Optimal Partition for Parallel Rendering

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Optimal Partition for Parallel Rendering

- Load balanced partition for rendering
  - Adhoc and Scan-like Tries
  - No Optimal Approaches for reducing Parallel rendering Hazards
- Partition algorithm for Parallel Rendering
  - Load Balance with Minimization Parallel Rendering Hazards
  - Realtime Partitioning Performance

Parallel Graphics Hazards

Processing Hazard

- Unbalanced Graphics Processing
  - vertices and pixel processing
  - overlap primitives between different partitions

Management Hazard

- Unbalanced Management Processing
  - frame coherency between each processor's partitions of animate frame se quence
  - out of core rendering resources management

Optimal Partition Generation for Parallel Graphics

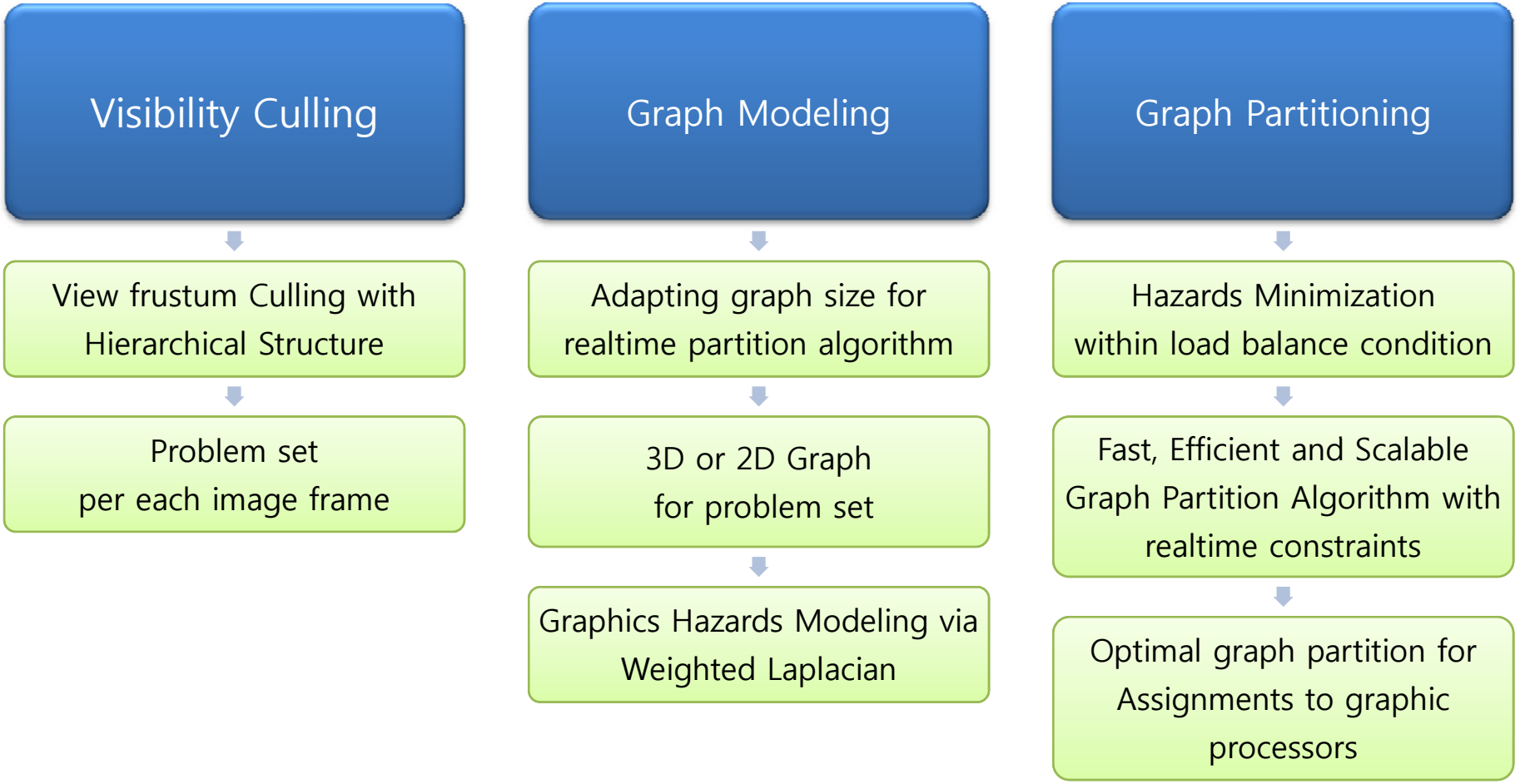
Typical Load balancing for Parallel processing

