CS4803DGC Design Game Consoles

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Workload Characterizations

- Benchmarking is critical to make a design decision and measuring performance
  - Performance evaluations:
    - Design decisions
      - Earlier time : analytical based evaluations
      - From 90's: heavy rely on simulations.
    - Processor evaluations
  - Workload characterizations: better understand the workloads

Measuring Performance

- Benchmarks
  - Real applications and application suites
    - E.g., SPEC CPU2000, SPEC2006, TPC-C, TPC-H, EEMBC, MediaBench, PARSEC, SYSmark
  - Kernels
    - "Representative" parts of real applications
    - Easier and quicker to set up and run
    - Often not really representative of the entire app
  - Toy programs, synthetic benchmarks, etc.
    - Not very useful for reporting
    - Sometimes used to test/stress specific functions/features

Performance Metrics

- GFLOPS, TFLOPS
- MIPS (Million instructions per second)

Normalizing & the Geometric Mean

- Speedup of arithmeitc means != arithmetic mean of speedup
- Use geometric mean: $\sqrt[n]{\prod_{i=1}^{n} \text{Normalized execution time on } i}$
- Neat property of the geometric mean: *Consistent whatever the reference machine*
- **Do not use the arithmetic mean for normalized execution times**

CPI/IPC

- Often when making comparisons in comp-arch studies:
  - Program (or set of) is the same for two CPUs
  - The clock speed is the same for two CPUs

- So we can just directly compare CPI's and often we use IPC's

Average CPI vs. "Average" IPC

- Average CPI = $(CPI_1 + CPI_2 + \ldots + CPI_n)/n$

- A.M. of IPC = ~~$(IPC_1 + IPC_2 + \ldots + IPC_n)/n$~~

  Not Equal to A.M. of CPI!!!

- Must use *Harmonic Mean* to remain $\propto$ to runtime

Harmonic Mean

- H.M.$(x_1, x_2, x_3, \ldots, x_n)$ =

$$\frac{n}{\frac{1}{x_1} + \frac{1}{x_2} + \frac{1}{x_3} + \ldots + \frac{1}{x_n}}$$

- What in the world is this?
  - Average of inverse relationships

A.M.(CPI) vs. H.M.(IPC)

- "Average" IPC = $\dfrac{1}{\text{A.M.(CPI)}}$

$$= \frac{1}{\frac{CPI_1}{n} + \frac{CPI_2}{n} + \frac{CPI_3}{n} + \ldots + \frac{CPI_n}{n}}$$

$$= \frac{n}{CPI_1 + CPI_2 + CPI_3 + \ldots + CPI_n}$$

$$= \frac{n}{\frac{1}{IPC_1} + \frac{1}{IPC_2} + \frac{1}{IPC_3} + \ldots + \frac{1}{IPC_n}} = \text{H.M.(IPC)}$$

GPU Benchmarks

- Stanford graphics benchmarks
  - Simple graphics workload. Academic
- Mostly game applications
  - 3DMark:
  - http://www.futuremark.com/benchmarks/3dmarkvantage
  - Tom's hardware

