CloudLight : Interactive Indirect Illumination in the Cloud

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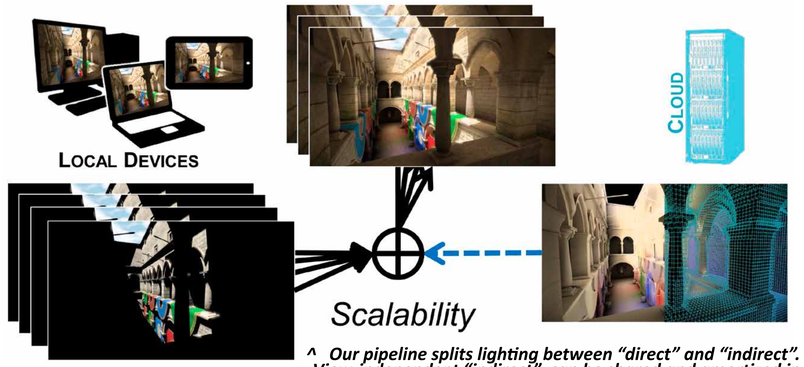
Motivation

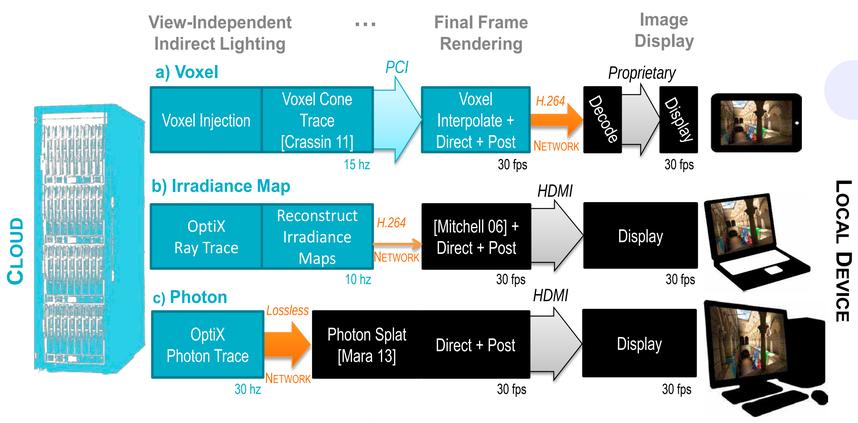
Games on mobile phones, tablets, and laptops have graphics processing limited by heat dissipation in their small form factors. **CloudLight** is a system for real-time game rendering that **computes lighting on distributed servers** separate from the processors that compute the final images. This allows **even better graphics** than today's PC and console games on **low-power mobile platforms**.

Cloud graphics also offers virtualization, load balancing, lower production costs, and piracy protection for developers. CloudLight offers **three different pipelines**, targeting different client devices.



^ *Our pipeline splits lighting between "direct" and "indirect". View-independent "indirect" can be shared and amortized in the Cloud over multiple clients*

^ *Our CloudLight framework demonstrates feasibility of Cloud indirect lighting for game-scale assets*



^ *The CloudLight pipeline for three global illumination algorithms: voxels, irradiance maps, and photons. Shift from cloud (blue) to local computation (black), suggests use of different algorithms depending on the targeted user device.*

Distributed System

CloudLight maps the traditional graphics pipeline onto a **distributed system** which separates **direct** (view-dependent) and **indirect** (view-independent) lighting computations so that they can be computed on different machines connected by a network and compressed data streaming.