- Preprocessed, Static Partition
- Load Balance with Minimization Cutting Edge between Partitions (for communication minimization)

New Load balancing for Parallel Realtime Graphics

- Runtime, Dynamic Partition with computing time constraints
- Load Balance with minimizing Parallel Graphics Hazards

Optimal Partition Generation for Parallel Graphics



Graph Partition Algorithm - Overview of Spectral Bisection

- A Workload Graph expresses as a Laplacian Matrix.
- Rayleigh quotient of Assignment Vector and laplacian matrix represents sum of cutting edge cost between two partitions.

Laplacian Matrix	$L_{ij} = \begin{cases} -1 & \text{if } (v_i, v_j) \in E \\ d_i & \text{if } i = j \\ 0 & else \end{cases}$
Discrete Optimization	$x^t Lx = 4 \times \{\#\text{edges connecting nodes in N- to nodes in N+}\}$ $x_i = \pm 1$
Continues Relaxation	$F(x) = \frac{x^t Lx}{x \cdot x} = \sum_{(i,j) \in E} (x_i - x_j)^2$

Graph Partition Algorithm - Overview of Spectral Bisection

- Spectral analysis of laplacian matrix; Second smallest eigenvector minimizes Rayleigh Quotient.
- Optimal assignment vector is a good approximation to load balanced graph partition problem with minimal communication edges between partitions.

Spectral Analysis	$L = \sum_{i=1}^{n} \lambda_i z_i z_i^t \qquad \lambda_1 = 0, z_1 = e \text{ and } \lambda_i < \lambda_{i+1}$
Optimal Assignment Vector	$\underset{\substack{x \neq 0 \\ e^t x = 0}}{\text{minimize}} \frac{x^t L x}{x \cdot x} \text{ over } x \Rightarrow x = z_2, \frac{x^t L x}{x \cdot x} = \lambda_2$

Graph Partition Algorithm – Algorithm Selection

Avoidance of computing full spectral analysis;
just need is second smallest Eigen vector.

Modification of conventional optimization method;
Conjugate Gradient Method

- Shows High convergence speed to
  second smallest Eigen vector of Laplacian matrix
- Meets Load balance constraint
- Requires Low memory

Conjugate gradient method for the spectral partitioning of graphs

$$F(x)=\frac{x^t Lx}{x\cdot x},\quad \nabla F(x)=\frac{2}{x\cdot x}(L\cdot x-F(x)x)$$

