Hybrid Techniques

Two Hybrid Rendering Techniques

- Techniques are not completely image-order or object-order, but actually are a combination of both

- Cell-by-cell Volume Buffer (Upson and Keeler, *Computer Graphics*, 22, 59, 1988)
  - Process cells in the volume in a front-to-back order
  - Use an image-order ray casting technique within each cell

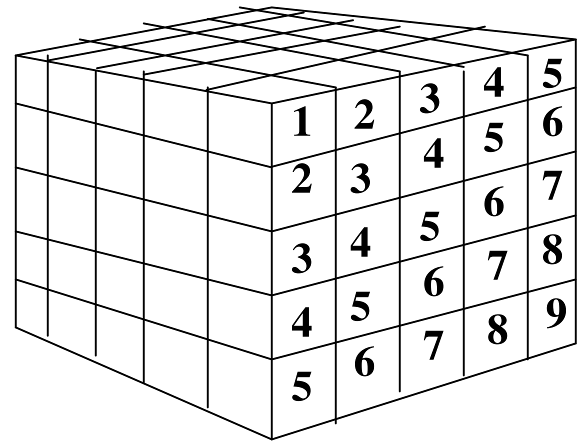
- Shear-Warp (Lacroute and Levoy, *Proc. SIGGRAPH 94*, 451, 1994)
  - Fast rendering algorithm
  - Based on a factorization of the viewing transformation into a shear and warp transformation.

Cell Processing

- Based on sweeping through the domain processing one cell at a time

- Determine a cell processing order

  - ➢ Start with the voxel plane closest to the viewpoint, and progress in a plane-by-plane manner



Cells numbered by processing priority

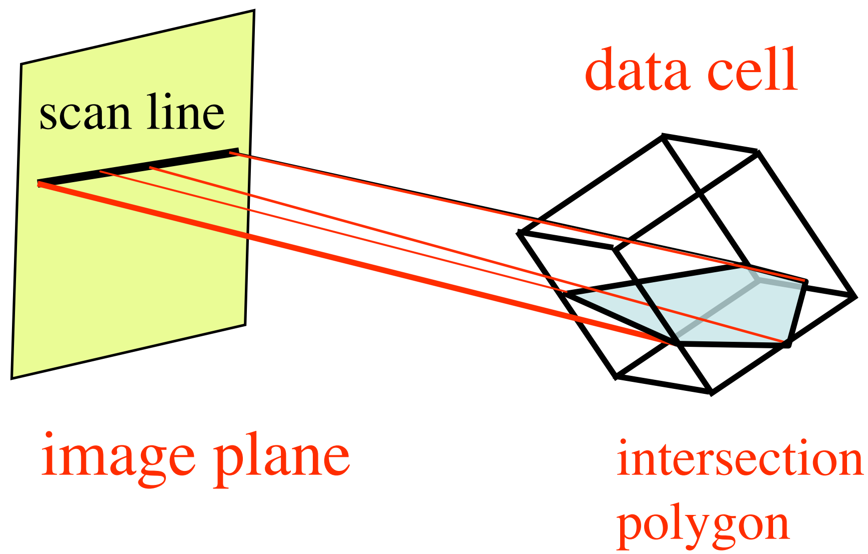
  - ➢ Within each plane, proceed from the closest cell to those adjoining this cell in the order of distance from the viewpoint

- Cells with the same number can be processed concurrently as they do not affect each other.

Pixel’s Color and Opacity

- For each scan-line in the image plane, determine which pixels are affected by a cell

- For each pixel an integration volume is determined to calculate the color and opacity as in raycasting method



- The process continues until all cells are processed, with contribution of every cell accumulated into pixel values
  - ➢ Processing a pixel can be stopped once its opacity reaches unity (by setting a flag)
  - ➢ Due to front-to-back nature, incremental display of the image is possible.

