

Supplementary Document

Parallel Compositing of Volumetric Depth Images for Interactive Visualization of Distributed Volumes at High Frame Rates

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1. Compositing sub-supersegments $\text{sub-}\mathbb{S}$ to form supersegments \mathbb{S}

As mentioned in the main text (Sec. 5.2), the process for compositing $\text{sub-}\mathbb{S}$ received from multiple **PEs** to generate a list of supersegments \mathbb{S} models the $\text{sub-}\mathbb{S}$ as discrete samples to be raycast over, combining them with α -compositing, and running an iterative γ search until up to $\mathbb{N}_{\mathbb{S}}$ are generated. Algorithm S1 shows the corresponding pseudocode for combining $\text{sub-}\mathbb{S}$ into \mathbb{S} for a given value of γ , i.e., this algorithm is iterated over during the γ search, and then finally used to generate the supersegments. Notations are consistent with those introduced in the main text.

2. Impact of $\mathbb{N}_{\mathbb{S}}$ on VDI Generation Rates

To supplement the VDI generation rates for different numbers of GPUs reported in the main text for $\mathbb{N}_{\mathbb{S}}=25$, Figure S1 additionally plots generation rates for $\mathbb{N}_{\mathbb{S}}=20$ and $\mathbb{N}_{\mathbb{S}}=30$ for both the Forced Isotropic Turbulence (FI) and Rotating Stratified Turbulence (RS) datasets. As in the main text, means and standard deviations are plotted over a 360° camera orbit with the camera rotating in 5° increments and two iterations at each viewpoint. Trends are similar at all values of $\mathbb{N}_{\mathbb{S}}$, with linear speed-ups for lower GPU counts reducing to sub-linear at higher counts. As expected, VDIs with smaller $\mathbb{N}_{\mathbb{S}}$ are faster to generate.

3. Quality of VDI Rendering in PSNR

Figure 10 in the main text compares the quality of VDI rendering with distributed direct volume rendering (DVR) using the SSIM metric. Figure S2 reports the same quality comparison using the Peak Signal-to-Noise Ratio (PSNR) as a metric. As in the main text, a VDI generated on 32 GPUs is rendered and compared with DVR on 32 GPUs. Mean values are reported over four viewpoints of VDI generation (V_O) at 90° rotations about the dataset.

Algorithm S1: Combining sub-supersegments into super-segments

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1: /* Combining sub-supersegments along a
   ray into supersegments for a given  $\gamma$  */
2: supersegmentIsOpen  $\leftarrow$  False
3:  $f(\mathbb{S}), b(\mathbb{S}) \leftarrow 0$ 
4:  $b(\mathbb{S})_t \leftarrow 0$ 
5:  $C(\mathbb{S}), \alpha(\mathbb{S}) \leftarrow 0$ 
6: transparent  $\leftarrow$  False

