Cache-Aware Iso-Surface Volume Rendering with CUDA

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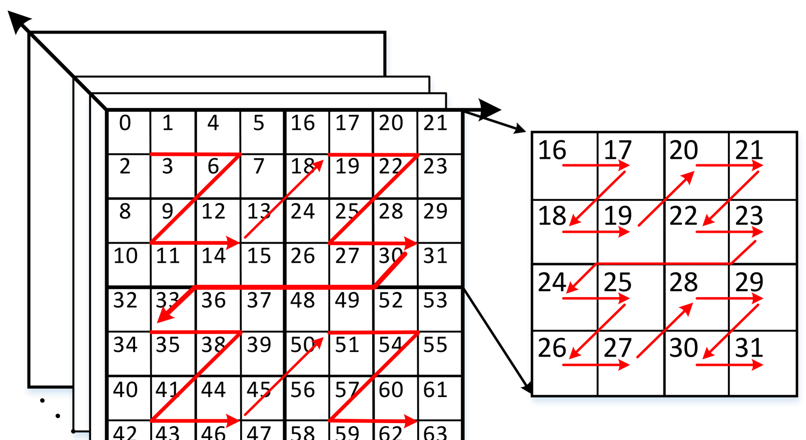
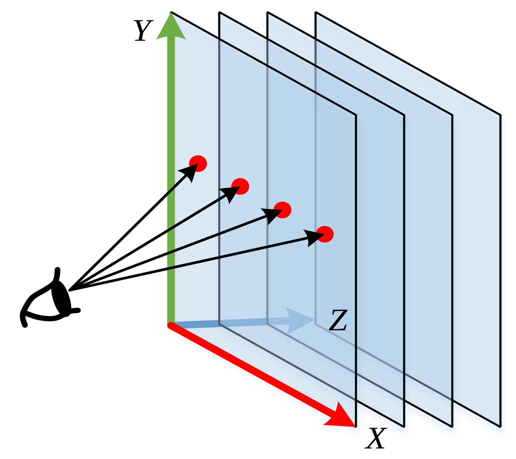
Introduction & Motivation

Most of the existing GPU-based ray casting algorithms map volume data to 3D texture of GPUs. However texture cache is optimized in 2D space. As a result, the viewing direction has significant effects on the texture cache hit rate. This paper mitigates the cache penalty by presenting a new sampling strategy, i.e. ***warp marching***.

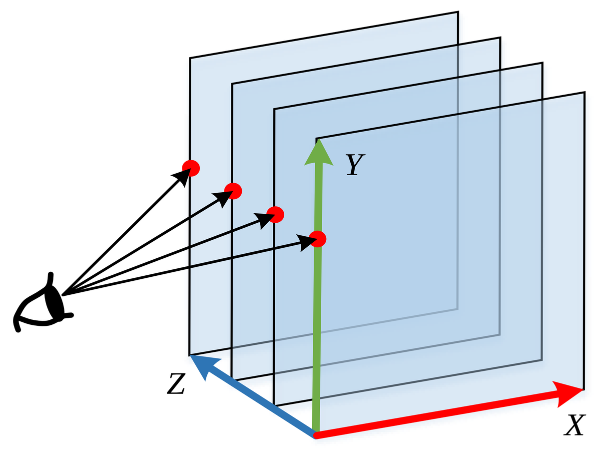
3D texture of the GPU is organized as many 2D slices and inside each slice, z-order curves are used to optimize the 2D spatial locality.



Standard Sampling: existing ray casting algorithms map one ray to one GPU thread. At any given instance, the samples of all rays are fitted into a plane. The algorithm accesses all these samples on the plane in parallel. It then marches this plane from front to back along a given camera orientation.

