EE 4702-1, GPU Programming

When / Where

- Room 1218 P.F. Taylor Hall, MWF 9:30-10:20 Fall 2023

  https://www.ece.lsu.edu/koppel/gpup/

Offered By David M. Koppelman

- Room 3316R Patrick F. Taylor Hall
- Office Hours: Monday-Friday 14:00-15:00

Prerequisites by topic:

- C++.

GPU Definition

GPU: Graphics Processing Unit

- Runs 3D graphics in place of CPU...

  ... because it's much better at it.
- Runs other computation in place of CPU, including ML and scientific workloads ...
- ... and yes cryptocurrency mining.

GPU is Main Component of Video Cards

Major Companies and Brands

- NVIDIA (RTX, Quadro, Tesla)
- AMD (Radeon, etc.)
- Intel

This Course

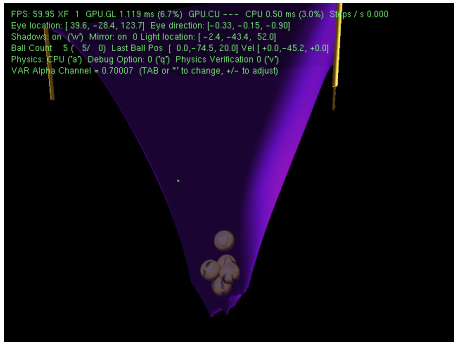
Focus is on GPU Programming

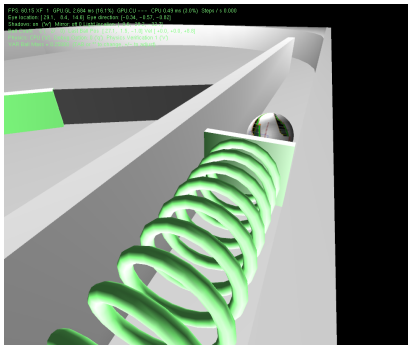
- *Vulkan host API; Shader* programming with *OpenGL Shader Language* (*OGSL)*.
- Both *rasterization* and *ray-tracing* rendering techniques.
- *GPGPU* programming with OGSL *Compute Shaders* and *CUDA*.

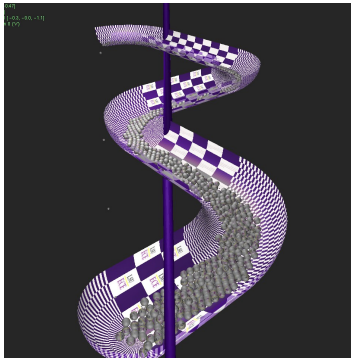
Also Some 3D Graphics, Game Physics

- Will cover enough graphics, Vulkan and CUDA to do fun stuff.

Past Student Project Screenshots:





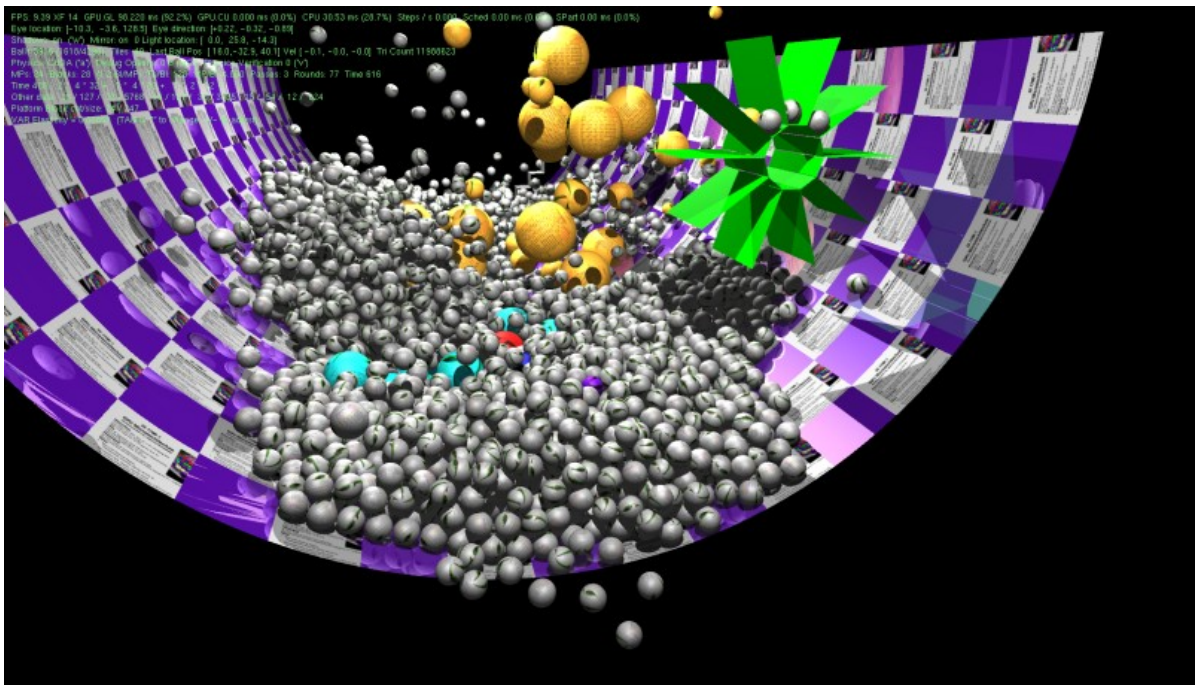


Balls Demo

Simulation of balls and wheel on curved platform.

