Interactive Direct Volume Rendering of Time-Varying Data on the Origin2000

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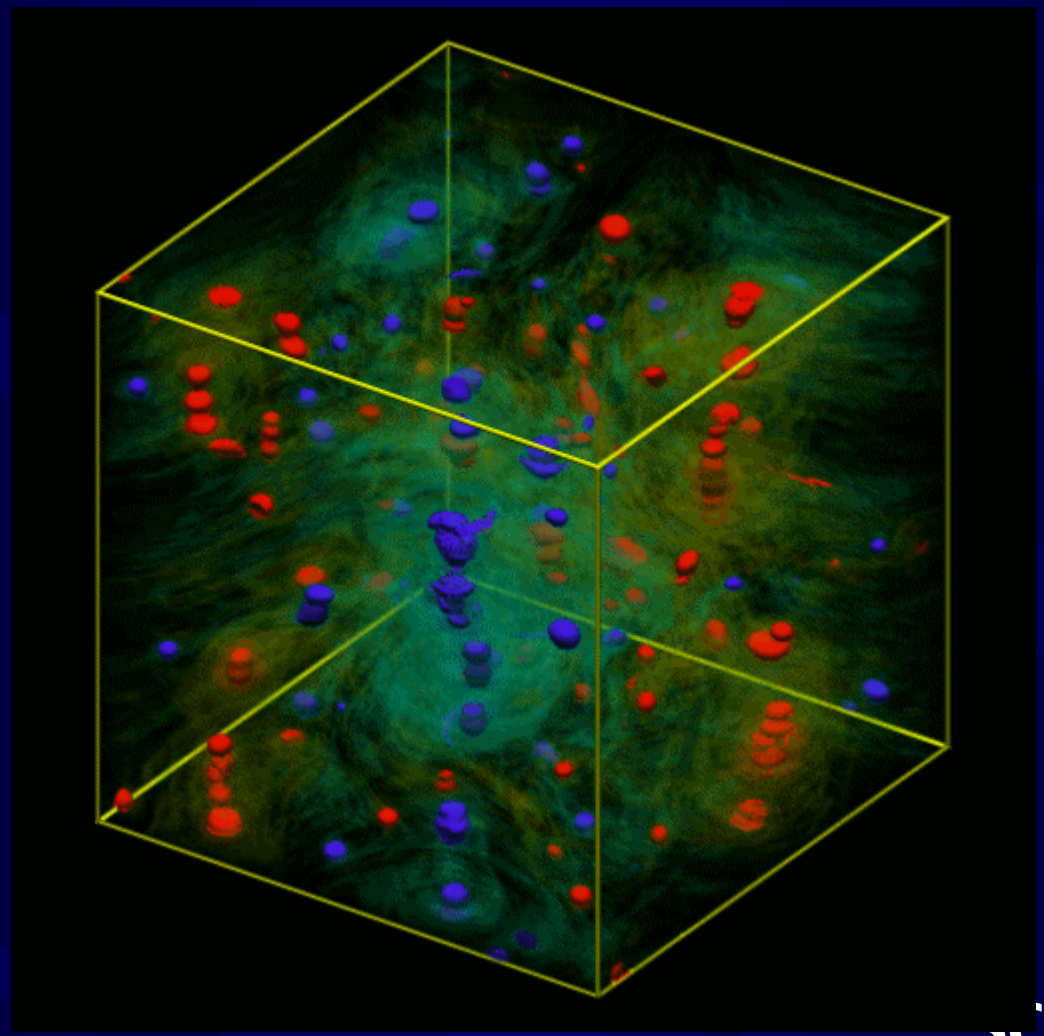
QG Video



Quasi-geostrophic Turbulence Visualization

- 256^3 volumes, 1492 time steps (25 GB's of data)
- Volume rendered in 1995 on single R4400 cpu in ~100 hours
- Applied combination of surface-fitting and volume rendering approaches
- SF essential because of interactivity
- Volume rendering essential to study amorphous features
- => Needed interactive DVR capability

Challenges to Volume Rendering Time-Varying Data

- I/O requirements are enormous
  - 256^3 * 1byte per voxel * 10 HZ = ~160MB/sec
- Many algorithmic optimizations assume static data
- Suitable rendering platforms typically lack directly-attached displays

