Fast Volume Rendering
and Deformation Algorithms

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Abstract

Volume data provides a unified description for the surface and inner structures of solid objects. Volume visualization is therefore attractive for applications like surgical operation simulation. The huge number of volume primitives (voxels) in a volume of reasonable size, however, leads to high computational expense. Interactive rendering and deformation of the volumetric object with brute force algorithms cannot be achieved on state of the art computing systems.

In this dissertation I developed two new algorithms for the acceleration of direct volume rendering and volume deformation.

The first algorithm accelerates the ray casting process. It is commonly observed that the ray casting acceleration techniques like space-leaping and early-ray-termination are only efficient when most of the voxels in a volume are mapped either opaque or transparent. When many voxels are mapped semi-transparent, the frame rate of rendering will decrease. Our goal is to improve the performance of ray casting of semi-transparently mapped volumes by a factor of 2~3 times, so that the hardware pipeline [8] can render middle sized volumes with arbitrary opacity transfer functions in real time. Our new algorithm achieved this by reducing the computational cost in semi-transparent regions by exploiting the opacity coherence in object space. This is realized with the help of pre-computed coherence distances. The rendering speed for semi-transparently mapped volumes is increased by a factor between 1.90 and 3.49. We developed an efficient algorithm to encode the coherence information, which requires less than 12 seconds for data sets with about 8 million voxels.

The second algorithm is for volume deformation. Unlike the traditional method, our method incorporates the two stages of volume deformation, i.e. volume deforming and volume rendering, into a single process. This is implemented by combining the free-form-deformation and inverse-ray-deformation in our approach. Instead of deforming each voxel to generate an intermediate deformed volume, the algorithm directly follows the inversely deformed ray to generate the deformation, thus it saves the involved computations to reconstruct the intermediate deformed volume and memory resource for storing the deformed volume. The smoothness of the deformation is guaranteed by adaptive ray division which matches the amplitude of local deformation. Unlike the previous implementation, our shading calculation in the deformed space is still gradient-based. This is done by backward transforming of the normal vector. We have shown that there is no problem of merging the ray casting acceleration techniques with the new deformation process, thus we achieve an additional speedup of factor 2.34~6.58 to the new deformation process.

Key Words: Volume Rendering, Volume Deformation, Algorithm Optimization, Ray Casting, Inverse Ray Deformation, Free Form Deformation.
“Seeing is believing!”
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Contents

Acknowledgements ................................................................................................................................. V

1 Introduction ......................................................................................................................................... 1
  1.1 Motivations .................................................................................................................................... 2
  1.2 Contributions of This Work ........................................................................................................ 5
  1.3 Outline of This Dissertation ...................................................................................................... 6

2 Background of Volume Graphics .................................................................................................... 9
  2.1 Volume Data ............................................................................................................................... 9
  2.2 Typical Volume Visualization Process ...................................................................................... 13
  2.3 Surface Based Volume Rendering .............................................................................................. 15
    2.3.1 Traditional 3D Graphics ....................................................................................................... 15
    2.3.2 Extract Surface Model from Volume Data .......................................................................... 17
    2.3.3 Discussion on Surface-Based Volume Rendering ................................................................. 18
  2.4 Volume Rendering Equation ......................................................................................................... 20
  2.5 Volume Resampling ...................................................................................................................... 26
    2.5.1 Nearest Neighbor Interpolation ........................................................................................... 27
4.4.3 The Taylor-Expansion-based EDC ................................................................. 90
4.5 Implementation of the Accelerated Ray-casting Algorithm ....................... 98
4.6 Results and Analyses .................................................................................... 102
4.7 Discussions .................................................................................................... 111
4.8 Chapter Summary .......................................................................................... 115

5 Object Deformation Techniques ..................................................................... 117
  5.1 Geometric deformation methods ................................................................. 118
  5.2 Physically-based Object Deformation ......................................................... 122
  5.3 Early Work for Deformation Simulation of Volumetric Objects .................. 127
  5.4 Chapter Summary ........................................................................................ 128

6 Ray-Casting in the Deformed Space ................................................................. 131
  6.1 Ray-Casting Deformable Objects by Inverse-Ray-Deforming ...................... 132
  6.2 Ray-Casting in the Deformed Space ............................................................. 134
    6.2.1 Implementing FFD with a Uniform B-spline Grid ................................. 134
    6.2.2 The Inverse-Deformed Ray Trajectory in the Deformed Space .......... 138
    6.2.3 Local Curvature Estimation ................................................................. 140
    6.2.4 Volume Compositing in the Deformed Space ..................................... 142
  6.3 Shading in the Deformed Space .................................................................. 146
  6.4 Rendering Deformable and Undeformable Objects in the Same Scene .......... 149
  6.5 Algorithmic Optimizations ........................................................................ 151
  6.6 Experimental Results and Analyses ............................................................ 151
  6.7 Conclusions .................................................................................................. 163