   /* The front element of all lists is
   initialized to the index of the first
   element */
7: frontIndex[0...n]  $\leftarrow$  1
8: while !samplesComplete do
9:    $C(\text{sub-}\mathbb{S}), \alpha(\text{sub-}\mathbb{S}), f(\text{sub-}\mathbb{S}), b(\text{sub-}\mathbb{S}), p \leftarrow$ 
   findNextSub(frontIndex[])
10:  if  $p = -1$  then
11:    samplesComplete  $\leftarrow$  True
12:  end if
13:   $l \leftarrow \text{distance}(f(\text{sub-}\mathbb{S}), b(\text{sub-}\mathbb{S}))$ 
14:   $\widetilde{\alpha}(\text{sub-}\mathbb{S}) = 1 - (1 - \alpha(\text{sub-}\mathbb{S}))^l$ 
15:  if supersegmentIsOpen then
16:    if  $f(\text{sub-}\mathbb{S}) > b(\mathbb{S})$  then
17:      transparent  $\leftarrow$  True
18:       $C(\text{sub-}\mathbb{S}), \alpha(\text{sub-}\mathbb{S}) \leftarrow 0$ 
19:       $b(\text{sub-}\mathbb{S}) \leftarrow f(\text{sub-}\mathbb{S})$ 
20:       $f(\text{sub-}\mathbb{S}) \leftarrow b(\mathbb{S})$ 
21:    end if
22:     $\widetilde{C}(\mathbb{S}) \leftarrow \frac{C(\mathbb{S})}{\alpha(\mathbb{S})}$ 
23:     $l_s \leftarrow \text{distance}(f(\mathbb{S}), b(\mathbb{S}))$ 
24:     $\widetilde{\alpha}(\mathbb{S}) = 1 - (1 - \alpha(\mathbb{S}))^{l_s}$ 
25:    if  $\gamma < ||\widetilde{C}(\mathbb{S})\widetilde{\alpha}(\mathbb{S}) - C(\text{sub-}\mathbb{S})\alpha(\text{sub-}\mathbb{S})||_2$  then
26:      newSupersegment  $\leftarrow$  True
27:    end if
28:    if newSupersegment || samplesComplete then
   /* Closing  $\mathbb{S}$ . If  $\gamma$  was the final value
   determined by iterative search, store
   sub- $\mathbb{S}$  */
29:      numTerminations  $\leftarrow$  numTerminations + 1
30:    else
31:       $C(\mathbb{S}) \leftarrow C(\mathbb{S}) + (1 - \alpha(\mathbb{S})) * C(\text{sub-}\mathbb{S}) * \alpha(\text{sub-}\mathbb{S})$ 
32:       $\alpha(\mathbb{S}) \leftarrow \alpha(\mathbb{S}) + (1 - \alpha(\mathbb{S})) * \alpha(\text{sub-}\mathbb{S})$ 
33:       $b(\mathbb{S}) \leftarrow b(\text{sub-}\mathbb{S})$ 
34:      if !transparentSample then
35:         $b(\mathbb{S})_t \leftarrow b(\text{sub-}\mathbb{S})$ 
36:      end if
37:      if !supersegmentIsOpen & !transparent then
38:        supersegmentIsOpen  $\leftarrow$  True
39:         $f(\mathbb{S}) \leftarrow f(\text{sub-}\mathbb{S})$ 
40:         $b(\mathbb{S}), b(\mathbb{S})_t \leftarrow b(\text{sub-}\mathbb{S})$ 
41:         $C(\mathbb{S}) \leftarrow C(\text{sub-}\mathbb{S}) * \alpha(\text{sub-}\mathbb{S})$ 
42:         $\alpha(\mathbb{S}) \leftarrow \alpha(\text{sub-}\mathbb{S})$ 
43:      end if
44:    end if
45:  end if

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46:  if  $p \neq -1$  & !transparent then /* Increment the
   front index of the process whose
   supersegment was selected */
47:    frontIndex[p]  $\leftarrow$  frontIndex[p] + 1;
48:  end if
49: end while

```

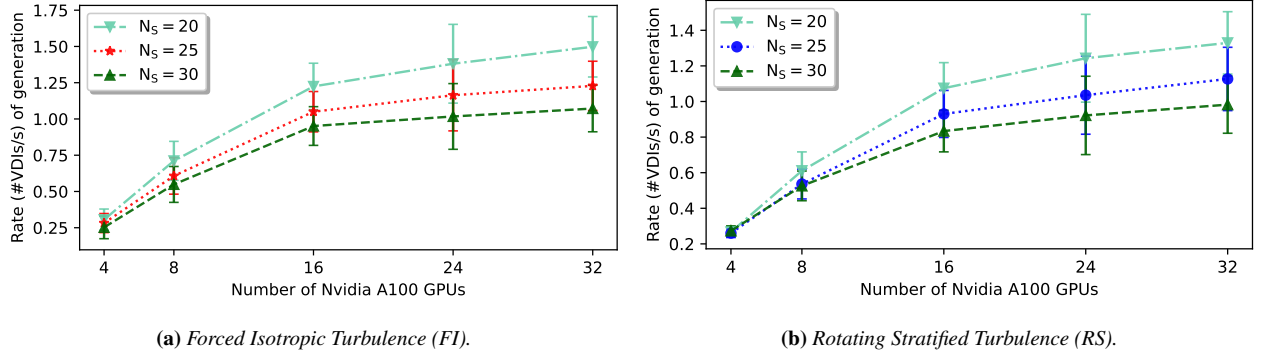


Figure S1: Number of VDIs generated per second (mean \pm standard deviation over a 360° camera orbit) for different numbers of Nvidia A100 GPUs and different values of N_S . $N_L = 1920 \times 1080$ VDIs are generated for the Forced Isotropic Turbulence (FI) (a) and Rotating Stratified Turbulence (RS) (b) datasets of 128 GiB each.

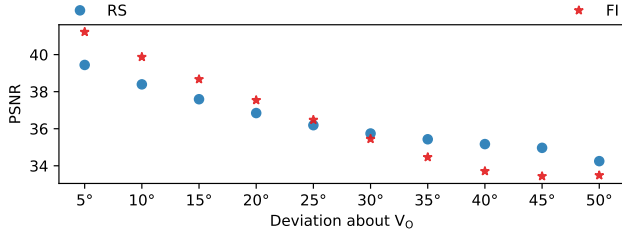


Figure S2: PSNR image similarity between VDI rendering and DVR for different values of V_N . Mean values are reported over four different V_O for two datasets (RS: circles, FI: stars).