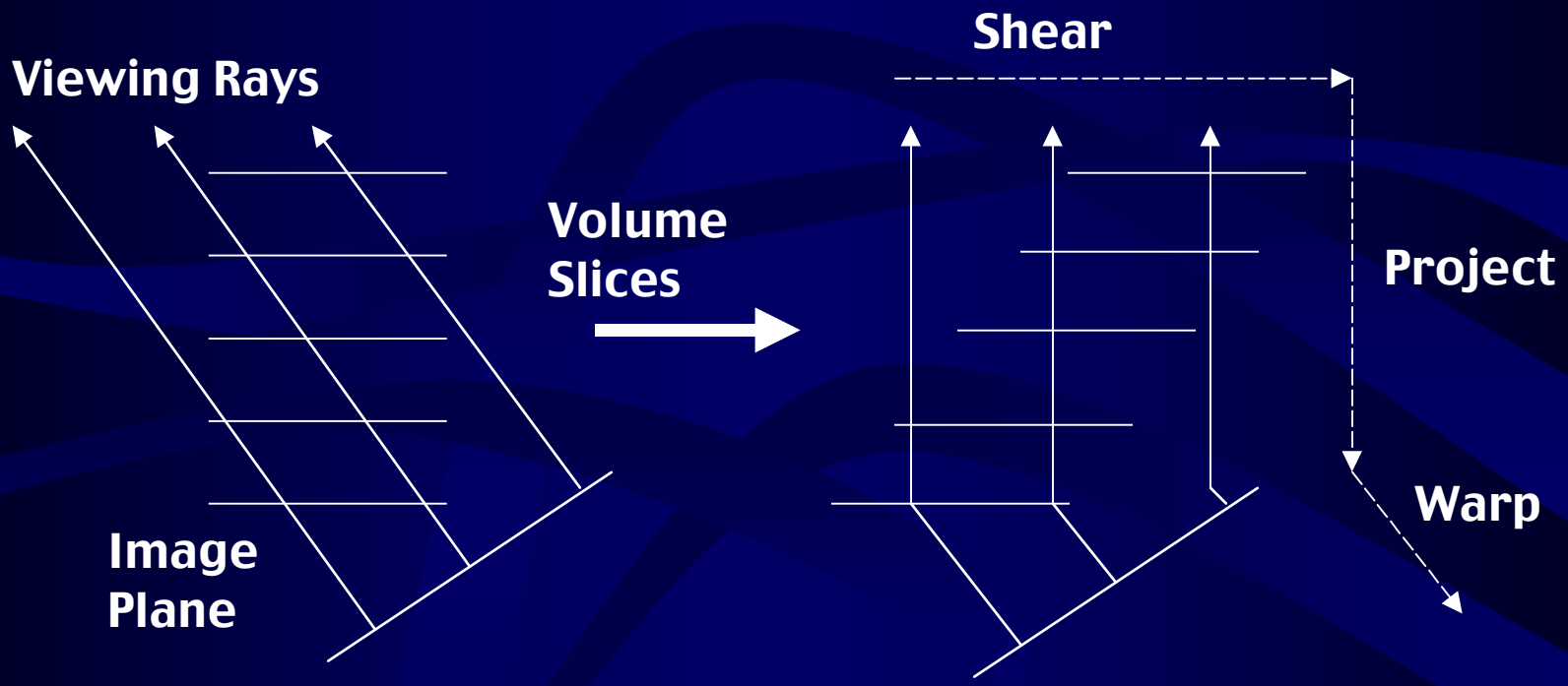
The Brute Force Approach

- Leverage advances in computing and exploits multiple technologies:
  - Availability of high-speed disk arrays
  - Improved performance/availability of commercial multiprocessors/microprocessors
  - High-bandwidth local area networking
  - Fast new rendering algorithms

Shear-Warp Factorization Algorithm

- Hybrid algorithm that exploits benefits of both image-order and object-order algorithms
- Operates by applying affine viewing transformation to transform object space into intermediate coordinate system
- Sheared object space is defined by construction such that all viewing rays are parallel to the third coordinate axis and perpendicular to the volume slices.
- Projection is a simple, fast compositing step
- The distorted, intermediate image must then be resampled into final image space

Shear-Warp



Advantages of Shear Warp

- Costly tri-linear interpolation avoided
- Resampling weights for 2D interpolations are invariant for each voxel slice
- Voxel and image scanlines are always aligned, minimizing addressing arithmetic
- Early ray-termination is readily supported
- Substantial additional performance gains possible by pre-classifying data and exploiting data coherency by skipping transparent voxels and opaque pixels

RLE Rendering Algorithm is Faster, But...