7 Conclusions ...................................................................................................... 165
  7.1 Final Summary ............................................................................................. 165
  7.2 Future Directions ........................................................................................ 169

Appendix A: Rendering Results ................................................................. 171

Appendix B: The Volume Ray Casting and Deformation Program .................. 177

Bibliography ..................................................................................................... 191
List of Tables

Table 4.1 Performance comparison between the new algorithm and VolPack.................70

Table 4.2 The performance of the spatial coherence accelerated ray casting by using the
brute force EDC.............................................................................................................104

Table 4.3 The performance of the spatial coherence accelerated ray casting by using the
Taylor expansion based EDC........................................................................................104

Table 4.4 The experimental results for volume data whose voxels are mapped either
empty or opaque...........................................................................................................105

Table 6.1 Comparison of rendering times between two shading schemes....................155

Table 6.2 Comparison of rendering times between the optimized algorithm and the brute
force algorithm.............................................................................................................155

Table 6.3 Ratios of overall sample number between the non-optimized deformation
algorithm and the optimized deformation algorithm.............................................159

Table 6.4 The deformation times for different brick sizes.........................................163
List of Figures

2.1 The drawback of polygon-mesh based surface models.......................................................10
2.2 Scene of voxelized geometric models in flight simulation.................................................11
2.3 Grid types of volume objects............................................................................................12
2.4 Irregular grid caused by volume deformation....................................................................12
2.5 The typical volume visualization process..........................................................................13
2.6 Preprocessing of volume data........................................................................................14
2.7 Pipeline architecture of OpenGL......................................................................................17
2.8 Images rendered by the surface-based volume rendering..............................................19
2.9 Ray-voxel interaction.........................................................................................................21
2.10 A ray penetrating the volume............................................................................................24
2.11 Discretizing the ray trajectory in the volume....................................................................24
2.12 The nearest neighbor interpolation function....................................................................27
2.13 The linear interpolation function......................................................................................28
2.14 Diffuse reflection model..................................................................................................31
2.15 Specular reflection for Phong shading model..............................................................32
3.1 Volume Rendering by Splatting......................................................................................38
3.2 Slices through the volume data in the parallel projection ......................................................40
3.3 Concentric spheres for a perspective projection in 3D texture mapping .................................41
3.4 Ray casting (parallel projection) ................................................................................................43
3.5 The digital differential analyzer (DDA) for volume navigation ..............................................44
3.6 The 6-connected path Bresenham algorithm for volume navigation ........................................44
3.7 Shear-warp transformation ........................................................................................................47
3.8 The performance benchmarks of different processors from AMD and Intel ............................48
3.9 Ray-casting of hierarchical enumeration ..................................................................................51
3.10 Distance coding ........................................................................................................................52
4.1 Coherence in volume data ..........................................................................................................58
4.2 Three data structures of the run-length encoded volume ............................................................61
4.3 Offsets of pixels in a scanline of the intermediate image ............................................................62
4.4 Traversal of voxel and image scanlines .....................................................................................63
4.5 Linearization of the opacity curve along a voxel scanline ..........................................................64
4.6 Pseudo-code for encoding homogeneity and linearity in a voxel scanline ..................................65
4.7 Pseudo-code for the new shear-warp algorithm ......................................................................67-69