Step 1: Initialize x_0 and gradient vector $g_0=-\nabla F(x_0), h_0=g_0$

Step 2: Fletch-Reeves Conjugate gradient method

$$\alpha_k=\min_{\alpha} F(x_{k-1}+\alpha h_{k-1})$$

$$x_k=x_{k-1}+\alpha_k h_{k-1}$$

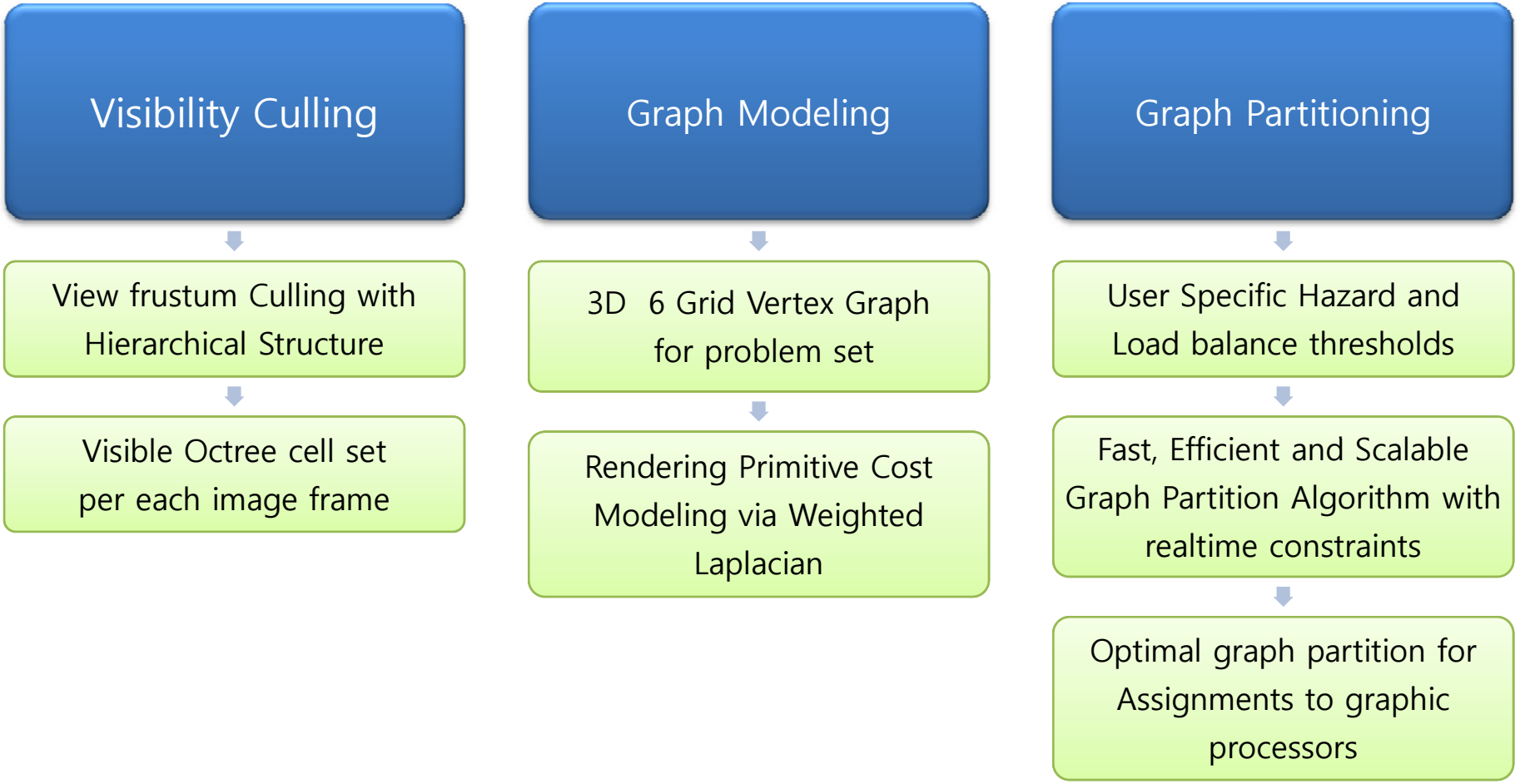
$$g_k=-\nabla F(x_k)$$

$$h_k=g_k+\frac{g_k\cdot g_k}{g_{k-1}\cdot g_{k-1}}h_{k-1}$$

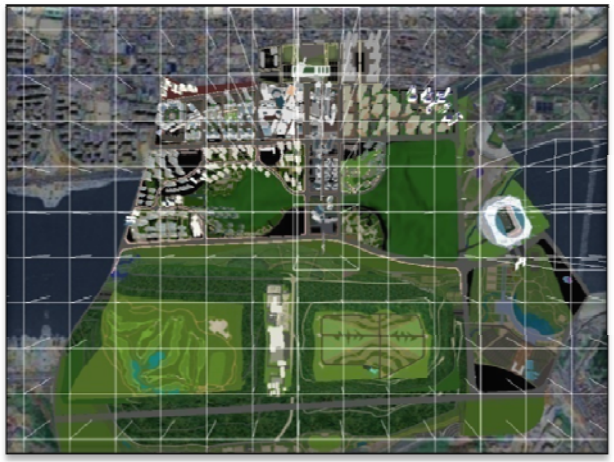
