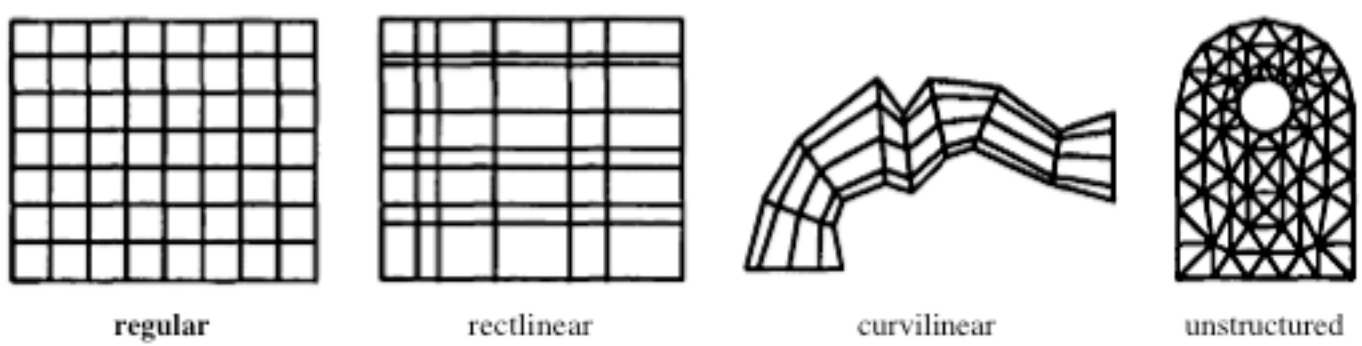
Visualization of Irregular Data

Types of Volume Data

- Regular
  - ➢ Regular grids are orthographic and the nodes are equally spaced and lie at integer positions; connectivity information is implicit
- Rectilinear
  - ➢ Orthographic with non-constantly spaced nodes
- Curvilinear
  - ➢ Non-orthographic with non-constantly spaced grid nodes
- Unstructured
  - ➢ No logical organization and no implicit cell-adjacency information.



Different Rendering Approaches

- Resampling to a regular grid
  - Involve two steps:
    - Identify the cell in which a sampling point is actually located
    - Interpolate F inside a warped (nonregular) cell primitive based on the values of F at the cell's nodes.
  - Often results in large grids
    - Large cells require substantial subsampling

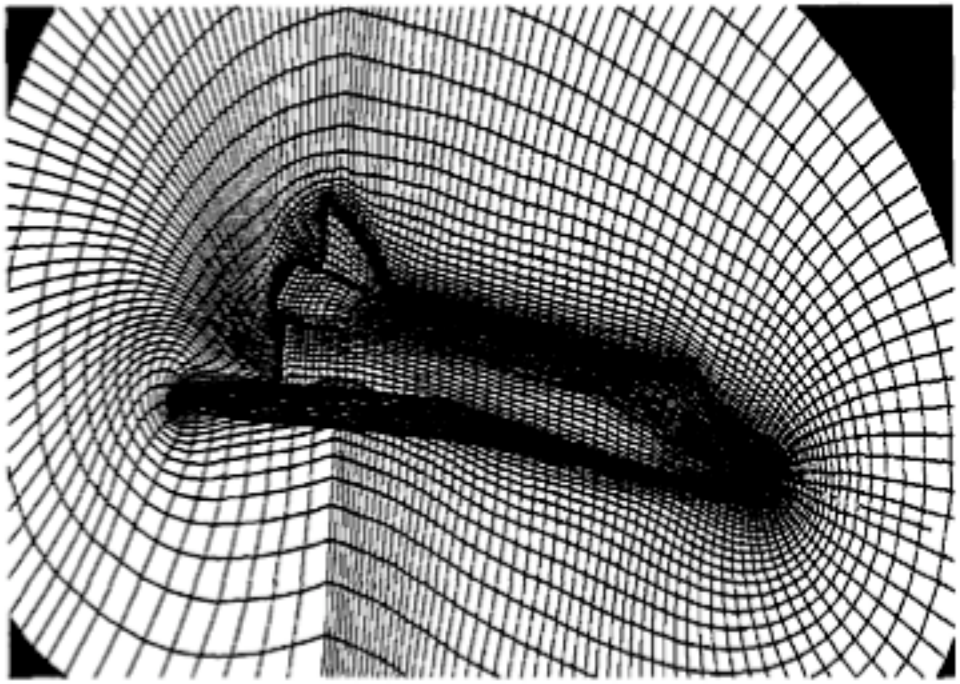
- Direct rendering through projection
  - All cells are projected onto the image plane in back-to-front or front-to-back order
  - Compute color and opacity from the data at grid nodes
  - Use depth-sorted lists of the cell faces per pixel for correct color accumulation