- RLE volumes may be substantially larger
- RLE volumes have fixed opacity

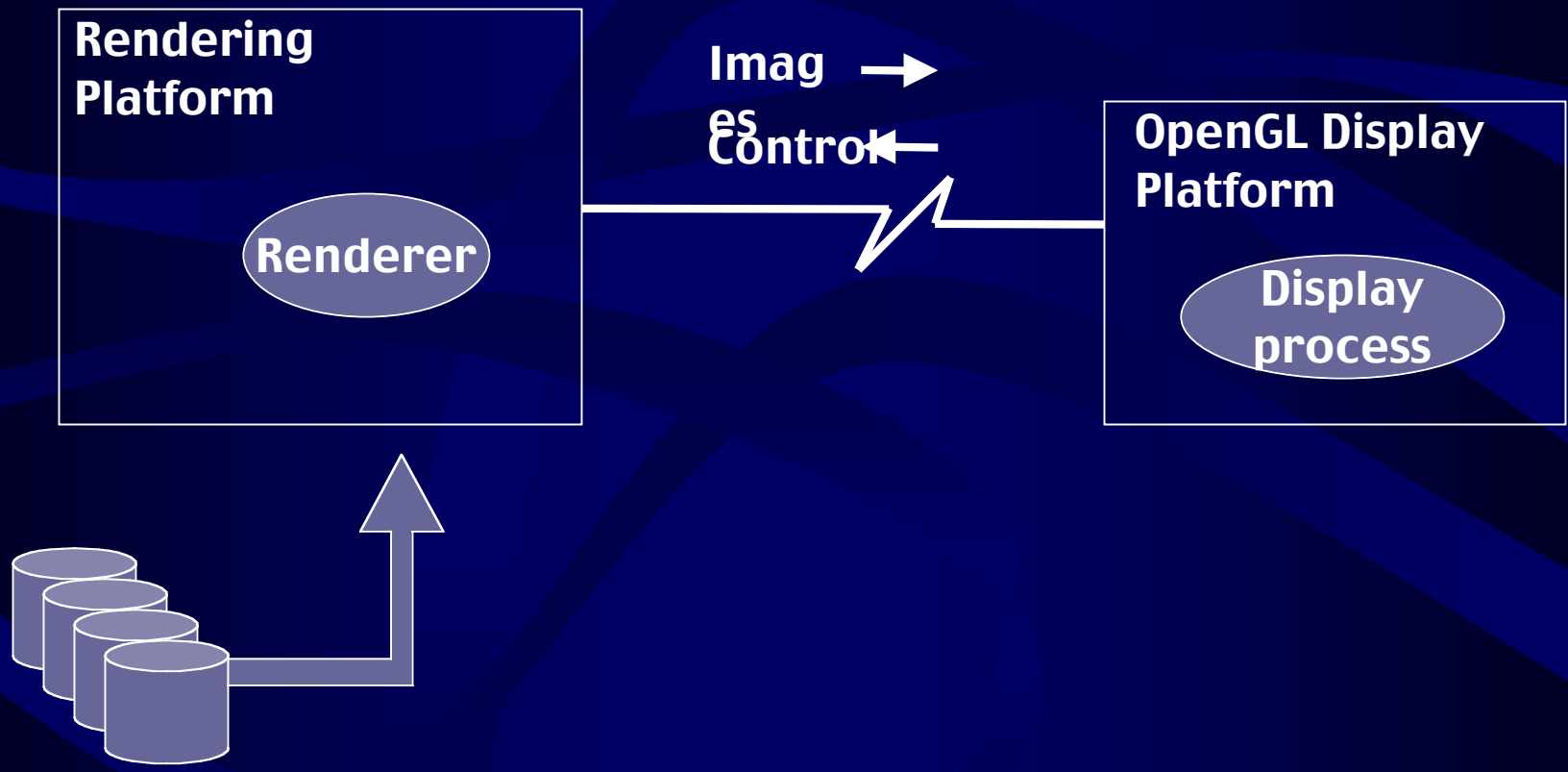
Parallel Shear-Warp

- Shared memory implementation
- Implemented using POSIX threads (pthreads)
- Simple (shared memory) and portable (pthreads)

