Parallel Rendering

Molnar, Cox, Ellsworth, and Fuchs. "A Sorting Classification of Parallel Rendering." ***IEEE Computer Graphics and Applications*****. July, 1994.**

Why Parallelism

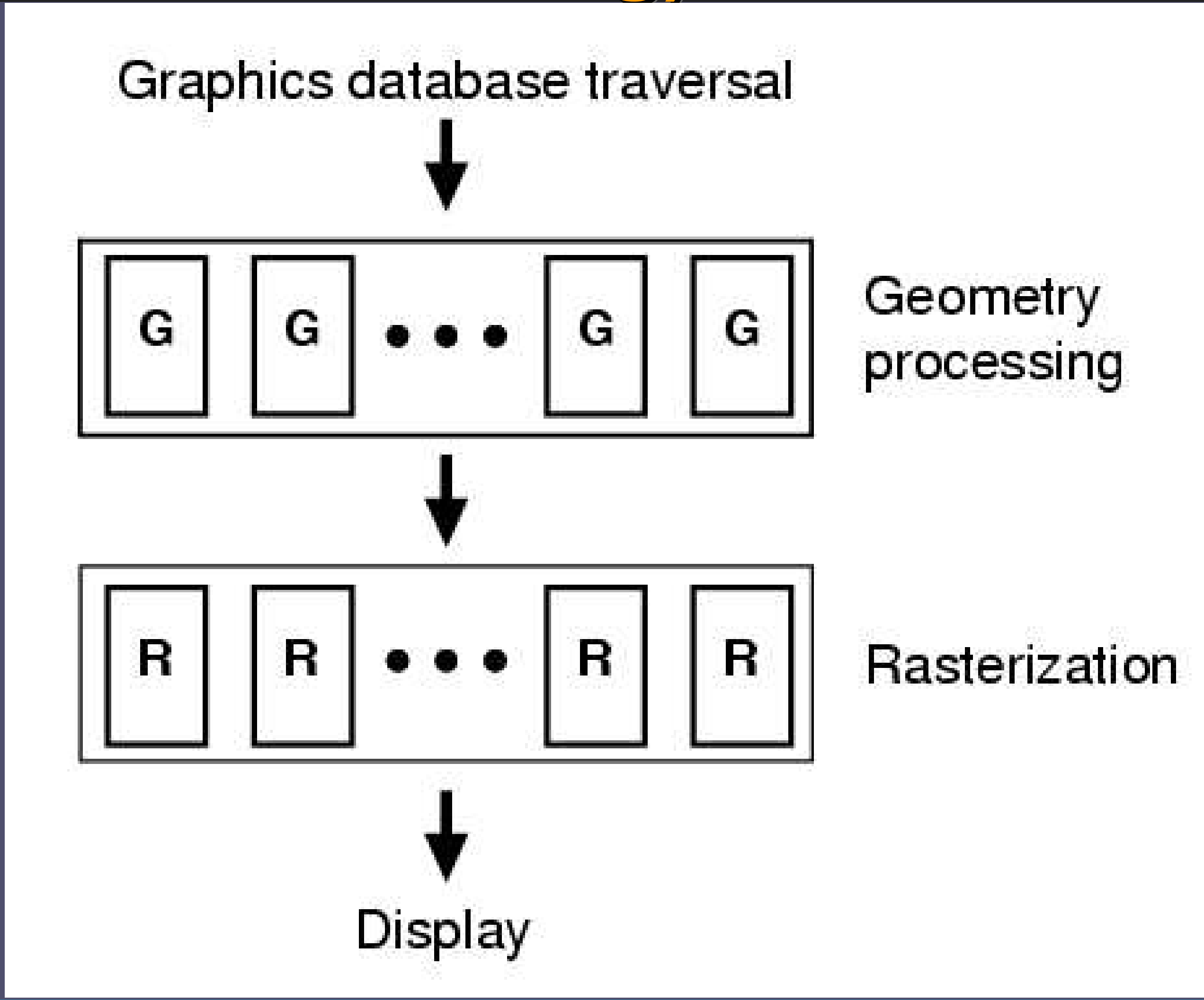
Applications need:

- High frame rates
- High resolution
- Large geometric models
- Stereo
- Antialiasing
- etc.