Shear-Warp

- Uses a raycasting-like rendering approach
  - Shear the volume such that the rays are perpendicular to the volume slices and are parallel to each other
  - Use bilinear interpolation (within the traversed volume slices) to obtain sample values along the rays
  - Composite the resampled slices together in front-to-back order

- A final warping step transforms the rendered image to image space (to get a final image)
  - This step can be accelerated with hardware texture mapping

- Employs a clever volume and image encoding scheme in combination with a simultaneous traversal of volume and image
  - Skipping opaque image regions and transparent voxels
  - A time-optimized rendering approach

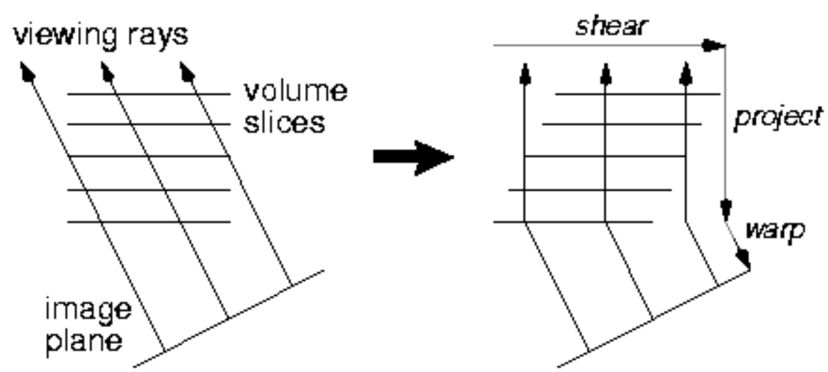
    Faster than ray-casting (5 times faster in the case of 256^3 volume)
  - The algorithm can be implemented on multiprocessors computer.

Parallel Projection: Shear-Warp

- Simple shear transformation:
  - ➢ Transform the slices into actual planes in the volume data, making the sampling linear and much more efficient for arbitrary viewing direction.

    Translation and sampling each slice
  - ➢ Composite the resampled slices together into an intermediate 2D image.
- Warping transformation:
  - ➢ Maintain the original viewing matrix, or the image is “smeared”

    Transpose the intermediate image to image space.



Shear-Warp Factorization

- Transformation from object space to sheared object space:

$$M_{\text{view}} = P \bullet S \bullet M_{\text{warp}}$$

where P is a permutation matrix transposes the coordinate system in order to make the z-axis the principal viewing axes.

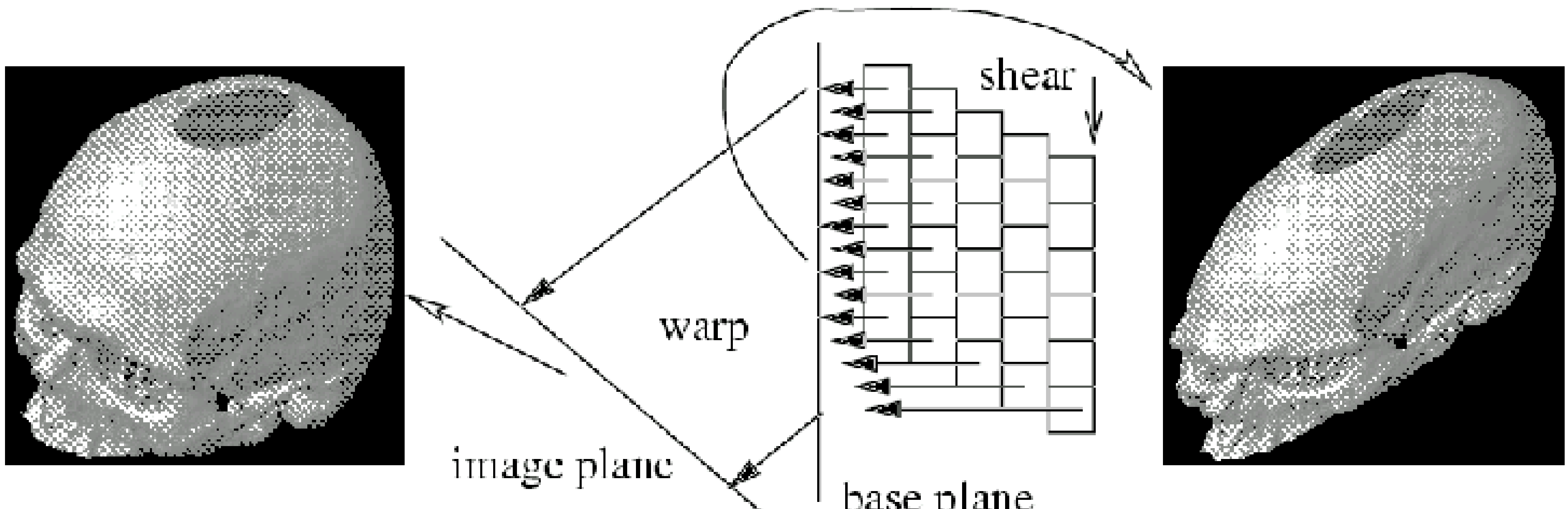
$$S_{\text{par}} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ s_x & s_y & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \qquad S_{\text{persp}} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ s'_x & s'_y & 1 & s'_w \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

