Real-Time Rendering (Echtzeitgraphik)

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Vortragender

- Michael Wimmer
  - Associate Professor am
  - Institut für Computergraphik und Algorithmen (http://www.cg.tuwien.ac.at)
- Lehre:
  - UE Einführung in die Computergraphik, UE Computergraphik, VU Echtzeitgraphik
- Forschung:
  - Echtzeitgraphik: Schatten, Sichtbarkeit, Image-Based Rendering, Games, Modellierung, Point-Based Graphics, …

Organisatorisches – Vorlesungsteil

- Zeit: Mittwoch, 14:15-15:45
  - Bis 18.11: von 15:00-16:30
- Termine: ca. 12 Einheiten
  genaue Einteilung am Web (wichtig!!!)
- Ankündigungen: TISS
- Vorlesungshomepage:
  `www.cg.tuwien.ac.at/courses/Realtime`
- Beurteilung:
  praktischer Teil + mündliche Prüfung
- Anrechenbarkeit…

Organisatorisches – Vorlesungsteil

- Ort: Seminarraum 186
- Lecture support:
  - Videoaufnahme?
  - ??

Organisatorisches – Übungsteil

- VU: Vorlesung mit Übung
- Kleines Demo-Projekt in 2er-Gruppen
  - Implementierung von “ein paar Techniken”
  - Ev. in bestehendes ***CGUE-Spiel***

- 3 Abgaben
- Präsentation am Ende des Semesters (27.1. Anwesenheitspflicht!!)
- Betreuung durch Tutoren im Informatik-Forum (Echtzeitgraphik-Forum)

Organisatorisches – Übungsteil

- 0. Abgabe (19.10.): Projektvorschlag
  - Welche Effekte
  - Quellenangaben!!!
- 1. Abgabe (30.11.): “Rendering-”Engine
  - OpenGL-Rendering
  - Kamera
  - Texturen
- 2. Abgabe (18.1.): Fertiges Projekt
  - Implementierung der Effekte, “schönes” Demo

Organisatorisches – Übungsteil

- Prerequisites
  - Needs to run on Windows 8.1 x64!
  - PC with NVIDIA GTX 960 or AMD R9 380!
    - More details on website when PCs are ready
  - Graphics API:
    - OpenGL 3.2+ core profile
    - DirectX 10 or 11
  - Needs to use fragment shaders
  - Need to explain in assignment
    - what effects
    - what sources (web pages, papers, tutorials, …) were used

Organisatorisches – Übungsteil

- Content
  - Total Textures
  - We have access to the full repository!
  - https://lva.cg.tuwien.ac.at/cgue/textures/
    - user: student
      passw: we4tex13

Organisatorisches – Übungsteil

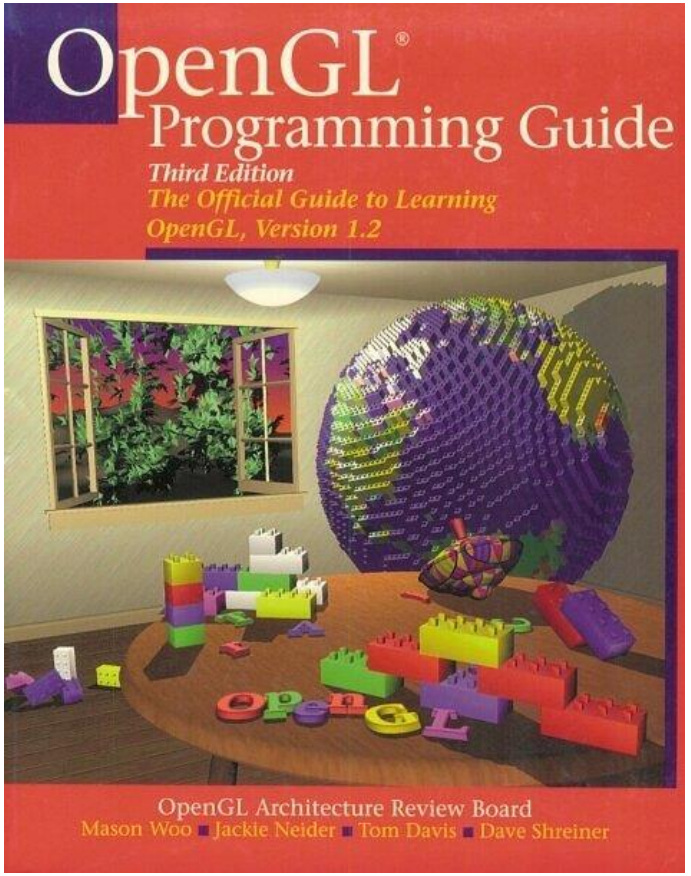
- Abgabesystem
  - Same as CGUE!
  - Need to subscribe in TISS, then login to Abgabesystem (lva.cg.tuwien.ac.at/rtr)
  - Need to use GIT and do regular commits!
    - Assignment is not complete without an up-to-date GIT repository!