Performance implications:

- Hundreds of MFLOPS compute power
- Gigabytes per second memory bandwidth

Stages of Parallelism (for object-order rendering)



Processing Tasks

Geometry Processors

- Each processor gets a subset of primitives
- Transformation
- (Lighting)
- Set-up for Rasterization

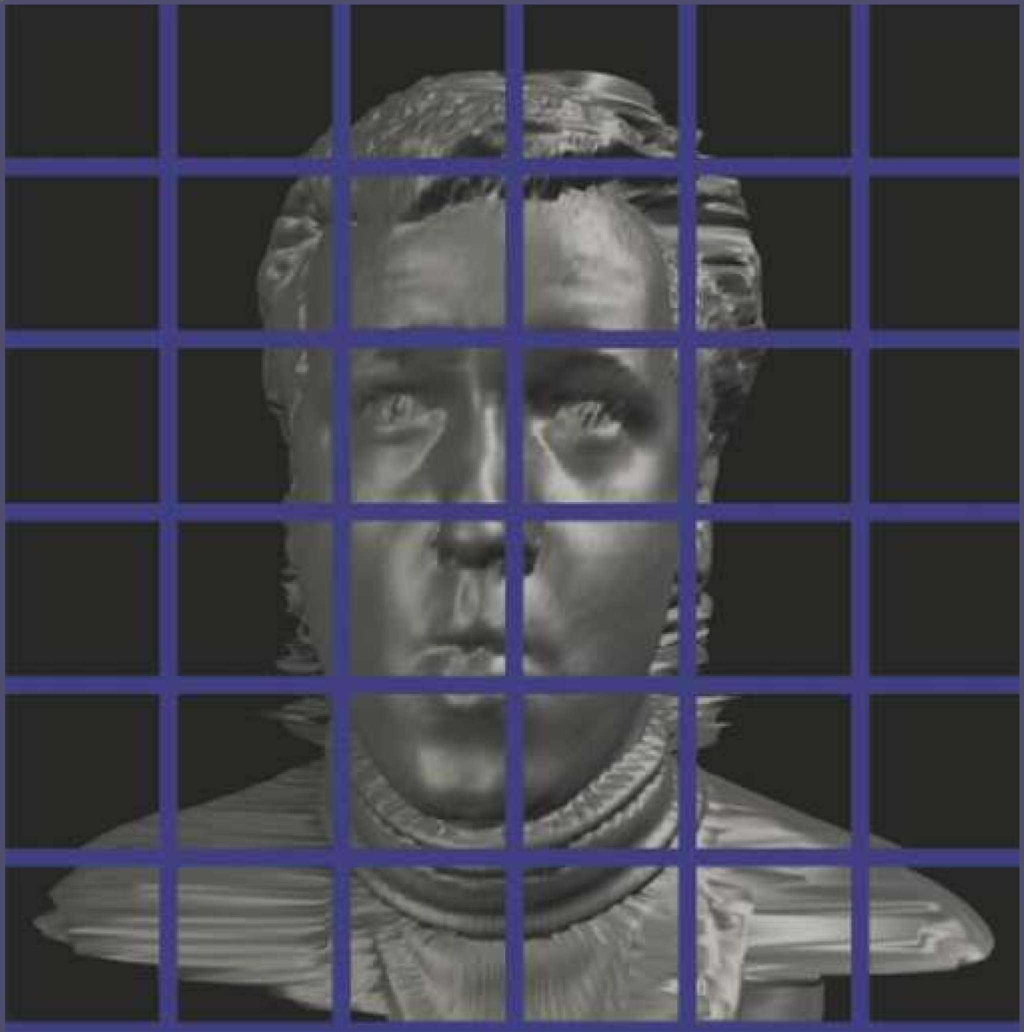
Rasterization Processors

- Each processor gets a subset of pixels
- Visibility computation
- Shading

Rendering as Sorting

- Primitives may lie anywhere on or off screen
- Determine effect of each primitive on each pixel
- Primitives are “sorted” onto screen
- Sorting affects distribution of data on geometry and rasterization processors