Addressing Data Distribution Costs for Time Varying Data

- High-speed disk arrays
- Double-buffered I/O
    - hide cost of I/O behind rendering

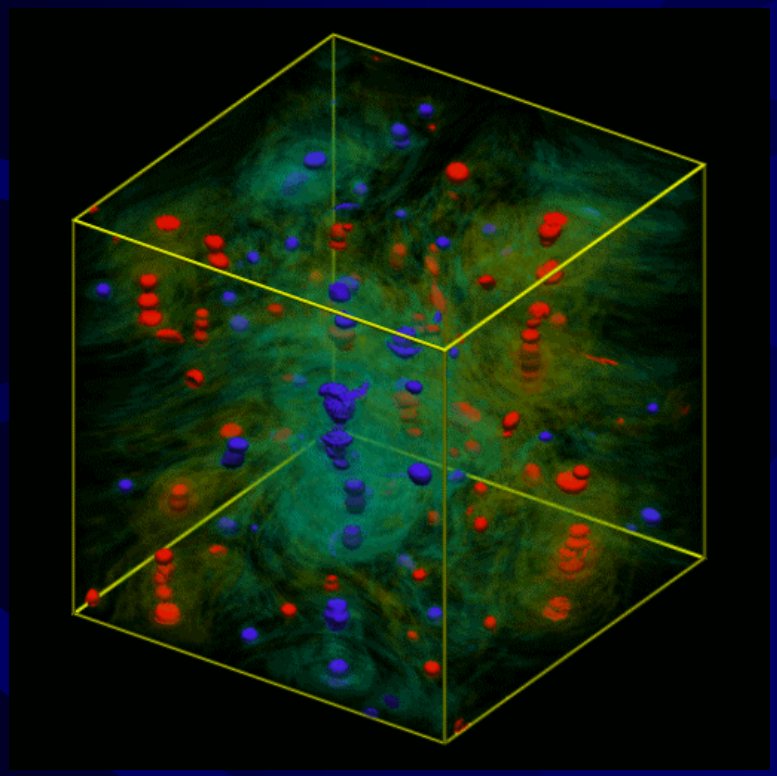
Volsh System Overview

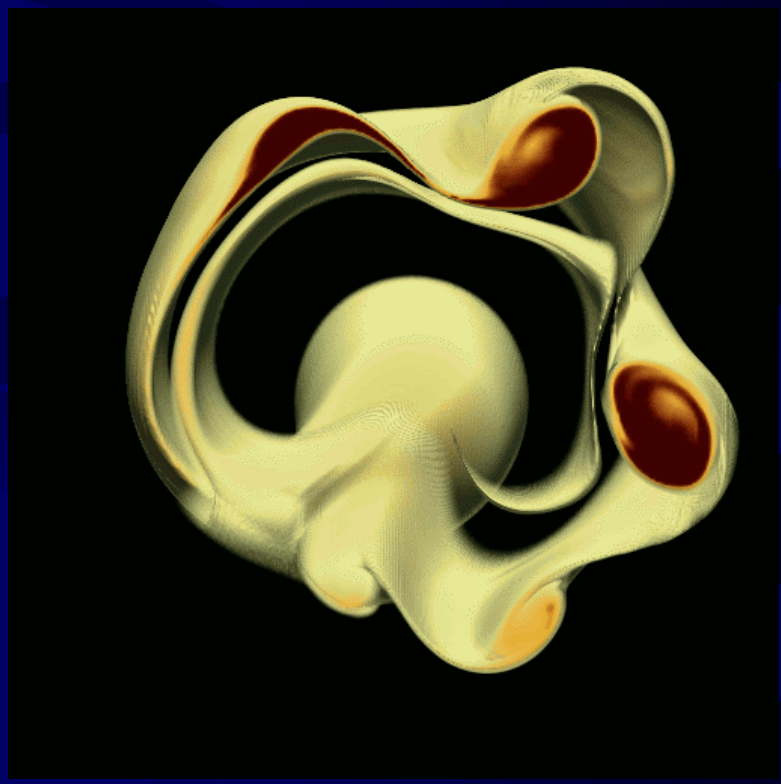


Benchmark Datasets

- 128^3 Quasi-geostrophic (QG)
  - Dense
  - Dominated by semi-transparent material
- 256^2x175 Polar Vortex (PV)
  - Sparse
  - Very little semi-transparent material
- RLE and raw data

