

Week 6 Task – Lighting and Nanite

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Mobile Game Lighting: Balancing Visual Quality with Performance Constraints

Within the mobile game development scene, optimisation is one of the most important things to make a mobile game that plays well, looks great, whilst still having good performance.

Mobile devices have significant lighting limitations compared to console and PC due to hardware constraints and power efficiency. In terms of dynamic lighting, mobile devices struggle to compute real-time light and shadows, meaning that dynamic lighting is very limited or avoided. A workaround for using dynamic lighting is to use one main directional light for dynamic shadow casting and then bake or fake the rest to keep the best performance possible. On mobile games, real-time shadows are also simplified, using a lower resolution and less accuracy than PC/consoles. Mobile devices that aren't very high-end often can't handle advanced shadow algorithms and soft shadows, so they are typically not usable. Another thing that is limited by mobile device limitations is post-processing effects. Effects such as bloom, depth of field, tone mapping and ambient occlusion are limited, and higher end features like ray tracing and global illumination are either unavailable or must be emulated.

Due to these limitations, higher contrast and brighter lighting are often used to boost clarity on smaller screens. Another method of boosting clarity on smaller screens, as well as readability is by using clear silhouettes and exaggerated lighting cues. Developers can also achieve compelling lighting within a strict performance budget by using static and baked lighting. Baked lighting is lighting that is precomputed and stores light information offline to avoid expensive real-time calculations. Post-processing effects can also be baked to reduce real-time calculations.

Engine techniques such as clustered forward rendering and level-of-detail lighting can reduce the per-frame workload. Clustered forward rendering divides the camera's view into a 3D grid of clusters and assigns lights to the clusters they affect, reducing the number of lights that need to be processed for each pixel. Level-of-detail lighting is a technique that reduces the level of complexity of lighting based on how far away from the camera they are.

Many successful mobile games approach optimisation in different ways to make them perform well on the majority of mobile devices. One popular game that does this is Genshin Impact (Genshin Impact, HoYoverse, 2020). The method that HoYoverse used to optimise Genshin Impact's lighting is by baking the environment lighting into lightmaps to allow detailed global illumination without runtime cost. Light probes are also used extensively to approximate indirect lighting for moving characters, helping them blend smoothly with static lighting environment. Genshin also has adaptive lighting quality settings that scale based on the device's capabilities. These settings adjust shadow quality and resolution, light count and dynamic light range, post-processing effects quality, level of detail and lighting, adaptive brightness and contrast tweaks, and dynamic light culling and batching.

Another popular game that uses different optimisation methods to run well on mobile devices is PUBG Mobile (PUBG Mobile, LightSpeed Studios, 2018). Just like Genshin Impact, PUBG also uses adaptive quality settings. In addition, it also uses efficient asset management to reduce loading times and prevent stuttering during gameplay. This is done by using compressed textures and optimised mesh data to work with the tight mobile memory budget. PUBG also uses level-of-detail systems, clustered forward rendering, and using low-resolution shadows or replacing shadows with blob or projected shadows.

Emerging mobile GPU features are changing mobile lighting workflows by making more expensive and

realistic lighting effects, which were previously exclusive to PC and consoles, usable on mobile devices. A lighting feature that is now supported by flagship mobile GPUs is real-time ray tracing. Ray tracing allows mobile games to achieve accurate reflections, shadows, and global illumination effects with physically based light interactions. Another feature that is now becoming supported by flagship GPUs is variable rate shading. Variable rate shading optimises rendering by adjusting shading rates across the screen, concentrating processing power on regions of focus while reducing detail in less critical areas. This improves performance and battery life without compromising visible quality. Advanced HDR and wide colour gamut standards are becoming increasingly supported too. This allows better lighting that adapts to mobile display characteristics. AI-accelerated technologies in some mobile GPUs assist with enhancing lighting quality through machine learning, enhancing visual quality at a reduced computational cost.

Developers can handle lighting scalability across mobile devices by using adaptive quality settings that adjust based on a device's hardware and capabilities, and by using runtime profiling and adaptive algorithms that detect thermal throttling or frame drops and downscale lighting features accordingly to sustain smooth gameplay. Graphics APIs such as Vulkan and Metal provide tools for fine-grained control over these adjustments, enabling real-time tuning according to device metrics.

In conclusion, lighting optimisation is a fundamental part of mobile game development, crucial for balancing performance and visual appeal across a wide range of devices. Since mobile hardware is inherently limited compared to PCs and consoles, developers rely heavily on baked lighting and simplified dynamic lighting setups to reduce runtime costs while preserving immersion. Techniques like clustered forward rendering and level-of-detail lighting help to distribute processing load more efficiently, maintaining smooth frame rates. Adaptive lighting quality settings play a vital role, scaling features such as shadow resolution, light counts, and post-processing effects based on the device's capabilities.

Looking at successful games like Genshin Impact and PUBG mobile shows how baked lightmaps combined with dynamic lighting cues and light probes create compelling visuals without overburdening hardware. In addition, emerging features in flagship mobile GPUs, including real-time ray tracing, variable rate shading, and AI-assisted denoising are gradually enhancing mobile lighting workflows. Despite these advances, developers must carefully tune these effects to stay within performance and battery constraints. Ultimately, a hybrid approach that combines precomputed lighting with selective real-time lighting and dynamic adaptability to hardware is essential. This ensures broad compatibility and rich visuals, demonstrating why lighting optimisation remains a cornerstone of effective mobile game design.

Bibliography

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