Step 3: Check for convergence.
If convergence has not been reached go to Step 2.

Step 4: Accept optimal vector $x=x_k$

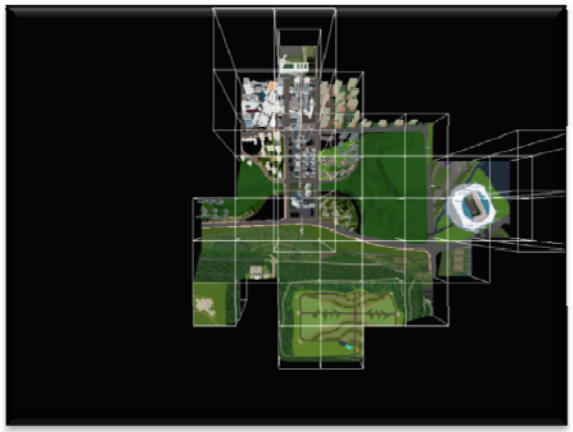
Experiment for feasibility study



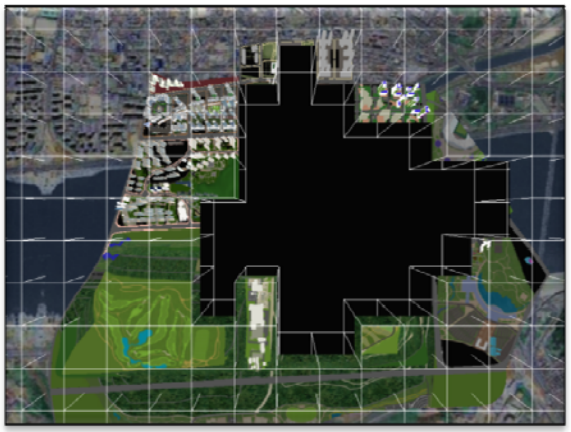
Load Balanced Partition Generation



Urban Scene (Digital Media City)
323863 triangles
[262 visible octree cells]