QG and PV Images

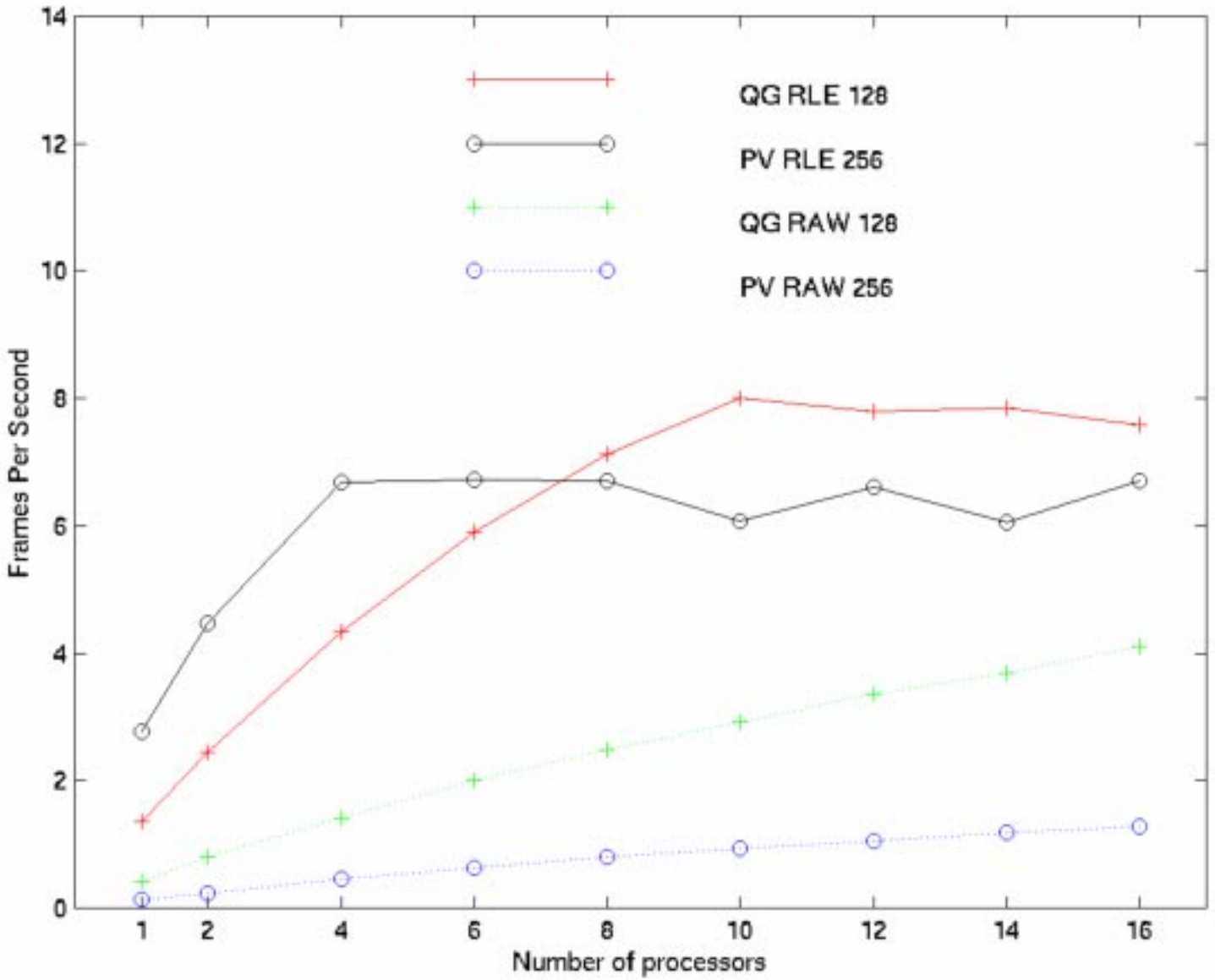




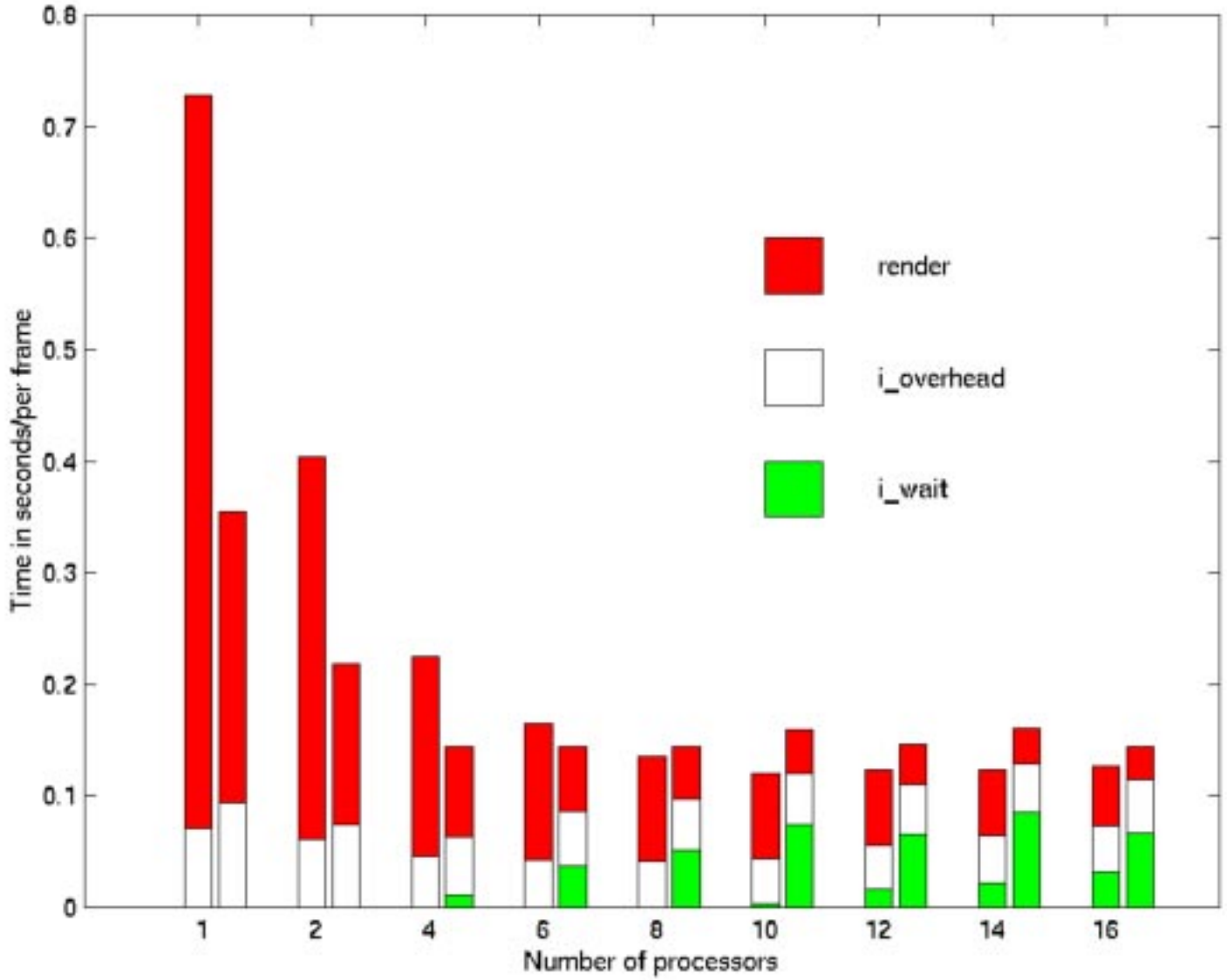
Hardware configuration

- 128 CPU's
- 250MHz R10000, 4MB cache
- 256MB RAM per Node
- 28 x 3 Fibre Channel Disk Array
- 100BaseT network to display host