Primitives in Screen-space Regions



Where to sort

Sort Middle

- Sort between geometry processing and rasterization

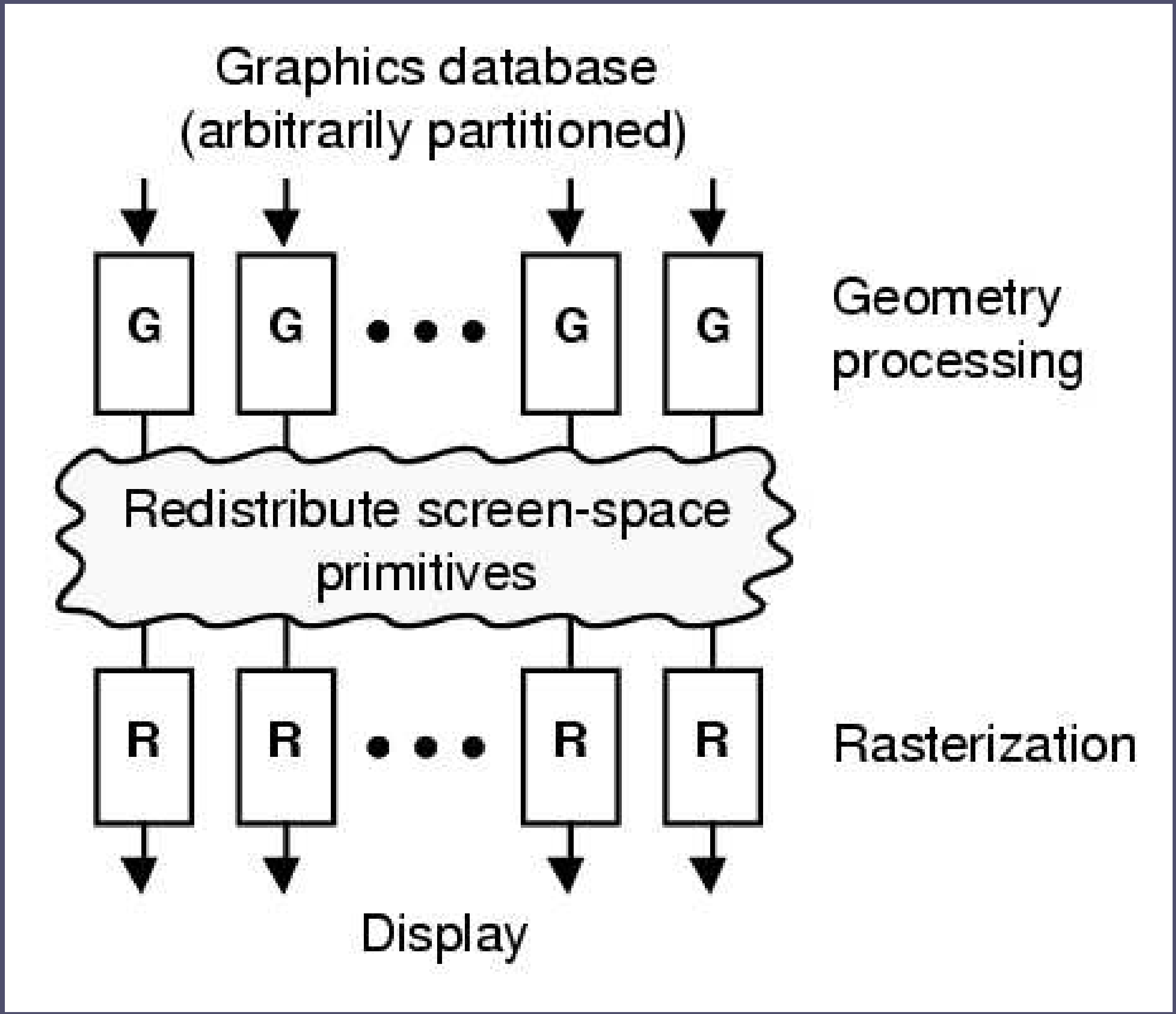
Sort First

- Sort during geometry processing

Sort Last

- Sort during rasterization

Sort Middle



Graphics database
(arbitrarily partitioned)
G
G
G
G
Geometry processing
Redistribute screen-space primitives
R
R
R
R
Rasterization
Display

