GPU Computing

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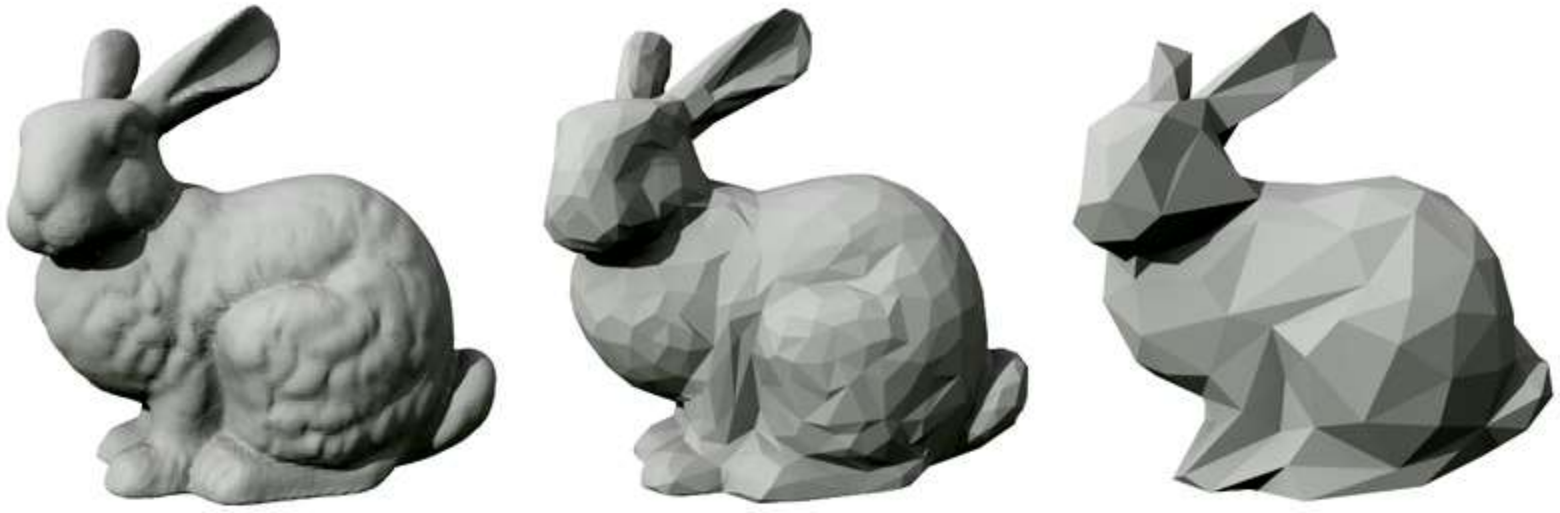
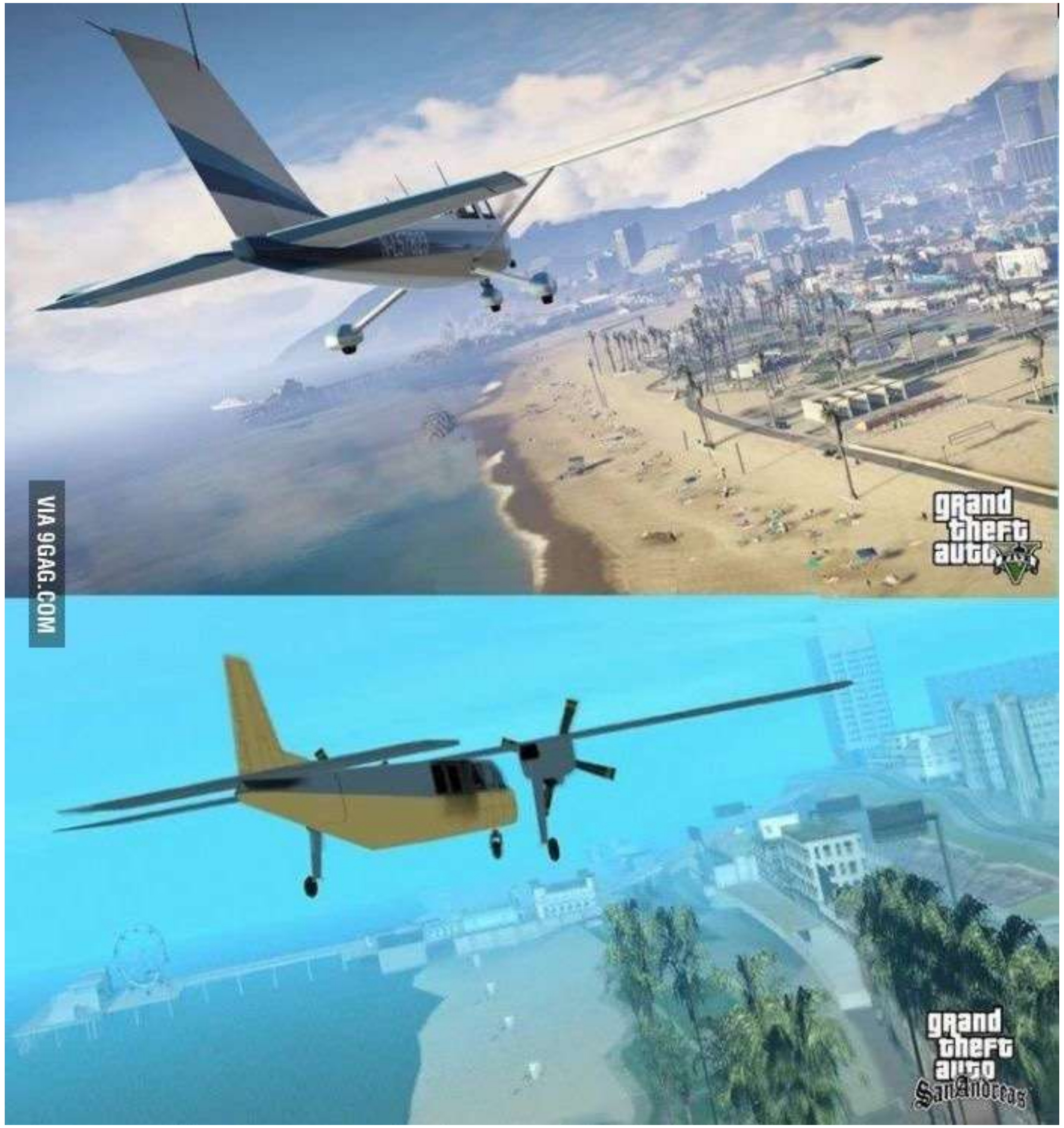
GPU (Graphics Processing Unit)