Organisatorisches – Übungsteil

- Debugging
  - AMD CodeXL
  - NVIDIA Parallel nSight
  - Glsldevil (up to OpenGL 3.2)

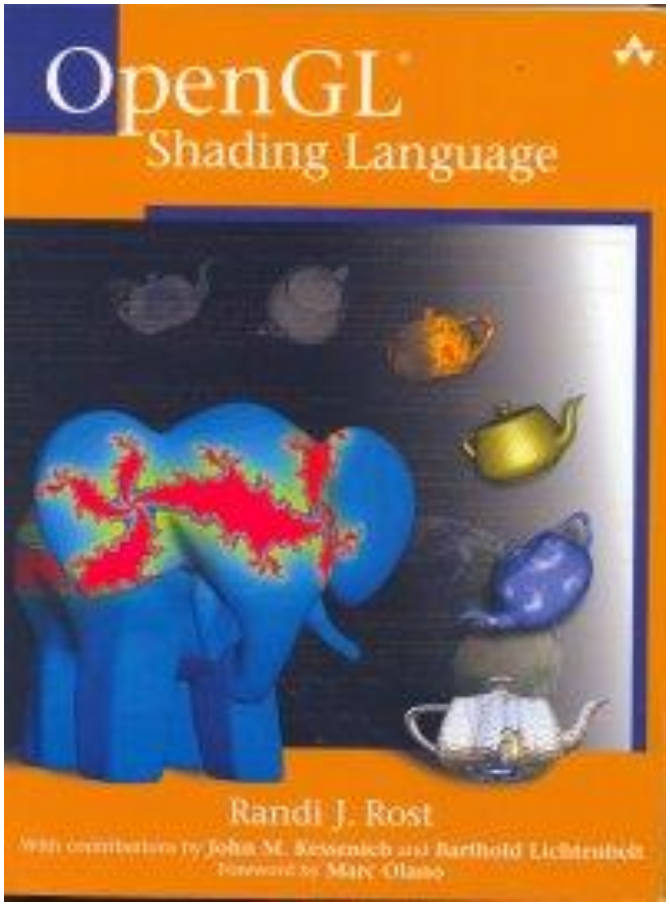
Prerequisites

- Basic Computer Graphics course
- Some knowledge about OpenGL
  - Google: “redbook pdf”