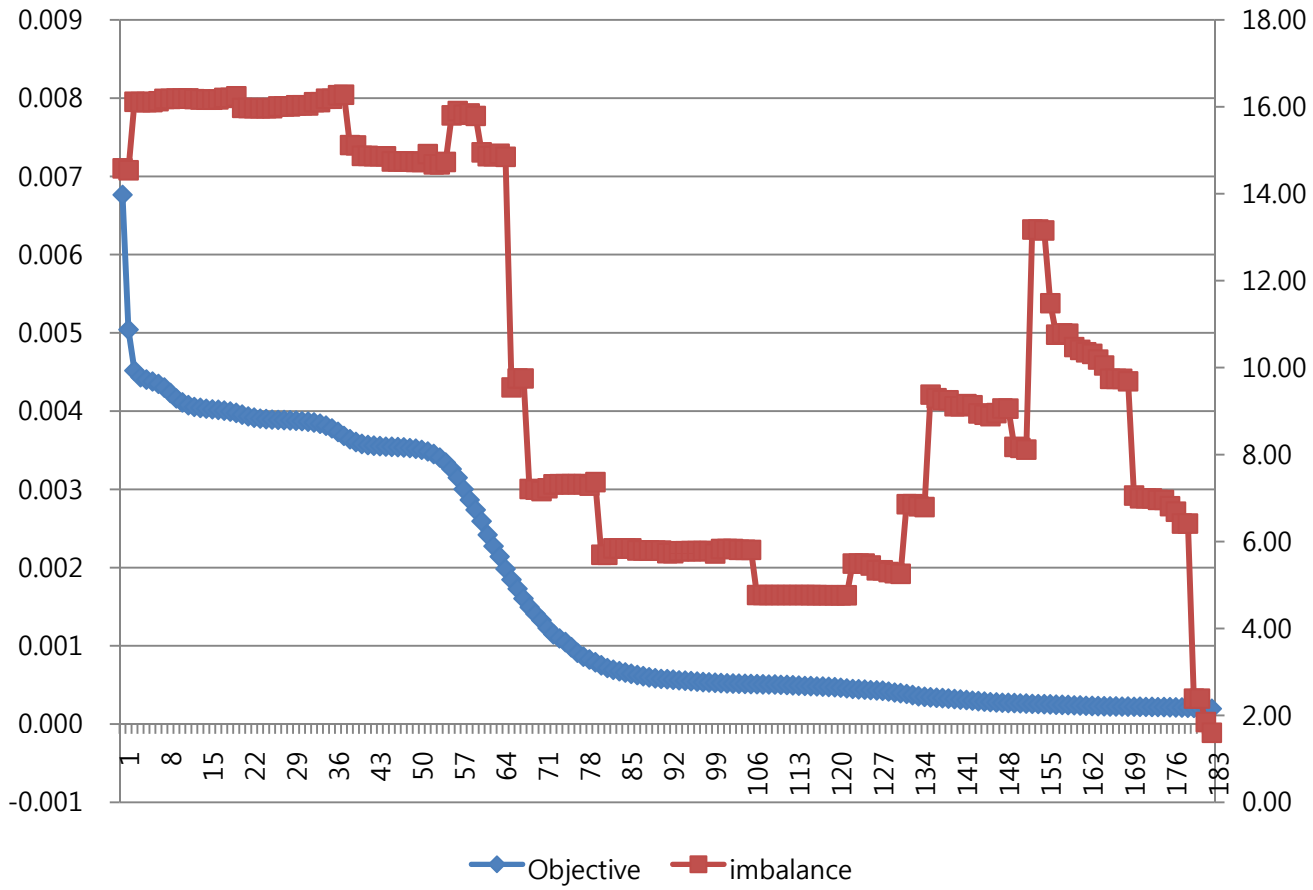
Positive Set
164524
[49]



Negative Set
159339
[213]