- Transformation sheared object space into image space:

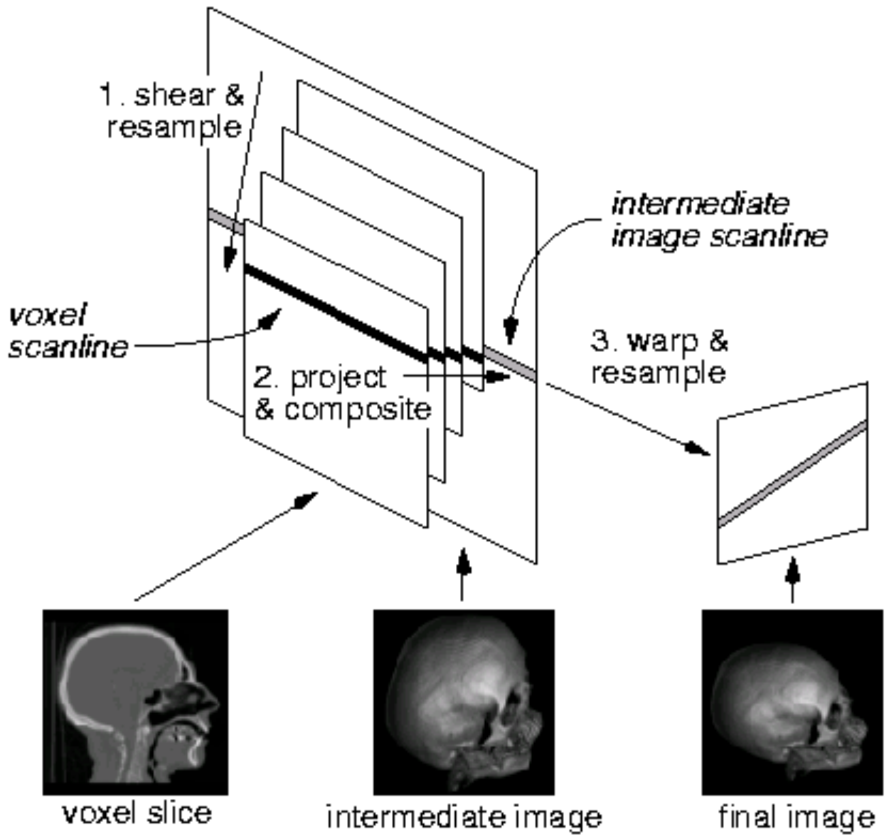
$$M_{\text{warp}} = P^{-1} \bullet S^{-1} \bullet M_{\text{view}}$$

Intermediate and Final Images

- Image 1: Projecting the volume into a 2D intermediate image in sheared object space
  - The shear direction is parallel to the base plane (one face of the volume)
  - The result is a distorted version of the rendered image
- Image 2: Transforming the intermediate image to image space
  - Get the correct final image on image plane



