CS 680: Advanced Computer Graphics
Final-Term Exam

(Open-book exam, total 7 pages)

Exam Time: 12:00pm on 15-Dec. (Mon.) ~ 11:59pm on 16-Dec. (Tue.)

Name: _____
Your student ID: _____

Note:
1. You are not allowed to discuss questions and answers with other students.
2. If you think that some questions are not clear, send email to the instructor and the student who made the questions.

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0. Feedback to this exam

Once you finished the exam, answer these items:

1. Do you think that most of questions are clear and useful in term of reviewing the course materials?

2. Provide us suggestions to improve this exam.

1. Coherent Ray Tracing (by BoChang Moon)

1. Why do coherent ray tracing techniques improve the performance of GI?

TRUE/FALSE questions; if false, explain why.

2. TRUE/FALSE: When we utilize SIMD instructions that a parallel architecture has for a GI method, the performance of the GI method will be improved.

3. TRUE/FALSE: When we render small models for GI that the memory requirement of those small models is smaller than an available main memory size, we can't get any performance improvement even though we use coherent techniques.

2. Parallel Photon Mapping (YongYoung Byun)

1. Explain each pass of the photon mapping:

1 pass:

2 pass:

2. Select all places where photons are stored

Specular Diffuse Both of specular and diffuse materials

3. On the second pass of photon mapping, the rendering equation is decomposed into 4 components depending on material properties for higher performance. What are the 4 components?

4. Write major steps of conventional kd-tree construction algorithm

5. Fill the blanks

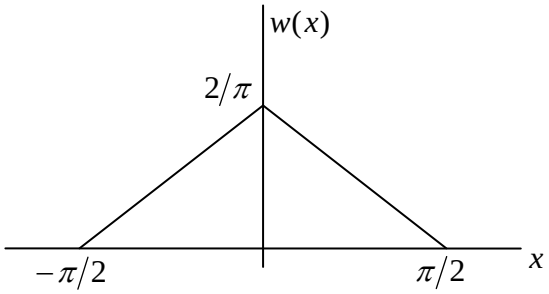
Irradiance caching is algorithm for fast computation of global illumination on _____ surfaces. Its main assumption is that indirect illumination is view-independent and change very _____ over surfaces. Therefore, we can use sparse sampling and _____ based on those samples.

3. PRT Approaches (by GeoYeob Kim)

1. True/False: In PRT, runtime performance is dependent on transport complexity (e.g., the number of bounces between materials and lights).

2. Consider a meshless hierarchical representation for light transport.

(1) By using a weight function $w(x)$ shown below, plot three *first level* basis functions which are sampled at $x=-\frac{\pi}{2}$, $x=0$ and $x=\frac{\pi}{2}$, respectively.



(2) Calculate each basis coefficient that is approximating the following function, f(x), given the basis functions derived in (1):

$$f(x) = \begin{cases} \sin x & \text{for} \quad x \in [-\pi, \pi] \\ 0 & \text{otherwise} \end{cases}.$$

Also, plot the reconstructed function.

(3) Assume that we want to construct *second level* basis functions. Is it okay to use the same weight function defined in (1) in order to represent high-frequency light-transport information? Justify your answer.

4. Translucent Material Rendering (by Min-Hyuk Sung)

1. What is the main reason that rendering translucent materials using BSSRDF takes more time than the normal rendering using BRDF?

True/False

A. Single scattering BSSRDFs need incoming lighting of only one specific direction. ()

B. In multiple scattering, incoming irradiance can be used instead of radiance value. ()

C. In the second step of two-pass algorithm, a hierarchical structure is necessary to compute incoming light of all samples efficiently. ()

