showed that graphic and haptic rendering rate is more than 40Hz and up to 3KHz respectively (See Fig 1.(e)). Therefore, we believe that the proposed approach plays an important role in performing graphic and haptic interaction for large scale datasets efficiently. The next phase of this work is to apply the multimodal (visual, auditory and haptic) interactions to a domain of 3D realistic broadcasting media.

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