4.8 Image quality comparison between the new shear-warp algorithm and VolPack ....................71
4.9 Image quality comparison between the new shear-warp algorithm and the 3D texture mapping technique ....................................................................................................72
4.10 The influence of encoding error ................................................................................................73
4.11 The influence of encoding error on the performance of the new algorithm ............................74
4.12 The rendering of a voxel scanline ..............................................................................................75
4.13 Approximating the voxel opacity value curve with piecewise linear segments .......................79
4.14 Shading calculation in the coherent region .............................................................................80
4.15 The tri-linear interpolation for continuous line drawing based ray-casting ............................81
4.16 Exploiting coherence in ray casting ...........................................................................................82
4.17 Arbitrary voxel traversal order for ray-casting .......................................................................83
4.18 Coherence encoding for ray casting .........................................................................................84
4.19 Space-leaping for ray casting using the encoded distance in a distance array ...........................85
4.20 Determining possible ray directions in 3D space ....................................................................86
4.21 Determining the initial coherence distance ..............................................................................87
4.22 The pseudo codes for the brute force EDC algorithm ..............................................................88-89
4.23 Drawback of examining less viewing directions (2D case) ......................................................90
4.24 The selected ray directions for different candidate coherence distance ................................91
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.25</td>
<td>The pseudo codes for the Taylor expansion based EDC algorithm</td>
<td>96</td>
</tr>
<tr>
<td>4.26</td>
<td>Pyramid hierarchical data structure in 1D case</td>
<td>97</td>
</tr>
<tr>
<td>4.27</td>
<td>The kernel pseudo code of the new ray casting algorithm</td>
<td>99-100</td>
</tr>
<tr>
<td>4.28</td>
<td>The main window of our ray casting program</td>
<td>101</td>
</tr>
<tr>
<td>4.29</td>
<td>The dialog pad for interactive control of visualization parameters</td>
<td>102</td>
</tr>
<tr>
<td>4.30</td>
<td>Rendition of volumes different opacity transfer functions</td>
<td>106-107</td>
</tr>
<tr>
<td>4.31</td>
<td>The impact of noise on the performance</td>
<td>108</td>
</tr>
<tr>
<td>4.32</td>
<td>The effect of filtering the noise in volume data</td>
<td>108</td>
</tr>
<tr>
<td>4.33</td>
<td>The impact of the encoding error to the performance of the new algorithm</td>
<td>109</td>
</tr>
<tr>
<td>4.34</td>
<td>Influence of light distance to the image quality</td>
<td>110</td>
</tr>
<tr>
<td>4.35</td>
<td>Shading comparison between the new algorithm and VolPack</td>
<td>111</td>
</tr>
<tr>
<td>4.36</td>
<td>Two strategies for opacity curve approximation</td>
<td>114</td>
</tr>
<tr>
<td>5.1</td>
<td>Global twist deformation</td>
<td>119</td>
</tr>
<tr>
<td>5.2</td>
<td>Free-form-deformation</td>
<td>120</td>
</tr>
<tr>
<td>5.3</td>
<td>Finite element representation of object</td>
<td>124</td>
</tr>
<tr>
<td>5.4</td>
<td>Mass-spring representation of deformable object</td>
<td>125</td>
</tr>
<tr>
<td>5.5</td>
<td>Lennard-Jones type function</td>
<td>126</td>
</tr>
<tr>
<td>6.1</td>
<td>Inversely deforming rays to generate visual effects of deformation</td>
<td>132</td>
</tr>
<tr>
<td>6.2</td>
<td>Ray deflector</td>
<td>134</td>
</tr>
<tr>
<td>6.3</td>
<td>A comparison between B-spline curve and Bézier curve</td>
<td>135</td>
</tr>
<tr>
<td>6.4</td>
<td>Determining ray trajectory in the deformed space</td>
<td>138</td>
</tr>
<tr>
<td>6.5</td>
<td>The relation between the polyline length and the local curvature radius</td>
<td>140</td>
</tr>
<tr>
<td>6.6</td>
<td>The pseudo code for ray casting in deformed space</td>
<td>143-144</td>
</tr>
<tr>
<td>6.7</td>
<td>Mismatch of deformed ray segments to the standard sample unit</td>
<td>145</td>
</tr>
<tr>
<td>6.8</td>
<td>Deformed head rendered via 3D texture mapping</td>
<td>147</td>
</tr>
<tr>
<td>6.9</td>
<td>Ray-casting the deformable and undeformable objects in the same scene</td>
<td>150</td>
</tr>
<tr>
<td>6.10</td>
<td>Result of ray-casting the jaw (deformable) and a stick (undeformable)</td>
<td>150</td>
</tr>
<tr>
<td>6.11</td>
<td>Example rendering of undeformed and deformed volume objects</td>
<td>152</td>
</tr>
<tr>
<td>6.12</td>
<td>Comparisons of deformation with and without shading adjusting</td>
<td>153-154</td>
</tr>
<tr>
<td>6.13</td>
<td>The impact of the deformation amplitude on the algorithm performance</td>
<td>157</td>
</tr>
<tr>
<td>6.14</td>
<td>Comparison of ray division methods</td>
<td>160</td>
</tr>
<tr>
<td>6.15</td>
<td>Brick deformation</td>
<td>161</td>
</tr>
<tr>
<td>6.16</td>
<td>Comparison of deformation results</td>
<td>162</td>
</tr>
<tr>
<td>A1</td>
<td>Rendering results of human jaw</td>
<td>171</td>
</tr>
</tbody>
</table>
A2 Rendering results of CT head.................................................................172
A3 Rendering results of MRI Brain............................................................173
A4 Deformation results of MRI Brain..........................................................174
A5 Deformation results of Heart.................................................................175
B1 Program structure overview of volume ray casting and deformation........178