5. Hardware Issues for GI (by Hong-Yun Kim)

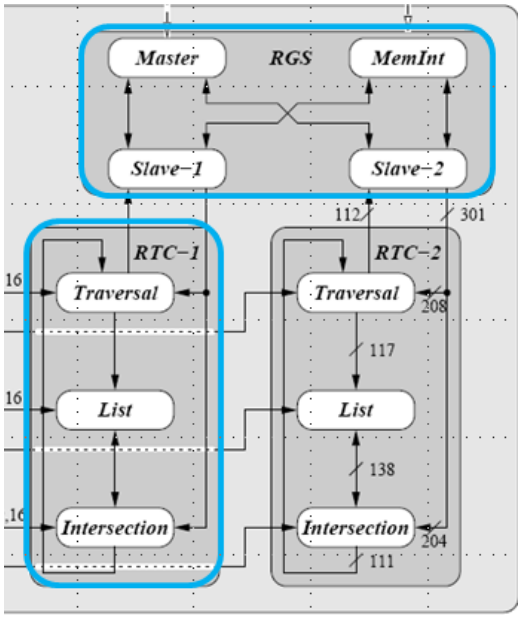
[True/False]

1. To implement ray tracing algorithm on GPU, Ray tracing algorithm is mapped to a streaming model

because of insufficient floating point computing power. [True / False]

2. Ray tracer on GPU is not bandwidth limited, but computation limited. So, it is suitable for mobile devices. [True / False]
3. If you are the hardware designer, you will increase the number of thread of ray tracing hardware when you use slow memory. [True / False]
4. Ray-Triangle intersection point is unchanged under a transformation mapping ray to unit triangle coordinate from world coordinate. [True / False]

[Problem 1] Ray Tracing algorithm is implemented on GPU system.



1) Briefly explain the operations of RTS and RTC.

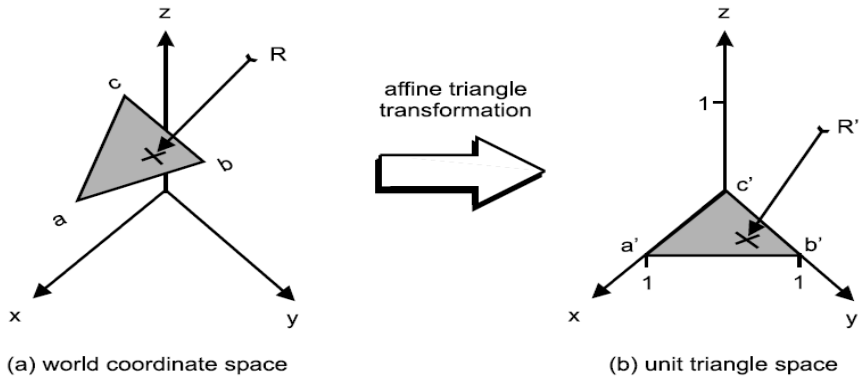
2) Both performance of RGS and hardware cost of RTC are given below.

- RGS requires 25 floating point ADDs and 50 floating point MULs for shading.
- RTC requires 10 cycles to complete a single ray.

If you want make both RGS and RTC busy all the time, how do you allocate the floating point units?

# of FP ADD = [ ] # of FP MUL = [ ]

[Problem 2] When we implement a dedicated hardware for ray tracing, unit triangle transformation is used to simplify an intersection test between ray and triangle.



(a) world coordinate space (b) unit triangle space

Explain the two advantages of unit triangle transformation.

[Problem 3] These are the resulting frame rates of dedicated hardware for ray tracing.

scene	#triangles	#lights	reflection-depth	rays shot
Cruiser	3 637 101	2	0	2 359 296
Office	33 952	3	3	3 863 846
BQD-1	2 133 537	1	3	1 583 402
BQD-2	2 133 537	1	3	1 548 632

As you can see from the picture and table, the two images' number of triangles is same, but the frame rate increment is different when the number of RTC unit increases. Explain the reason why sub-linear relation is occurred in BQD-2 image. And suggest your solution.

Answer)

6. Compression Methods (by TaeJoon Kim)

1. Why is the data compression needed?

2. What is the difference between instant radiosity and incremental instant radiosity?

3. Clustering is used for supporting random access. True or False

4. Incremental instant radiosity allows changing lights. True of False

7. Shadow Mapping Techniques (by Hubert Mohr-Daurat)

1. Show how Perspective Shadow Mapping differs from a classic shadow mapping technique by describing the main steps of the method.