Sort Middle: Data Arrangement

Geometry processors

- Arbitrary (random) distribution of primitives
- Good for load balancing

Rasterization processors

- Screen-space distribution of primitives
- Load balancing difficult

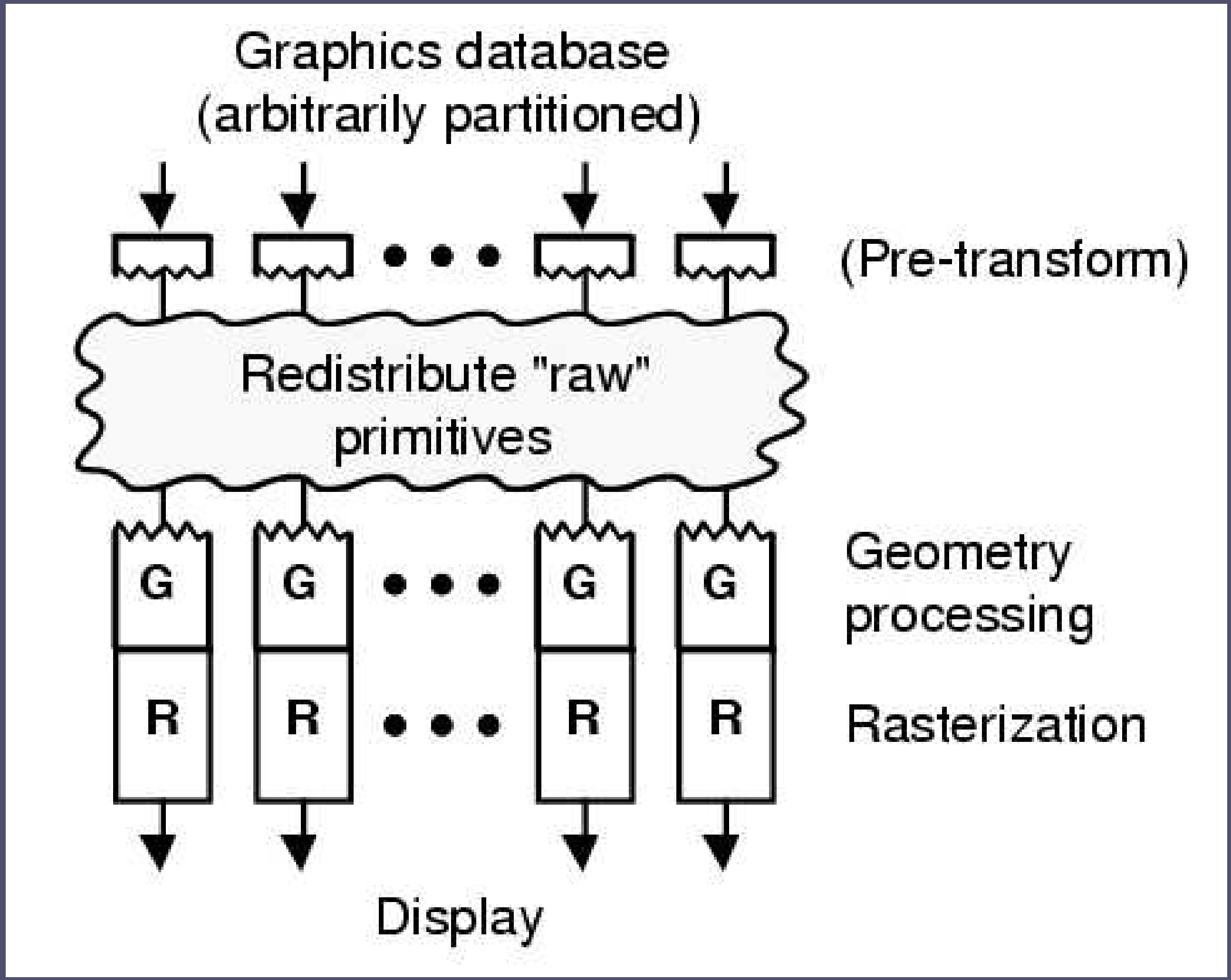
Sort Middle: Communications

All geometry transformed primitives must be communicated every frame

All geometry processors must communicate with all rasterization processors

- $O(n^2)$ communications paths

Sort First


Graphics database
(arbitrarily partitioned)
(Pre-transform)
Redistribute "raw" primitives
G
R
Geometry processing
Rasterization
Display