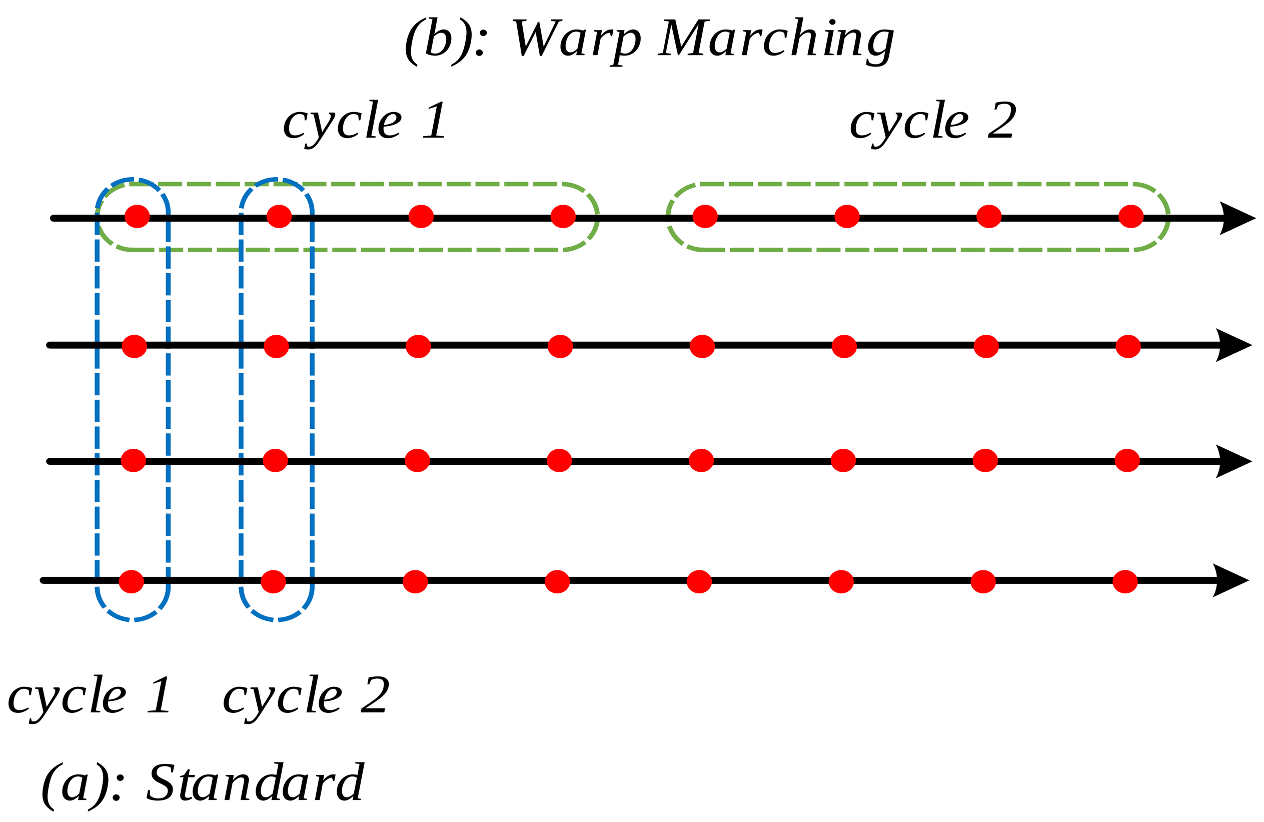


facing XY
Samples are on the same slice



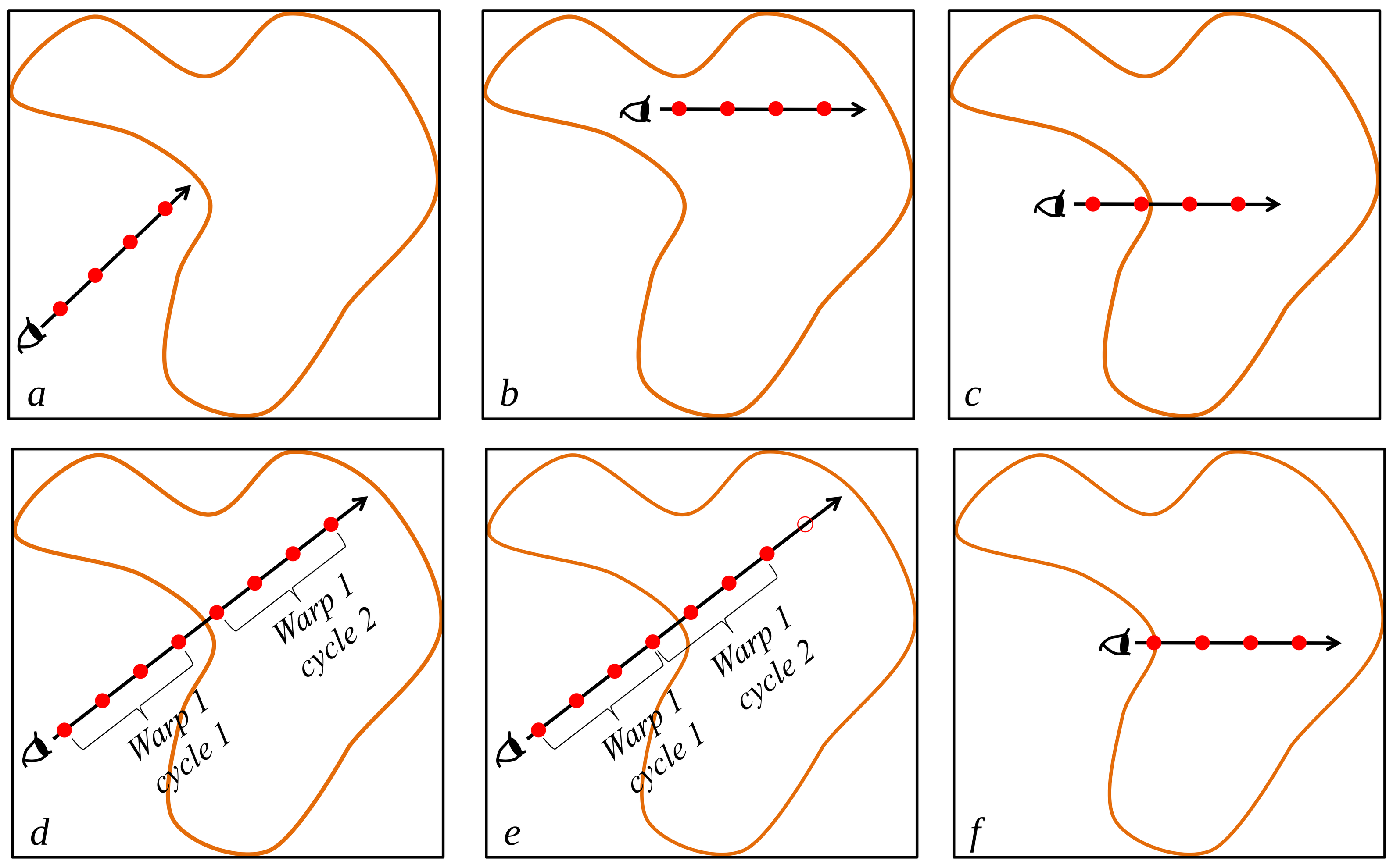
facing ZY
Samples cover multiple slices

Warp Marching



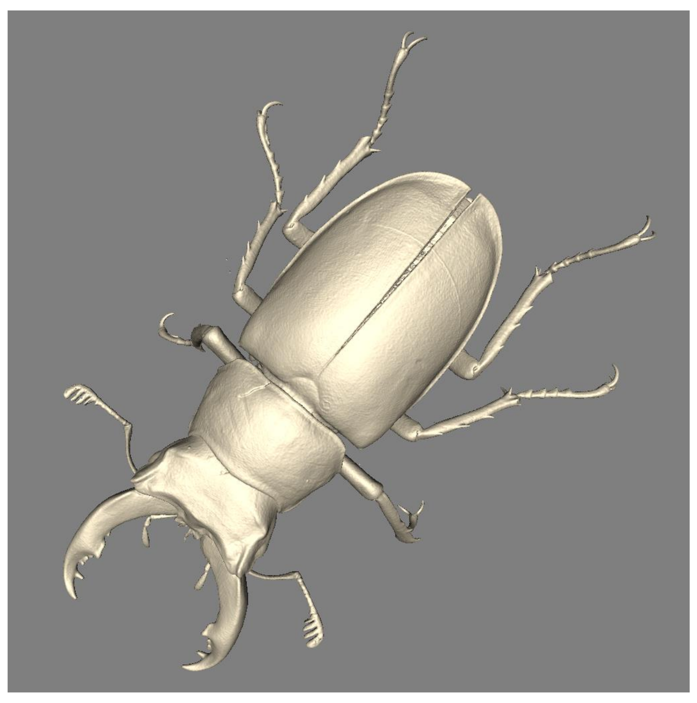
(a): Standard

Standard Sampling: one thread per ray and marches one sample on four rays in one warp cycle.
Warp Marching: four threads per ray and marches four samples on one ray in one warp cycle.

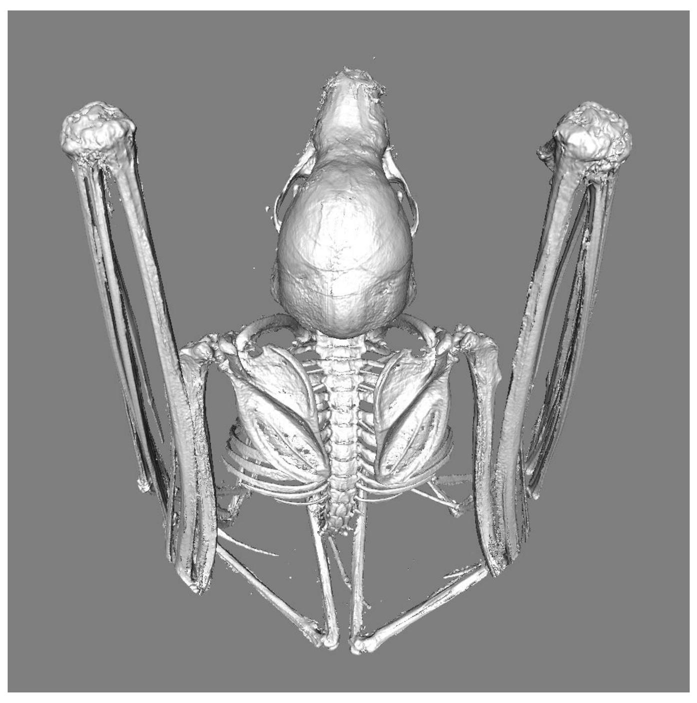


Three General Cases
a. Densities of the warp of samples < the iso-value;
b. Densities of the warp of samples >= the iso-value;
c. Some density values are lesser than the iso-value, while others are larger than the iso-value.