2. When using the Soft Shadow Volume method for ray tracing, how is it possible to reconstruct the whole visibility function using the silhouette edges with only one ray casting to the light source?

3. True/False questions:
- In "Sample Based Visibility for Soft Shadows using Alias-free Shadow Map":
  a) the size of the shadow map depends on the camera view.
  b) the influence region doesn't depend on the geometry of the light source.
- In "Fast Calculation of Soft Shadow Textures using Convolution":
  c) when source, occluder and receiver are not parallel, error on the shadow computation is necessarily higher than when all three are parallel.

8. LODs for Rasterization (by Pio Claudio)

1. Explain the following methods:
- Multi-resolution representation:
  -
- View dependent LOD selection
  -
- View culling, occlusion culling
  -

2. Why is LOD in rasterization important to study for global illumination?

9. Dynamic Models (by Duksu Kim)

1. In dynamic scenes, the best quality image can be abandoned for interactive performance. (True/False)
2. Write three ways to update bounding volume hierarchies.

3. Direct illumination has high coherency between neighboring frames. (True/False)
4. A feature changed smoothly in dynamic scene has high temporal coherency. (True/False)

10. Real-time Rendering (by JaePil Heo)

1. Direct-to-Indirect Transfer for Cinematic Relighting

TRUE/FALSE: If we sampled 64k gather samples, can we think that the process of computing multiple-bounce matrix is similar to using standard photon mapping with 64k light sources?

2. Implicit Visibility and Antiradiance for Interactive Global Illumination

Problem)

If we replace the global transport operator G with the un-occluded transport operator U, then the rendering equation will be L = E + KUL. Is this rendering equation L = E + KUL equivalent to the equation L = E + KGL ? If not, why are these two equations different?

3. Interactive Relighting of Dynamic Refractive Objects

The main contribution of this paper is to provide new rendering pipeline for interactive relighting of dynamic refractive objects with complex material properties. Each stage of the new rendering pipeline runs entirely on the GPU. So, the system adopts voxel-based representation such as octree for photon mapping instead of kd-tree or BVH. The system constructs octree based on refractive indices.

Problem)

Why do they construct octree based on refractive indices other than being well suited to run on GPUs?

11. LOD for Gi (by JungHwan Lee)

1. The difference of quality between when the path length is 1 and when he more path length is used is highly liked to be quite large. (T/F)
2. When the ray differentials are large, the memory coherency of the set of ray is highly liked to be large. (T/F)
3. R-LOD algorithm can handle the full global illumination effect. (T/F)

12. Many-Light Problems (by DaSung Han)

1) In many-light problems, two main difficulties are time complexity, O(mn), where m is the number of surface points and n is the number of lights, and expense in computing visibility for each shadow ray, c. For Lightcuts, Multidimendional Lightcuts and Matrix Row-Column Sampling technique, check O or X for the corresponding issue(s) that each technique tries to solve:

(a) Lightcuts: m (O / X), n (O / X), c (O / X)
(b) Multidimensional Lightcuts: m (O / X), n (O / X), c (O / X)
(c) Matrix Row-Column Sampling: m (O / X), n (O / X), c (O / X)

2) Read each sentence and check true or false according to its correctness:

(a) Lightcuts clusters many lights using a light tree (true / false)
(b) In Lightcuts, a new light tree is constructed per each pixel (true / false)
(c) Multidimensional Lightcuts uses both a light tree and a gather tree (true / false)
(d) In Multidimensional Lightcuts, a new gather tree is constructed per each pixel (true / false)
(e) Multidimensional Lightcuts is a GPU-based technique (true / false)

(f) Matrix Row-Column Sampling technique formulates the many-light problem as a matrix and efficiently computes all elements of the matrix using a GPU-based shadow mapping technique (true / false)

(g) Single-pass Scalable Subsurface Rendering technique clusters the complete paths, i.e., eye-subsurface-light paths (true / false)

(h) Tensor Clustering technique for Many-Light Animations [Hašan et al. EG 08] adds one more dimension for frames to the matrix formulation (true / false)

(i) In Tensor Clustering technique, pixel mapping allows for reusing shading over frames (true / false)