APAL Project Proposal: Tour Of 2D Global Illumination Techniques

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Figure 1: Seattle Mariners at Spring Training, 2010.

1 Problem Description

One of the most critical components of realistic rendering is **Indirect Illumination**, also known as **Global Illumination (GI)**. Offline renderers typically solve for the radiance of visible surfaces in a scene using Monte Carlo raytracing, iterating until the image converges to a noise-free result. This level of computation is infeasible for real-time rendering without specialized optimizations because of ray-tracing's long running time to converge.

2 Literature Review

Over the past decade, real-time GI solutions have relied on secondary scene representations, probe-based methods, or pre-baked lighting for static environments. These techniques generally fall into the following four categories:

(1) **Lightmaps**
- Store ray-traced lighting data in texture maps.
- Baked in advance for static scenes.

(2) **Tracing with Alternative Scene Representations**
- Uses efficient structures such as:
  - Discrete Signed Distance Fields
  - Voxels
  - Proxies
- Traces rays against these representations rather than mesh geometry.

(3) **Screen-Space Methods**
- Ray-traces using information from the G-buffer.
- Limited to what is visible on-screen, missing off-screen details.

(4) **Probes**
- Stores a coarse irradiance field.
- Can be precomputed or updated dynamically.

Additional modern techniques that try to bring Monte Carlo Integration into realtime include:

- **Machine Learning (ML)**
  - Traces a low number of rays and infers missing details through denoising and upscaling.
- **Caching & Reuse**
  - **Temporal Accumulation & Reprojection**: Uses previous frames to refine current results.
  - **ReSTIR**: Reuses and resamples importance-traced rays for efficient global illumination.

Among these techniques, **Irradiance Probes** have been one of the most favorable approaches due to their:

- Simplicity
- Scalabilty
- Precomputed nature
- High performance

However, they have notable limitations:

- They are usually have a coarse resolution because they are placed sparsly limts their ability to capture fine details.
- Ambient soft shadows are often missing, leading to a lack of depth and realism.
- Occluded areas feel "ungrounded" due to insufficient indirect lighting information.

For non static scenes increasing probe density significantly raises computational costs since the number of required rays scales accordingly. Thus, finding an optimal balance remains a challenge in real-time GI solutions.

3 Application

I aim to develop a 2D Global Illumination Benchmark/Renderer application. This app will allow users to load scene descriptions, including lights, primitives, and material definitions. The application will then render the scene using three different GI solutions for benchmarking purposes.

(1) Reference monte-carlo raytracer CPU.

(2) Reference monte-carlo raytracer GPU.
(3) Irradiance probes GPU.
(4) Radiance cascades GPU.

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