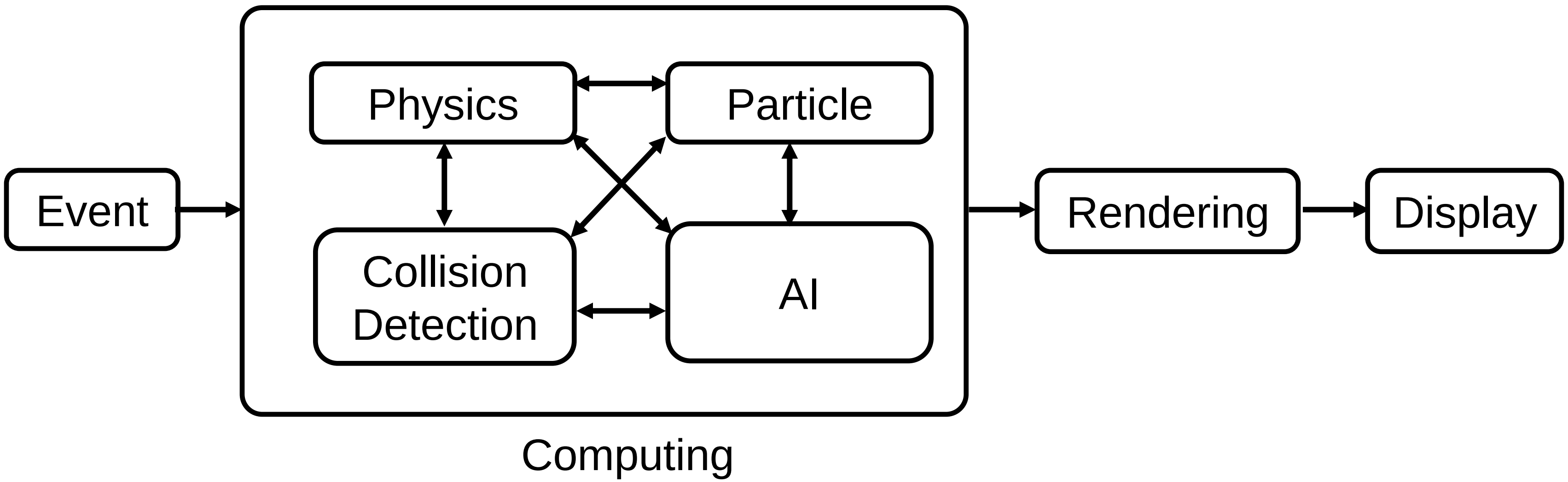
Game Workload Charcterizations

- Still graphics is the major performance bottlenecks
- Previous research: emphasis on graphics

Game workloads

- Several genres of video games
  - First Person Shooter
    - Fast-paced, graphically enhanced
    - Focus of this presentation
  - Role-Playing Games
    - Lower graphics and slower play
  - Board Games
    - Just plain boring

Overview of Game Engine



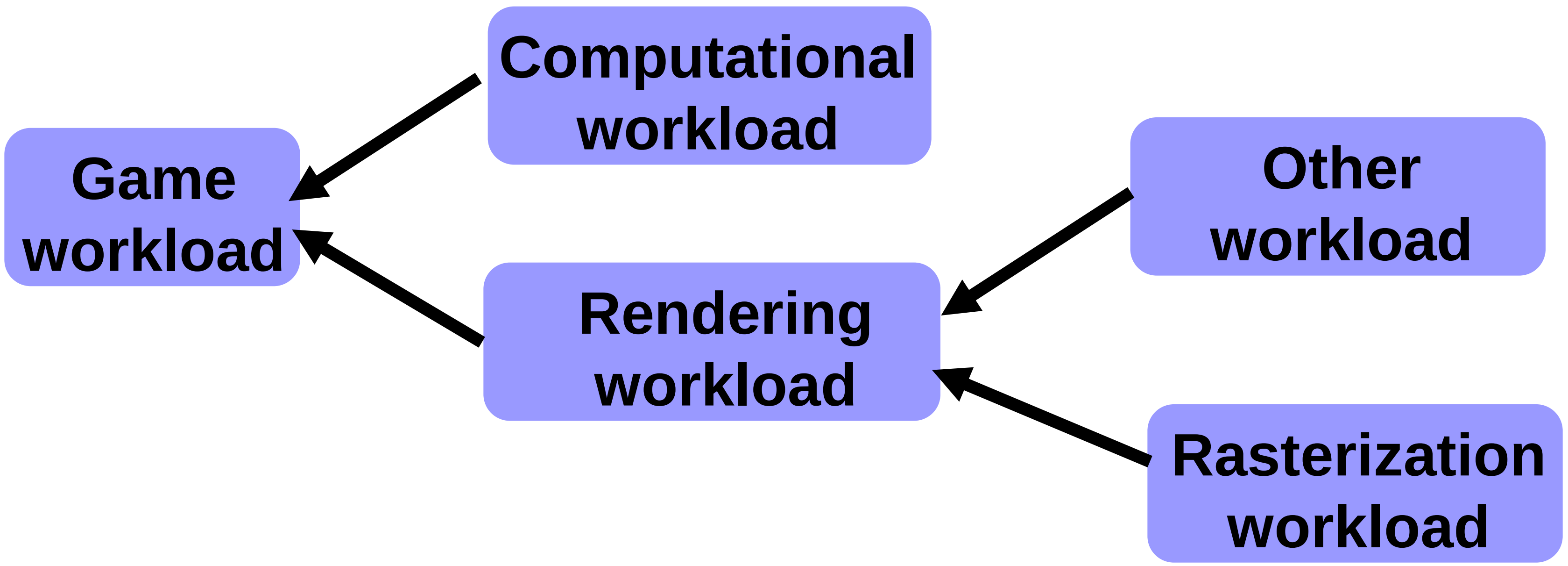
Frame Rates

- Current game design principles:
  - higher frame rates imply the better game quality
- Recent study on frame rates [Claypool et al. MMCN 2006]
  - very high frame rates are not necessary, very low frame rates impact the game quality severely

A First Cut: Reduce Frame Rates

Snapshots of animation [Davis et al. Eurographics 2003]

Game workloads



Game workload characterization

- Case study
  - Workload characterization of 3D games, Roca, et al. IISWC 2006 [WOR]
  - Use ATTILA