- Raycasting of nonregular/unstructured data
  - Computational-space-based
  - Sweep-plane-based

Computational Space Based Raycasting

- Raycasting is applied in regular computational space
  - Avoids difficulties of computing ray/cell-face intersections and of performing interpolations
  - Speeds up the visualization process

- Computational space:
  - An abstract representation of the logical organization of non-regularly structured physical grid
  - Mapping the warped grid to a regular grid
  - Applicable to rectlinear and curvilinear grids
  - Size, quality and topology information of the original data is preserved.



Coordinates Transformation

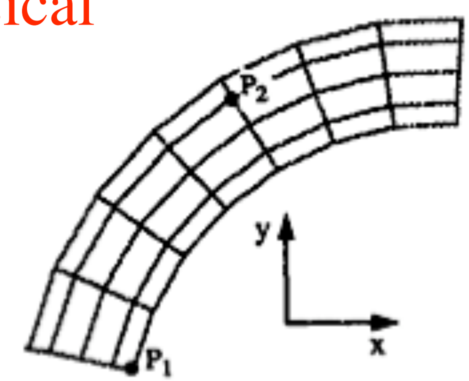
- Relationship between physical coordinates and computational coordinates

$$x_i = J_{ij} \bullet \xi_j$$

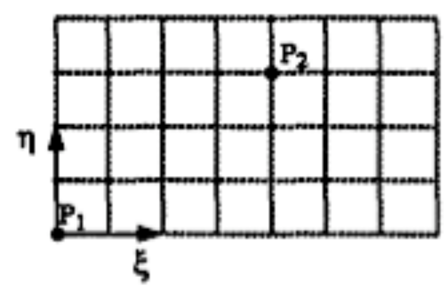
with the Jacobian matrix

$$J_{ij} = \frac{\partial x_i}{\partial \xi_j}$$

physical



computational



Casting Rays

- Assign rays (vectors) at all physical nodes
  - Direction is determined by the viewpoint and the projection type

- Use isoparametric formulation to transform the vectors to computational space using

$$r_{Cj} = J_{ij}^{-1} \bullet r_{Pi} \quad \text{with } J_{ij} = \frac{\partial x_i}{\partial \xi_j} = \frac{1}{2}\cdot\left(\frac{x_i(n) - x_i(n-1)}{\xi_j(n) - \xi_j(n-1)} + \frac{x_i(n+1) - x_i(n)}{\xi_j(n+1) - \xi_j(n)}\right)$$

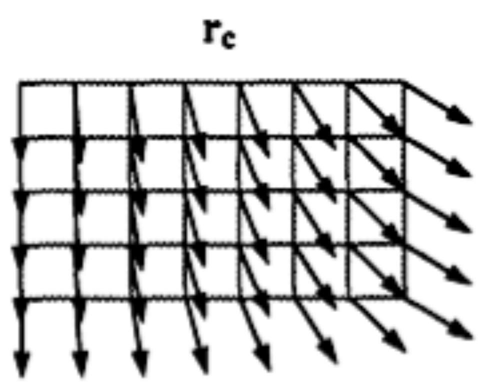
$$r_{Cj} = \frac{1}{2}\left[x_i(n+1) - x_i(n-1)\right]^{-1} \bullet r_{Pi}$$