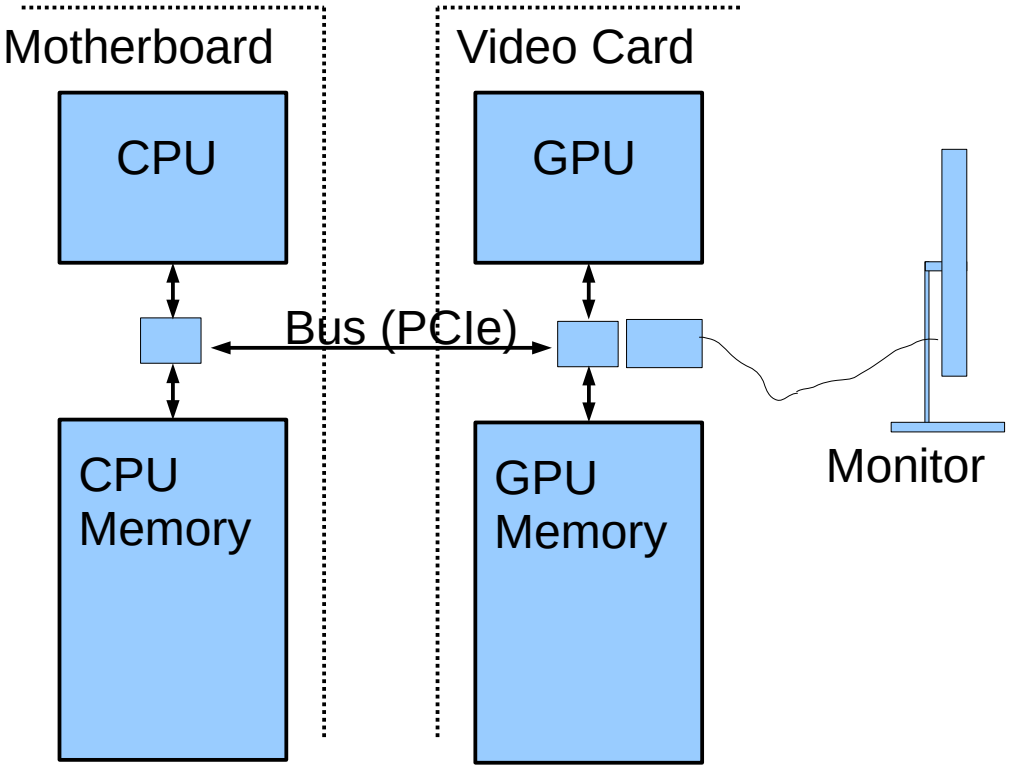
GPU always runs 3D graphics.

Can switch between CPU-only and CPU/GPU physics, and Rasterization and Ray Tracing



System Overview

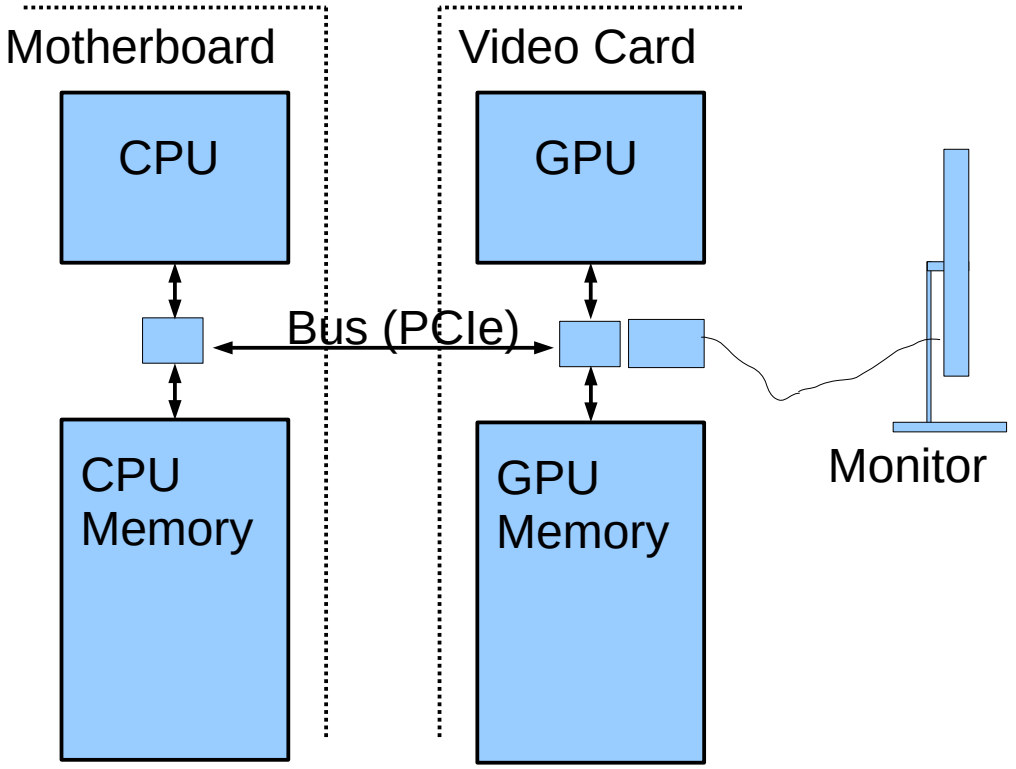
Quick look at how the GPU fits into the larger system...