- Rendering
    - 3D surfaces
    - Textures
    - Lights
    - Views



https://en.wikipedia.org/wiki/File:Stanford_bunny_qem.png

https://en.wikipedia.org/wiki/Utah_teapot



https://www.quora.com/What-has-a-better-story-GTA-V-or-GTA-San-Andreas

GPU Rendering

- Direct3D
- OpenGL

- Use primitives to render a frame

GPU ~~Rendering~~ Computing (Before 2007)

- Direct3D
- OpenGL

- Use primitives to render a frame
- Make your 2D array as a frame and call render primitives

GPU Computing (After 2007)

- CUDA (~~Compute Unified Device Architecture~~)
- C/C++, Fortran
- GPGPU (General-Purpose computing on Graphics Processing Units)
- OpenCL

GPU Architecture

- 108 Streaming Multi-processor (SM)
- 40 GB High-Bandwidth Memory (HBM)
  - 1555 GB/sec
  - 6912 FP32 CUDA cores
- 432 Tensor Cores, TensorFloat-32(TF32) Dense Tensor (156 TFLOPs)
- 192KB * 108 L1 Cache
- 40960 KB L2 Cache

GPU Scheduling

- SIMT (Single Instruction Multiple Thread)
- Warp
- Dangerous to implement critical section (Pre Volta)

- Independent Thread Scheduling (After Volta)

CUDA Programming

- Kernel
- Grid
- Block
- Thread
- Warp

- Host Memory
- Device Memory
    - Global Memory
    - Shared Memory

CUDA Programming

```
__global__
void saxpy(int n, float a, float *x, float *y){
        int i = blockIdx.x * blockDim.x + threadIdx.x;
        if (i < n)
                y[i] = a * x[i] + y[i];
}
```

CUDA Programming

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saxpy<<<nB, nT>>>(n, a, x, y);
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CUDA Programming

device memory

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```

```
float* x;
cudaMalloc(&x, n * sizeof(float));
```

```
cudaError_t cudaMalloc ( void** devPtr, size_t size )
```

Host Memory vs. Device Memory

- cudaMalloc, cudaFree
- cudaError_t cudaMemcpy (void* dst, const void* src, size_t count, cudaMemcpyKind kind)
  - cudaMemcpyHostToHost = 0
    - Host -> Host
  - cudaMemcpyHostToDevice = 1
    - Host -> Device
  - cudaMemcpyDeviceToHost = 2
    - Device -> Host
  - cudaMemcpyDeviceToDevice = 3
    - Device -> Device
  - cudaMemcpyDefault = 4
    - Direction of the transfer is inferred from the pointer values. Requires unified virtual addressing

CUDA Compilation

- nvcc a.cu -o a.out -O3 -Xptxas -O3
- cuda-gdb
    - -g -G (without optimizations)
    - info cuda threads
    - cuda thread 0
- cuda-memcheck
- nvprof
    - nvvp

Scan

- Inclusive scan
- Exclusive scan

- Naïve scan
- Work-efficient scan