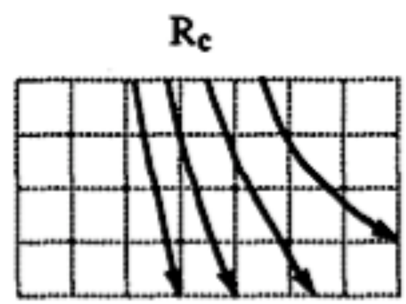
Bent Rays

- Tangential curves in the vector field $\mathbf{r_c}$ are the rays $\mathbf{R_c}$ through the computational space

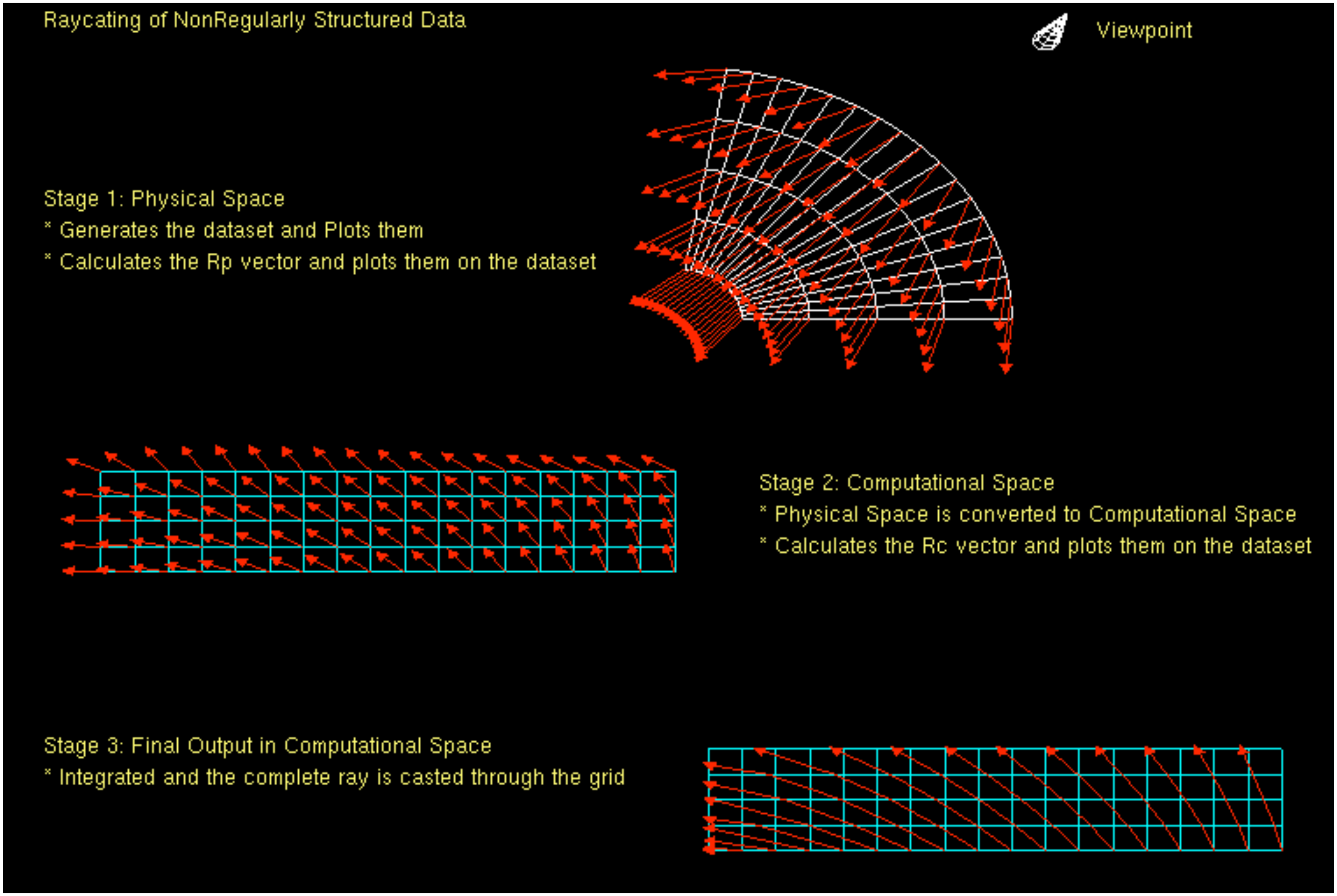
$$\frac{d\xi_j}{dt} = r_{Cj}(\xi_i)$$

with t as the integrational parameter along a streamline





Example: 2D Case

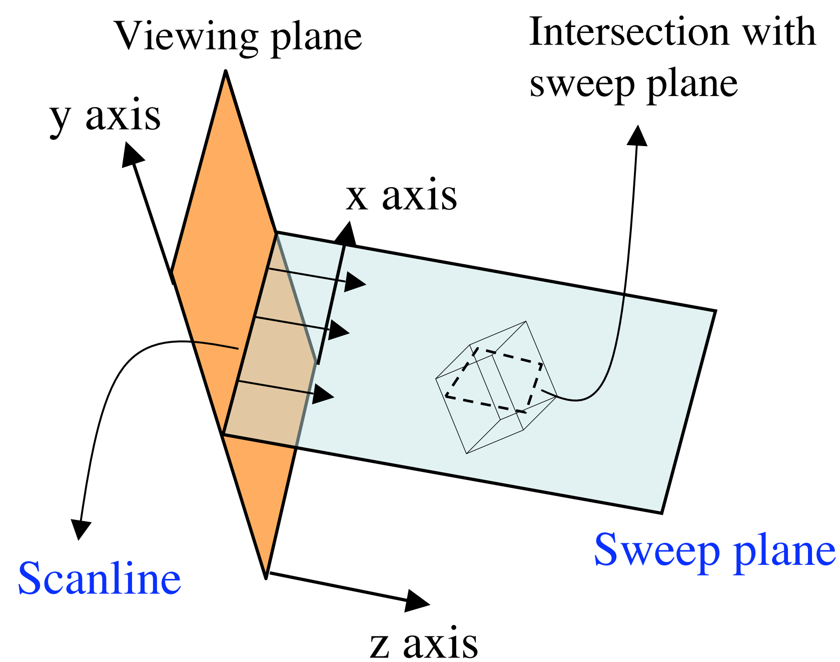


Sweep-Plane Based Raycasting

- A hybrid-type approach

- Handles unstructured irregular grids
  - Including disconnected and nonconvex grids
  - Using adjacency information to determine ordering

- Sweeping 3D-space reduces the raycasting problem to a 2D cell sorting problem
  - Sweep-plane is orthogonal to the viewing plane (the xy-plane) and parallel to scanlines (i.e., parallel to the xz plane)
  - Raycasting within each slice of the sweep plane by a sweep line method.



Sweep Data Structure and Algorithm

- Sort the vertices of mesh S by their y-coordinates and put them into an event priority queue, an array A
- Use the active tetrahedra list (ATL) to maintain a list of the tetrahedra currently intersected by the sweep plane
- While A is not empty, do:
  - Pop the event queue until hit is vertex
  - Update ATL
  - Render current scanline
- The algorithm terminates once the last scanline is processed.

References

- T. Fruhauf, Raycasting of nonregularly structured volume data, Eurographics ‘94, 13, 293, 1994
- T. Silva et al., Fast rendering of irregular grids, 1996 IEEE Volume Visualization Symp., 15, 1996
- P. Bunyk et al., Simple, fast, and robust ray casting of irregular grids, Proceedings of the Dagstuhl ’97—Scientific Visualization Conference, 30, 1997
- H. Berk et al., Direct volume rendering of unstructured grids, Computers & Graphics 27, 387, 2003.