System Overview: Hardware

Typical Hardware

- On Computer motherboard: CPU, CPU Memory
- On Video Card GPU, GPU Memory
- Connection between CPU/GPU via Bus, e.g., PCI Express (PCIe).
- Connection from video card to monitor.



System Overview: Frame Buffer

Frame Buffer

- Area of memory continuously converted to a video signal.
- Simple mapping from memory address to pixel coordinate.

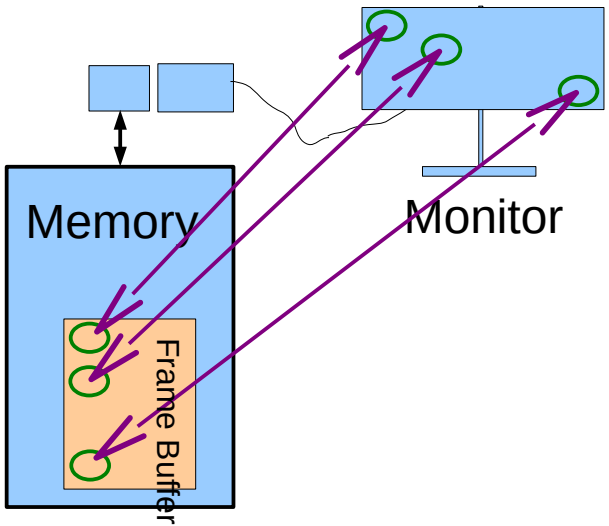
Older Systems

- Frame buffer in CPU memory.
- Application programs wrote frame buffer directly.

Typical Current Systems

- Frame buffer in GPU memory.
- Frame buffer written by GPU hardware (typical)...

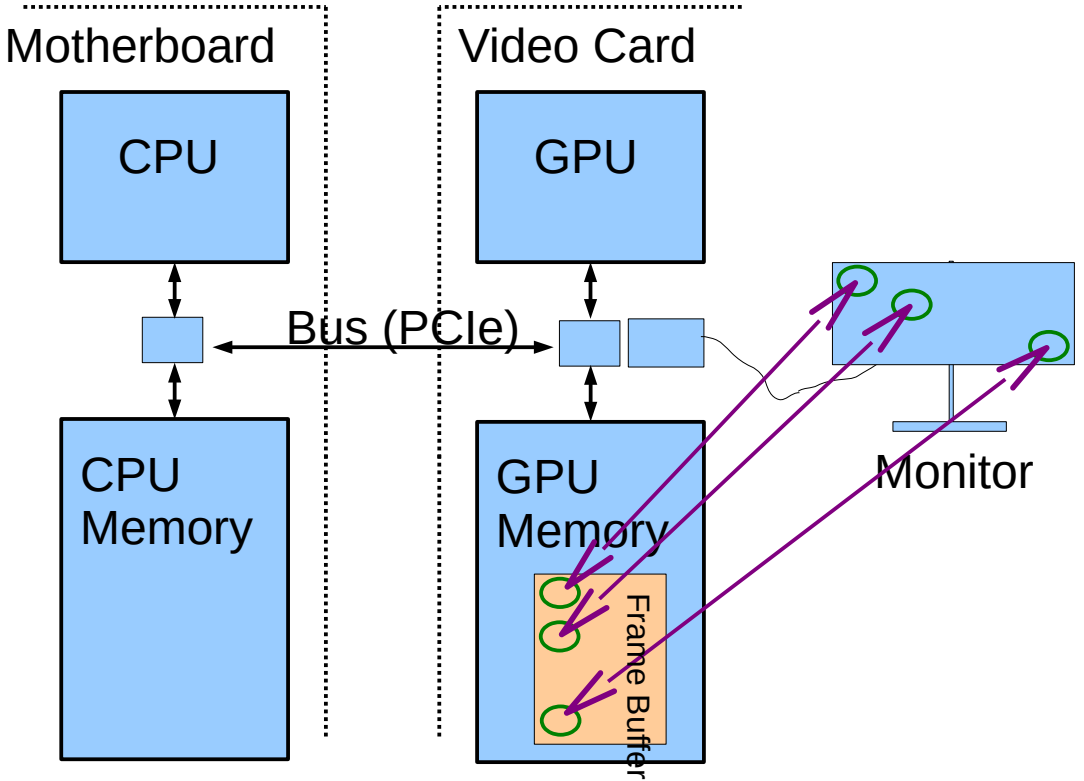
  … in response to code on CPU.