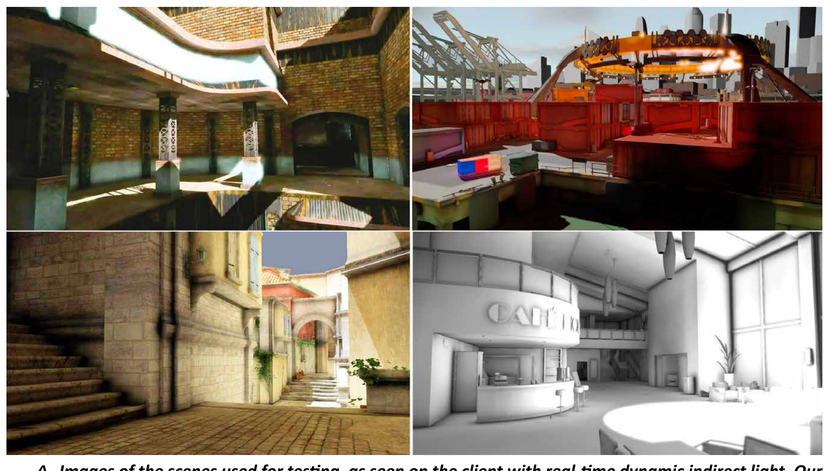
A distributed graphics pipeline has several differences from a single-machine one. It must:

- Leverage the **asymmetric resource distribution** between stages of the pipeline.
- Tolerate **high latency** and **low bandwidth** between certain pipeline stages.
- **Amortize computation** across users.

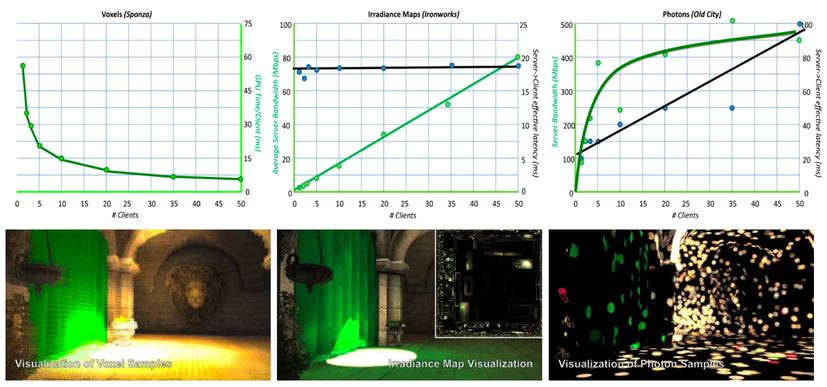
Indirect Lighting Pipelines

We developed three different pipelines within CloudLight to solve this for different network and client scenarios:

- **Voxel cone-tracing**: Clients only decode final frames computed on the server and streamed as a video. This allows the most amortization of server resources, but also requires a very low latency network.
- **Irradiance maps**: Clients render direct light and combine it with indirect light streamed asynchronously from server. This is good for medium-power clients with low latency that are limited by low bandwidth and is robust to network instabilities.
- **Photon mapping**: Clients reconstruct indirect light from photons generated on the server. This is gives the most reactive lighting through progressive update for a PC or console-class client.



^ *Images of the scenes used for testing, as seen on the client with real-time dynamic indirect light. Our system is based over commercially-deployed systems like OptiX, hardware video encoders and NVIDIA*



^ *Our experiments run in the Cloud on a GeForce TITAN + 2 secondary Quadro K5000 GPU for voxel (render frames and perform H.264 encoding). Photon reconstruction use a GeForce 670.*

Results

We demonstrate **scaling up to 50 users per server node**, allowing better quality global illumination for similar per-user costs.

For each thechniques, we analyse the **server-side overhead** depending on the number of clients, as well as the **effective latency** of indirect lighting. We show that only **coarse synchronization** between direct and indirect light is necessary, and even **high latencies can be acceptable** for indirect lighting.

For *voxel*, the common overhead becomes quickly insignificant with increasing number of clients. Each K5000 GPU can simultaneously serve at least 5 clients with a consistent 30 FPS. For *irradiance map*, per-user latency is essentially constant. Due to larger bandwidth requirements, *photon mapping* does not scale as well.

Main references:

- *Interactive indirect illumination using voxel cone tracing.* Computer Graphics Forum 2011. CRASSIN, C., NEYRET, F., SAINZ, M., GREEN, S., AND EISEMANN, E.
- *Toward practical real-time photon mapping: Efficient gpu density estimation.* ACM I3D 2013. MARA, M., LUEBKE, D., AND MCGUIRE, M.
- *Shading in Valve's source engine.* ACM SIGGRAPH Courses 2006. MITCHELL, J., MCTAGGART, G., AND GREEN, C.