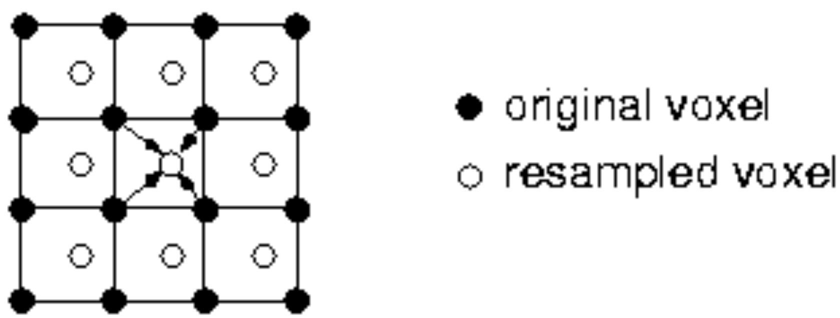
Three Basic Steps



Step 1: Sampling the Volume

- Since each slice of the volume is only translated, each sampled voxel in the slice has the same sampling mask
  - Sampling is easier and faster

- A bilinear interpolation is used for the resampling.



Step 2: Compositing the slices

- The slices are composited together front to back, as in ray casting algorithms

- An early ray termination may be implemented, but not immediately

- The apparent thickness of a slice of voxels is view dependent.
  - Use a lookup table to correct the voxel opacity for the current viewing.

Step 3: Warp Transform

- The intermediate image should be transformed to “image space” using the warp transform

- A bilinear filter is used

- Only in the final step, the actual parameters of the image space are used.

Scanline Optimization

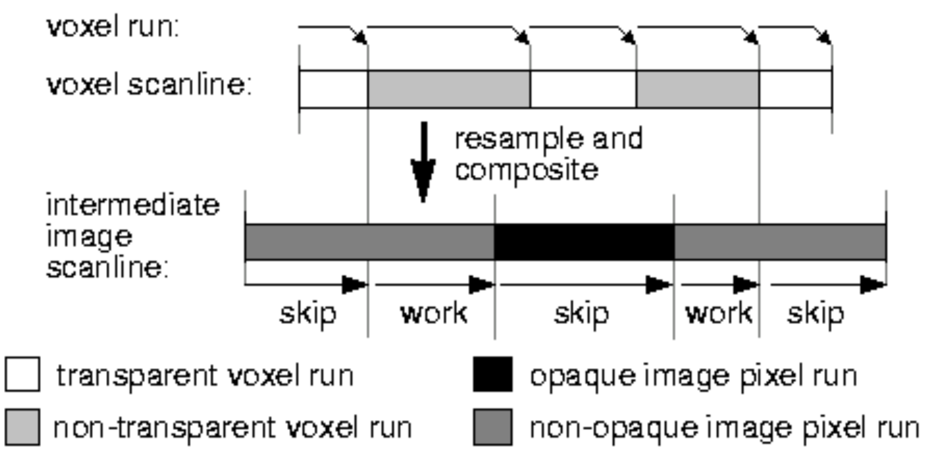
- After the shear transformation, the pixels' scan-lines of the intermediate image are parallel to the voxels' scan-lines of the volume data
  - This property enables us to pass both the volume and the image in scanline order
- Pass simultaneously over two scanlines in the volume (for the sampled voxels) and one scanline in the image
  - Scanline order also reduces addressing arithmetic
- When passing through a line, no action is taken when there are:
  - Opaque pixels in the image
  - Transparent voxels in the volume.

Scanline Data Structures

- Transparency run length encoding for each scanline in the volume
  - This enables us to skip groups of transparent voxels
  - For each principle viewing direction, this data-structure is precalculated

- In the image scanline, for each pixel an offset for the next non opaque pixel is maintained
  - Opaque pixels occlude the voxels behind them, so they may be skipped efficiently
  - Equivalent to early ray termination in ray casting

- Only non-transparent and visible voxels are sampled and composited to the image.



Perspective Projection: Shear-Warp

- Perspective projection may help with depth ambiguities

- Uses more complicated shear-warp factorization
  - Volume slices are scaled (uniformly) as well as sheared (translated)
  - The sampling weights are different for differently scaled slices
  - More than two scanlines may be traversed together for sampling a single scanline in the intermediate image.