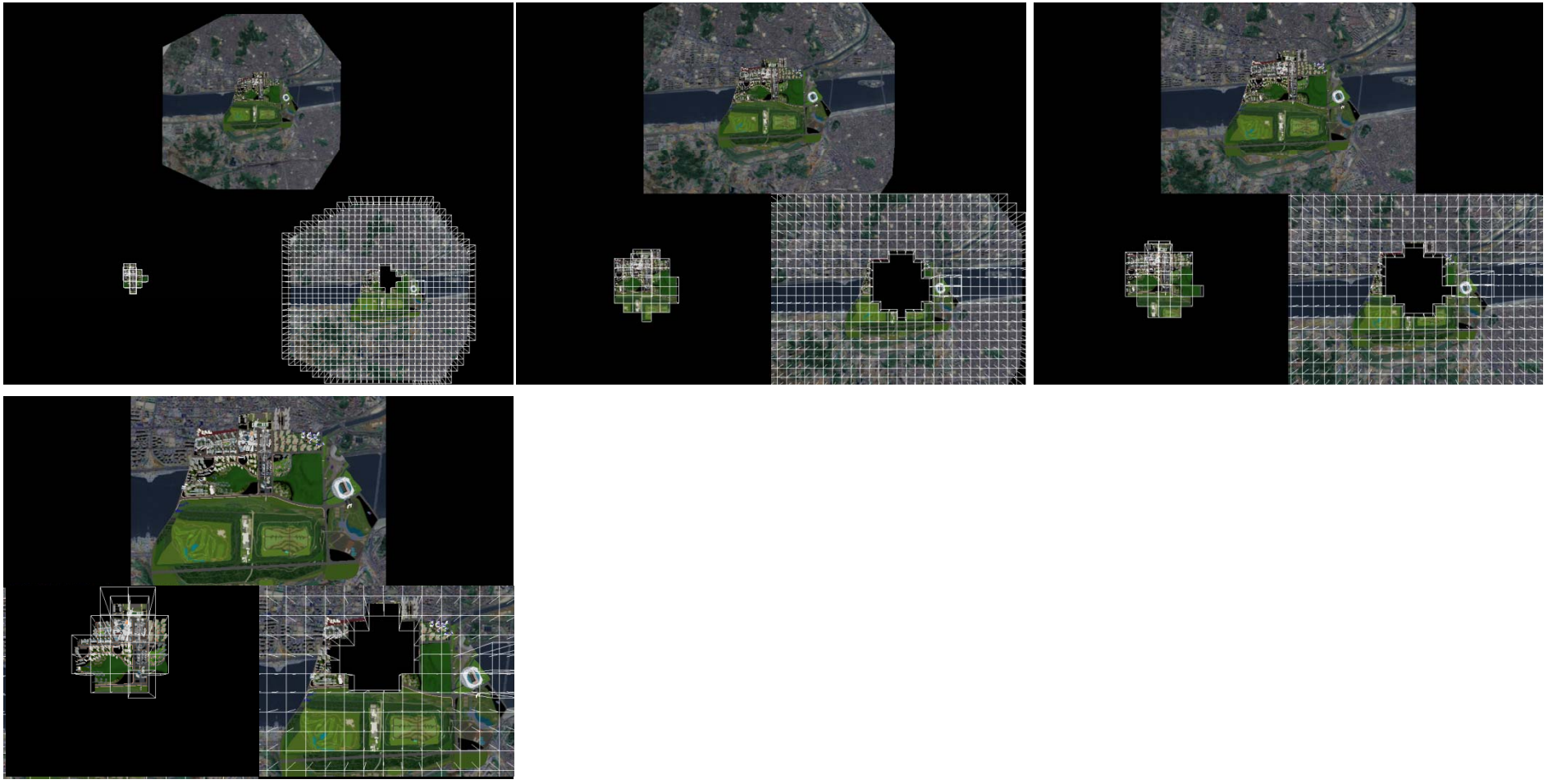
Imbalance
5185 / 323863 = 1.60%

Optimal Bisection for a image frame



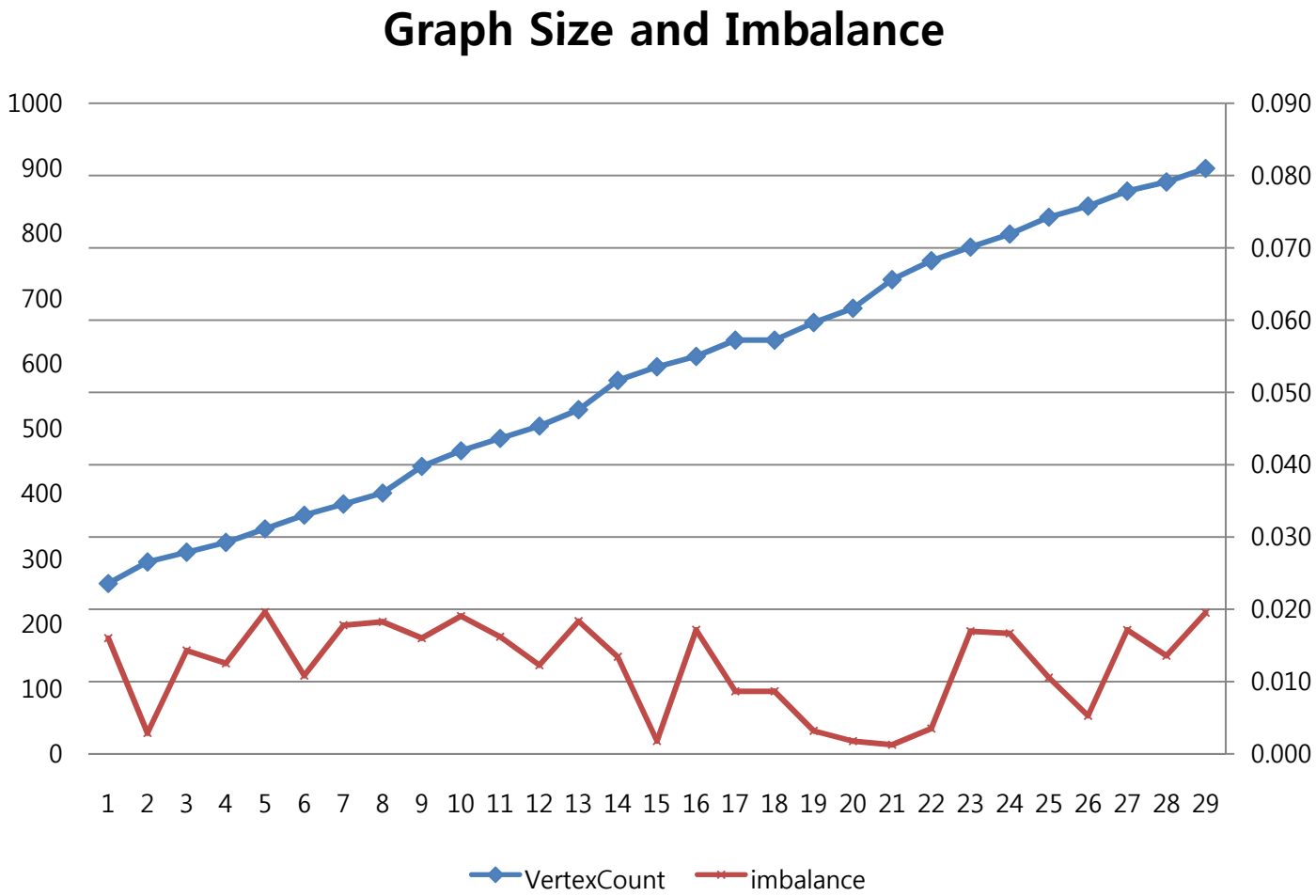