Two Special Cases
d. Iso-surface is located in the gap between two warp cycles.
f. Boundary condition: warp marching cannot detect the iso-value if it is on the first sample of the warp.

Result & Analysis



beetle (16 bit, 0.65GB)
832x832x494



bat (8 bit, 1.12GB)
906x911x1466

		Facing XY		*Facing ZY*	
		beetle	*bat*	*beetle*	*Bat*
Texture Cache Hit Rate	*Standard*	*94.67%*	*94.13%*	*56.32%*	*33.13%*
	Warp Marching	*78.58%*	*75.33%*	*95.83%*	*97.38%*
	Speedup	*0.83*	*0.80*	*1.70*	*2.94*
FPS	*Standard*	*39.62*	*30.13*	*9.80*	*2.10*
	Warp Marching	*31.92*	*25.81*	*35.99*	*29.49*
	Speedup	*0.81*	*0.86*	*3.67*	*14.04*

GPU used: NVIDIA GeForce GTX TITAN. Sampling distance along rays is 0.3 voxel length. Thread block size: 256 threads per block.

Conclusion & Future Work

We introduce a new sampling strategy for the texture-based iso-surface volume rendering. The strategy takes advantage of cache coherence and increases rendering performance at certain camera orientations. Applying warp marching to other types of GPUs, even those with varying warp sizes, is a promising direction for future exploration. Also, a hybrid approach that adjusts sampling strategy based on viewing direction is worth trying.

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