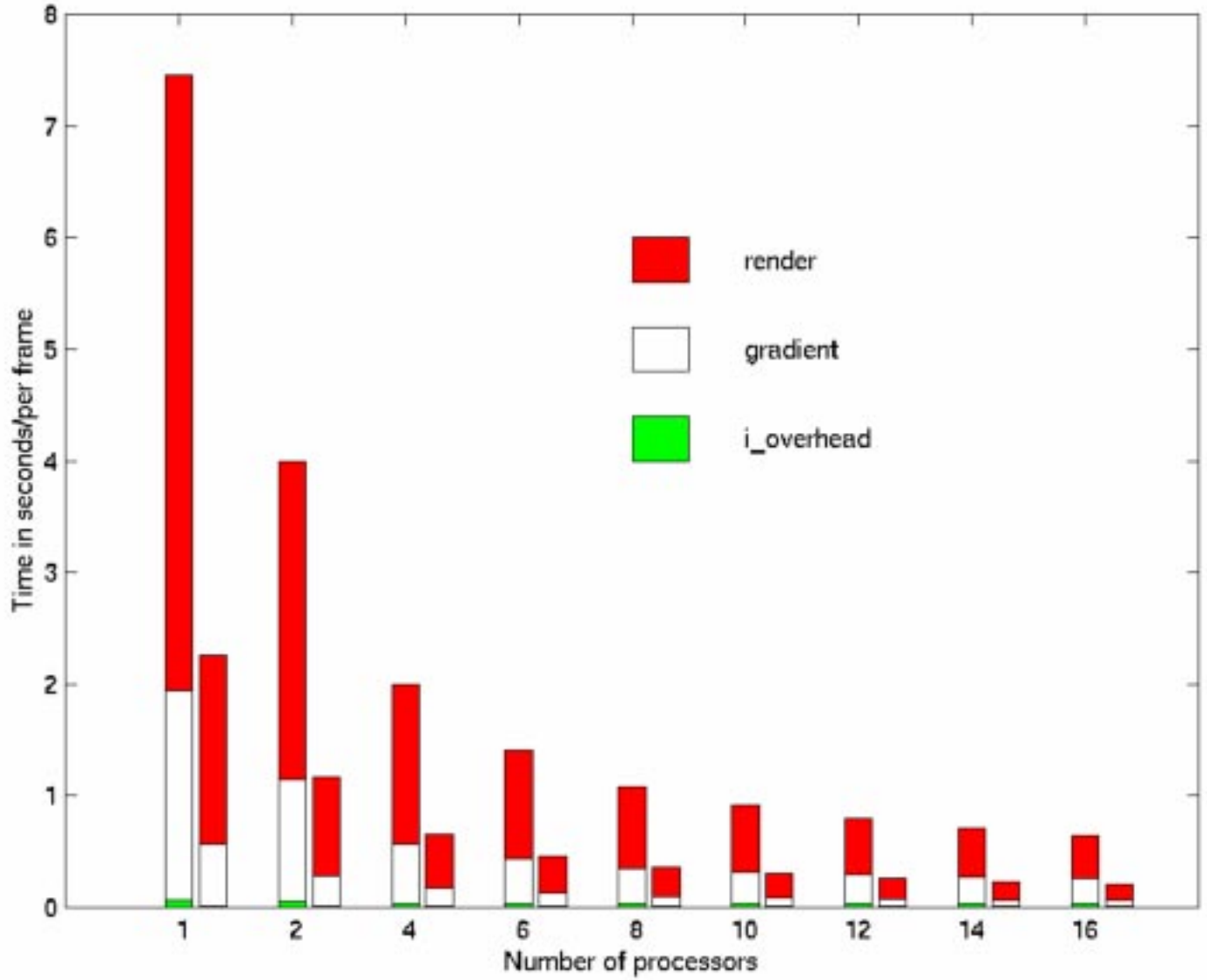
Frame Rate vs. Number of Processors



Execution Time vs. Number of Processors (RLE)



Execution Time vs. Number of Processors (raw)



Memory Layout

- Implementation targets generic shared-memory system
- No consideration given to Origin's switched-based architecture
- Result: memory placement defaults to single node board
    - => Contention

Pthreads

- Interface defined without consideration for DSM's
- No facilities for specifying affinity between process and processor
    - => Can't enforce local access of memory

Video2

Final Remarks

- Interactive volume rendering of TV data is possible
- Pthreads, though portable, don't appear to be best choice for HPC on Origin
- Just because the origin offers a shared-memory programming model doesn't mean that you can ignore the underlying architecture
- Addressing speedup issues doesn't address I/O problems
- Software available from www.scd.ucar.edu/vg/Software/volsh