TABLE III

AVERAGE INDICES PER BATCH AND FRAME AND TOTAL BW

Game/Timedemo	avg. indexes per batch	avg. indexes per frame	bytes per index	BW @100fps
UT2004/Primeval	1110	249285	2	50 MB/s
Doom3/trdemo1	275	196416	4	79 MB/s
Doom3/trdemo2	304	136548	4	55 MB/s
Quake4/demo4	405	172330	4	69 MB/s
Quake4/guru5	166	135051	4	54 MB/s
Riddick/MainFrame	356	214965	2	43 MB/s
Riddick/PrisonArea	658	239425	2	48 MB/s
FEAR/built-in demo	641	331374	2	66 MB/s
FEAR/interval2	1085	307202	2	61 MB/s
Half Life 2 LC/built-in	736	328919	2	66 MB/s
Oblivion/Anvil Castle	998	711196	2	142 MB/s
Splinter Cell 3/first level	308	177300	2	35 MB/s

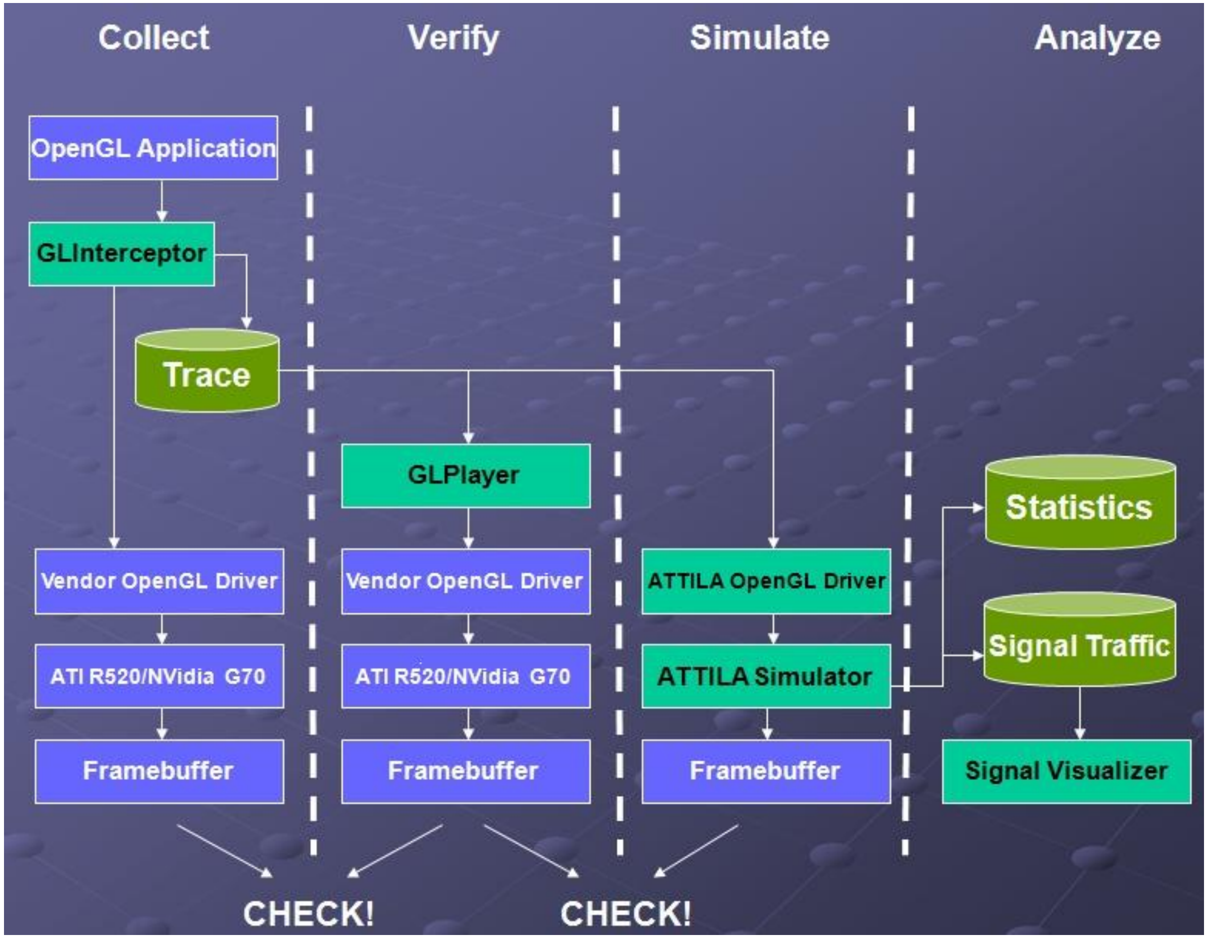
Characterization Items

- Average primitives per frame
- Average vertex shader instructions
- Vertex cache hit ratio
- System bus bandwidths
- Percentage of clipped, culled, and traversed triangles
- Average triangle sizes