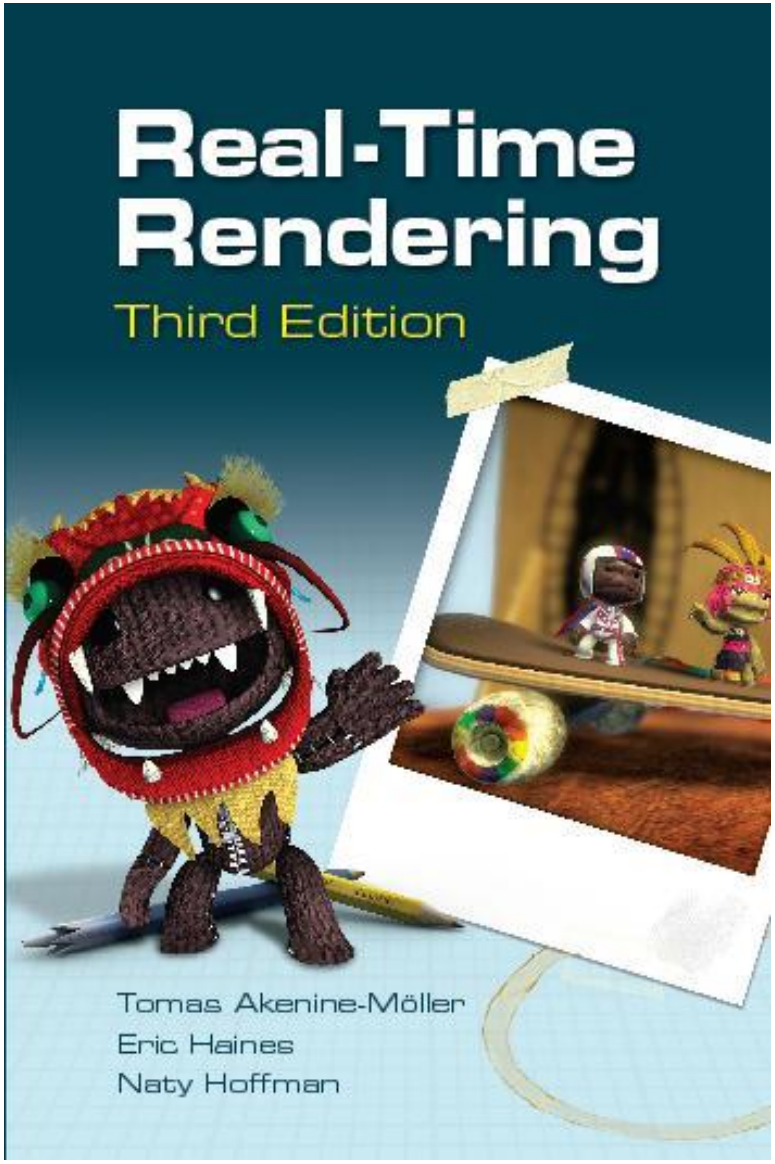
Book…

- Some knowledge about GLSL
  - Orange Book



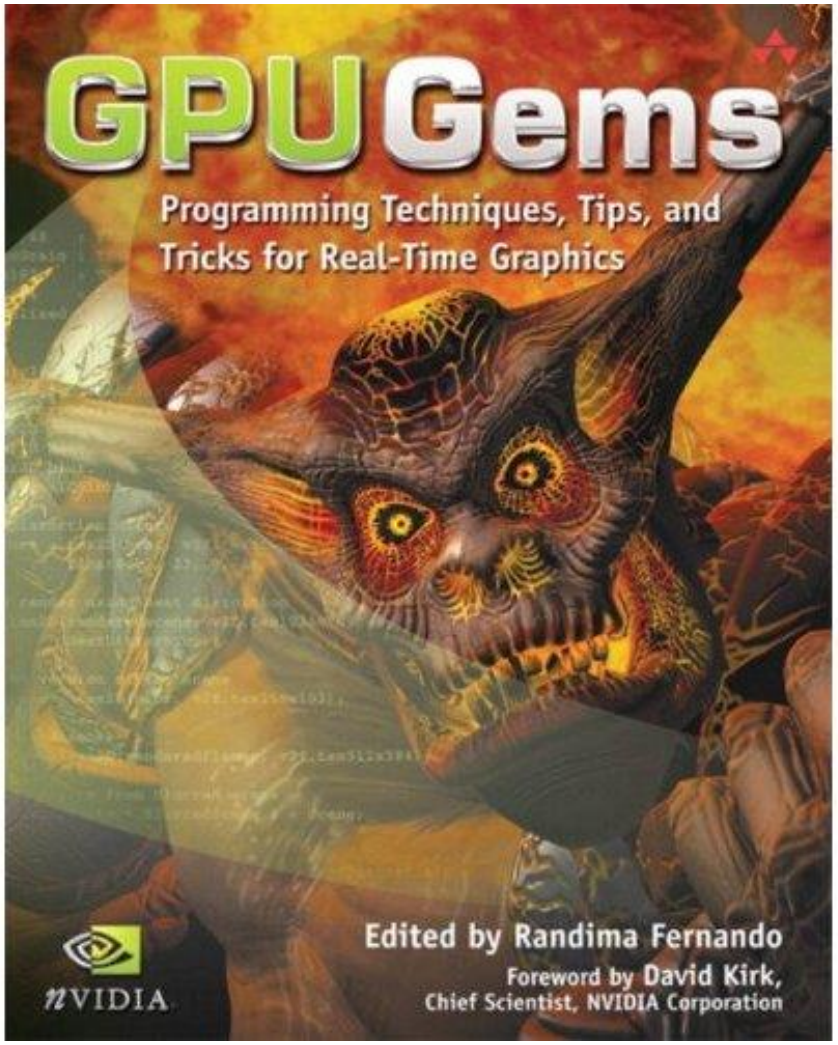
Book...