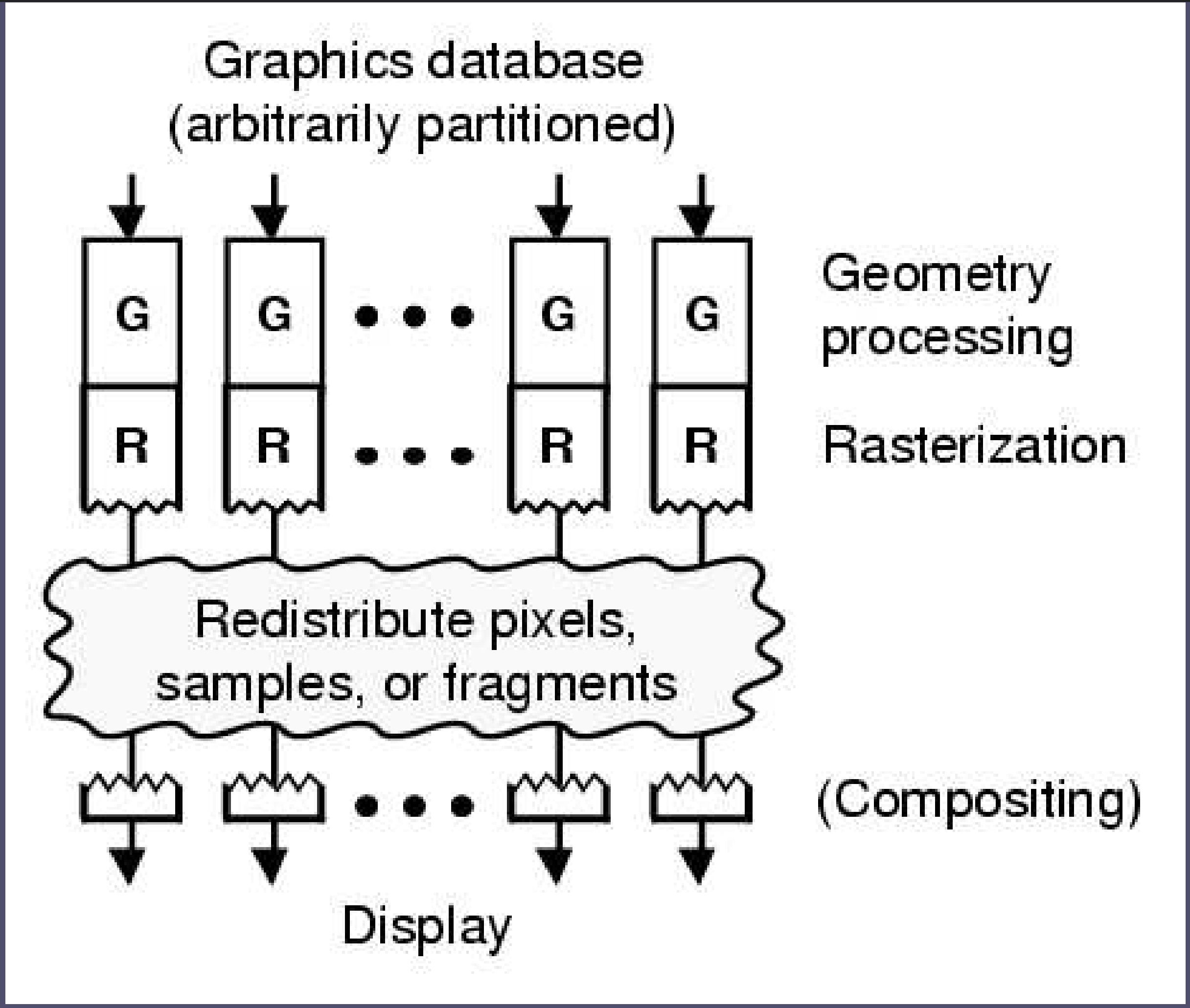
Sort First: Data Arrangement

- Distribute both geometry and rasterization work according to position of primitives on screen
- Load balancing difficult
  - Different screen regions of equal sizes may contain different numbers of primitives
  - May need dynamic region sizes

Sort First: Communications

- Must determine primitive screen coverage before full transformation
- Exploit frame-to-frame coherence
  - Shuffle primitives between geometry processors only if screen coverage changes
- Possibly employ primitive clustering and bounding volumes
  - Pre-transform bounding volumes for small groups of primitives

Sort Last


Graphics database
(arbitrarily partitioned)
G
G
G
G
Geometry processing
R
R
R
R
Rasterization
Redistribute pixels, samples, or fragments
(Compositing)
Display

Sort Last: Data Arrangement

- Arbitrary (random) arrangement of data on both geometry and rasterization processors
- Great for load balancing
- Each rasterization processor makes image of entire screen, with subset of primitives

Sort Last: Communications

- Rasterization processors must communicate final pixel data
- Composition of pixel data may take place along linear or tree-shaped network
- Requires high bandwidth, assuming pixel data is much larger than primitive data

Advantages and Disadvantages

	Advantages	Disadvantages
SF	• Low communications when good coherence • Each processor implements entire pipeline	• Susceptible to load imbalance • Retained mode and complex data handling
SM	• General and straightforward • Natural communications placement	• High communication cost • Rasterizer load imbalance
SL	• Each processor implements entire pipeline • Easier load balancing • Linear scalability	• Large communication cost, especially for high resolution or multisampling