System Overview: Frame Buffer

Frame Buffer Contents

- Position in FB corresponds to particular pixel on display.
- In illustration, first FB element is upper-left pixel.
- A common FB element size is 32 bits.
- Frame buffer format varies with video mode and of course system.



Simple Frame Buffer Code Example

Consider Code

- frame_buffer[10][20] = 0;

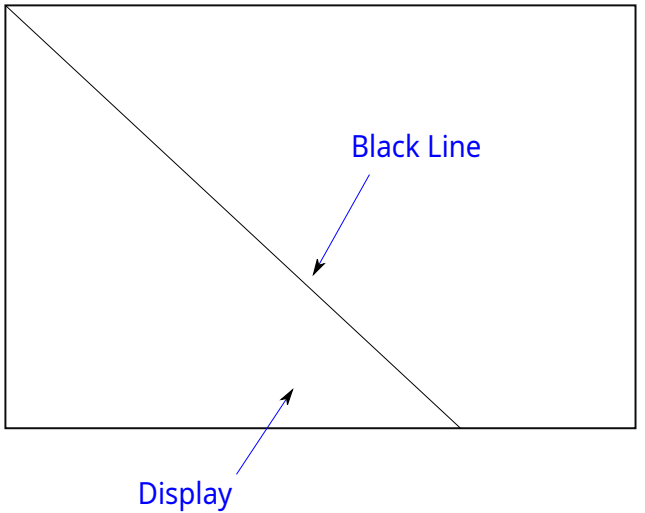
For Simple Code Example Assume

- The frame buffer is in CPU memory.
- Array frame_buffer points to the frame buffer location.
- Writing a “1” to the array makes a pixel white.
- Writing a “0” to the array makes a pixel black.

Simple Frame Buffer Example

```
// Make screen all white. (Assume 1 is white.)
//
for ( int x = 0;  x < width;  x++ )
  for ( int y = 0; y < height; y++ )
    frame_buffer[x][y] = 1;


// Draw a black diagonal line.
//
for ( int x = 0; x < height; x++ )
  frame_buffer[x][x] = 0;
```



GPU Rationale

Code on prior slide looked simple.

How much more complex would balls code be?

Alot, of course!

Motivation for a GPU:

- Graphics (3D animated, especially) requires alot of computation.
- CPU is less suited for that kind of computation.

Course Coverage

Emphasis: GPU coding for high performance.

Topics Needed For Term Project (a dynamic simulation)

Topics

- Rudiments of Animation by Dynamic Simulation
- 3D Graphics basics: coordinates, transforms, primitives, colors, textures.
- Rasterization and Ray Tracing.
- Coding with GPU Vulkan/OpenGL *shader* model, CPU/GPU load balancing.
- Coding with CUDA, GPU physics.

APIs, Languages, Standards Used

API for Controlling GPU from CPU

- Vulkan (Version 1.3)

OpenGL Shader Language (Version 4.60)

- A language for code (usually graphical) that runs on GPUs.

CUDA (Version 12.2)

- An NVIDIA language for code (usually not graphical) that runs on GPUs.

C++20

- A common programming language.
- Students are assumed to be familiar with C++.

Toolchain

Operating Systems

- Red Hat Enterprise Linux 9

Compiler

- gcc (GNU C Compiler)

Debugger

- gdb (GNU Debugger)
- Students expected to learn **and use** gdb.

Text Editor

- EMACS (recommended)

Code Repository

- Git. (Classroom examples, homework assignments, etc.)

Graphics Equipment

For assignments, use equipment in Workstation Lab

Workstation Lab

- Live Status Updates: https://www.ece.lsu.edu/koppel/gpup/sys-status.html
- Back of room 2241 P.F. Taylor Hall
- Several kinds of computers.

Graphics Workstations

- Mix of high-end graphics GPUs.
  - NVIDIA RTX 4090s.
- Some machines have scientific-computing-grade accelerators:
  - NVIDIA H100