ATTILA

- GPU execution driven simulator
- https://attilaac.upc.edu/wiki/index.php/Architecture
- Can simulate OpenGL at this moments

Attila Frame



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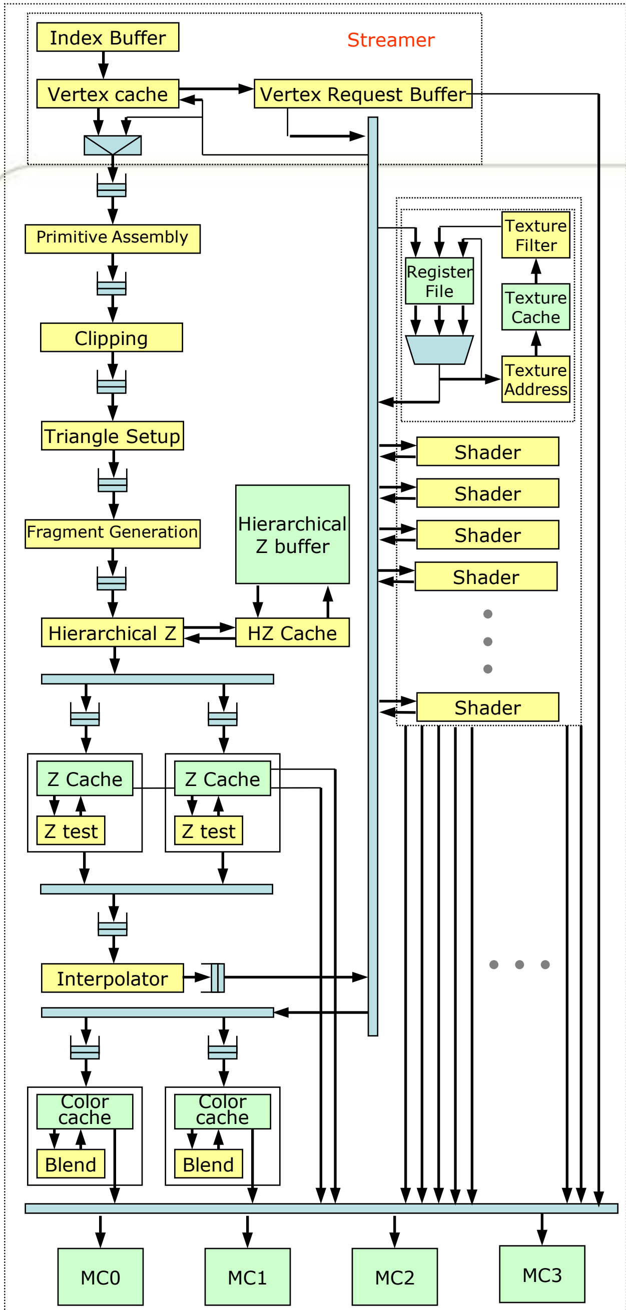

- Attila architecture

Unit	Size	Element width
Streamer	48	16x4x32 bits
Primitive Assembly	8	3x16x4x32 bits
Clipping	4	3x4x32 bits
Triangle Setup	12	3x4x32 bits
Fragment Generation	16	3x4x32 bits
Hierarchical Z	64	(2x16+4x32)x4 bits
Z Tests	64	(2x16+4x32)x4 bits
Interpolator	---	---
Color Write	64	(2x16+4x32)x4 bits
Unified Shader (vertex)	12+4	16x4x32 bits
Unified Shader (fragment)	240+16	10x4x32 bits

Table 2. Queue sizes and number of threads in the ATTILA reference architecture

Simulation

- Execution driven:
  - Correctness, long development time,
  - Execute binary
- Trace driven
  - Easy to develop
  - Simulation time could be shorten
  - Large trace file size

Analytical Model

- No simulation is required
- To provide insights
- Statistical Methods
- CPU
  - First-order
- GPU
  - Warp level parallelism

CPU workload characterizations

- Hardware performance counters
  - Built in counters (instruction count, cache misses, branch mispredicitons)
- Profiler
- Architecture simulator
- Characterized items
  - Cache miss, branch mispredicition, row-buffer hit ratio

P#1

- States Lab setting
- Recommended deadline (1/25)
  - No penalty until 1/27
- Newsgroup:
  - Active participants will get extra credit
- Lab assignment TAing
  - Volunteer
  - Graduate (who have taken CS6290 course)
  - Send email to me.