182 iteration for partitioning weighted graph
of 262 octree cells

Optimal Bisection for animation frames



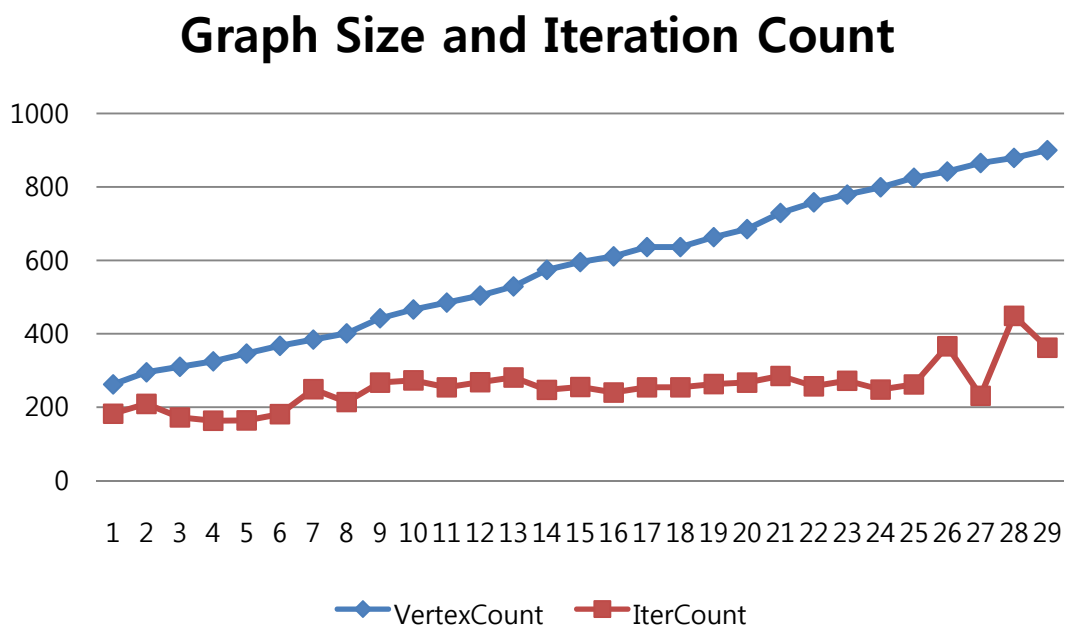
Camera Closing to urban ground and Partitions

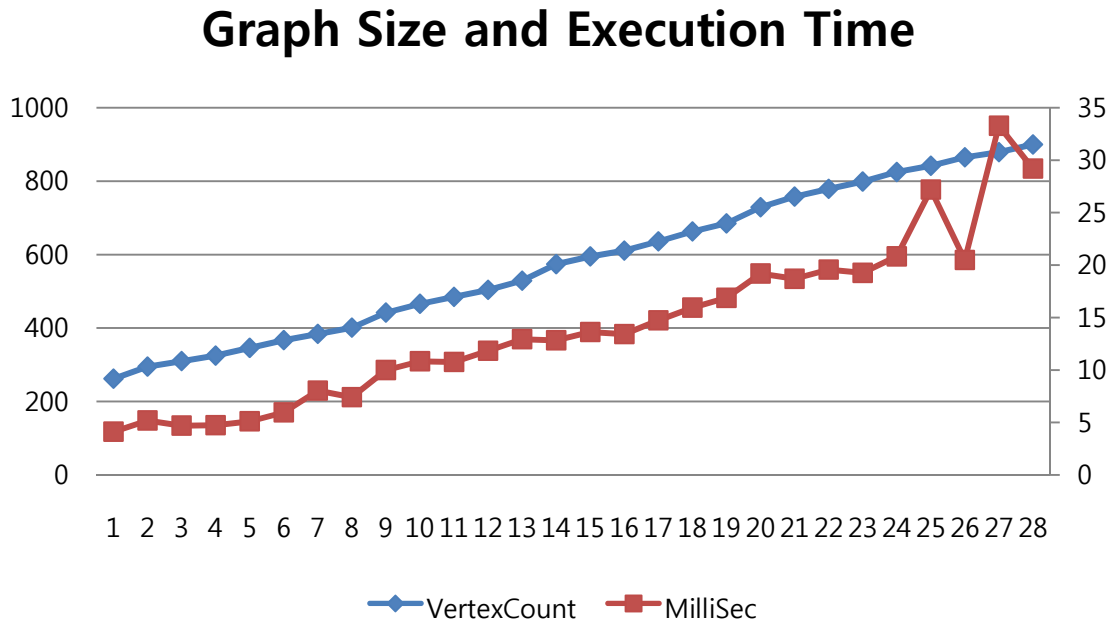
Dynamic Workload by camera movement



With Objective function threshold 0.0002, Imbalance threshold 2%

Time Complexity and Execution Time





Intel Pentium 2.4Ghz
3Giga Memory

Conclusion

- Optimal partition could be solved in real-time for parallel graphics and simulations.

- Future works
  - Graphics Hazards Modeling
    - for reducing parallel graphics hazards
  - Valley Constraint Optimization
    - for partition's frame coherency
  - Recursive partitioning
    - for K-way processors

Thanks a lot.