- Real-Time Rendering, Third Edition
  - AK Peters, 2008 (new: third edition)
- Not mandatory
  - But covers all standard methods
- Lecture slides!



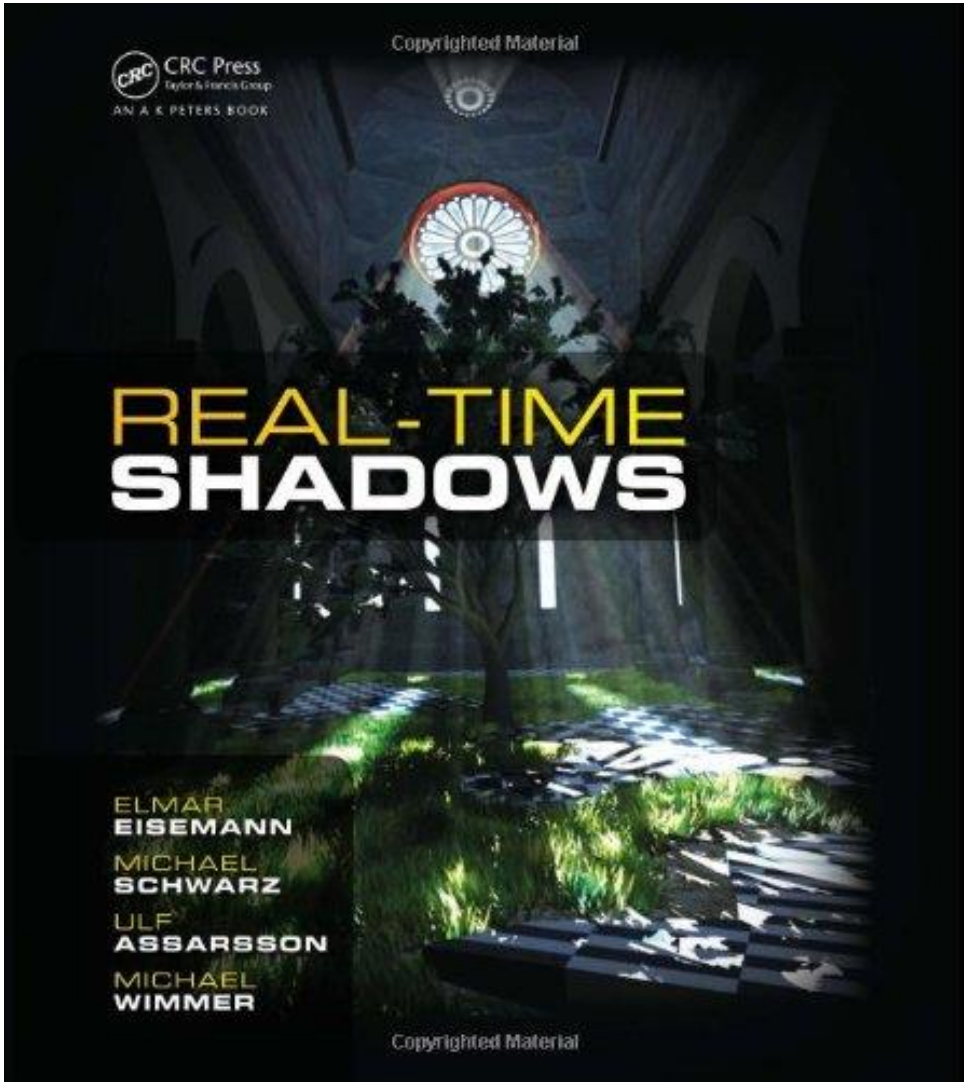
Book...

- GPU Gems 1, 2, 3
  - Many nice effects
  - Available online
- ShaderX/GPU Pro series



Book...

- Real-Time Shadows
  - Shameless plug ☺




GEARS OF WAR

What's it all about

And some of the following…

- Evolution of graphics hardware
- Perception issues
- Level of detail
- Graphics programming
- Performance techniques
- Shading models
- Terrain rendering

But most importantly..

all of this at 60 frames per second!

Why 60?

- Actually, more might be needed
  - CRT refresh rate!
- Explanation: eye sees double images
- LCDs might have different artifacts (softness, ghosting)
- Also…
  - Multiple displays
  - Stereo rendering

Real-Time Rendering Hardware Development

3DFX Voodoo (1996)

GeForceGTX980

Radeon/Fury/…

Axes of Advancement

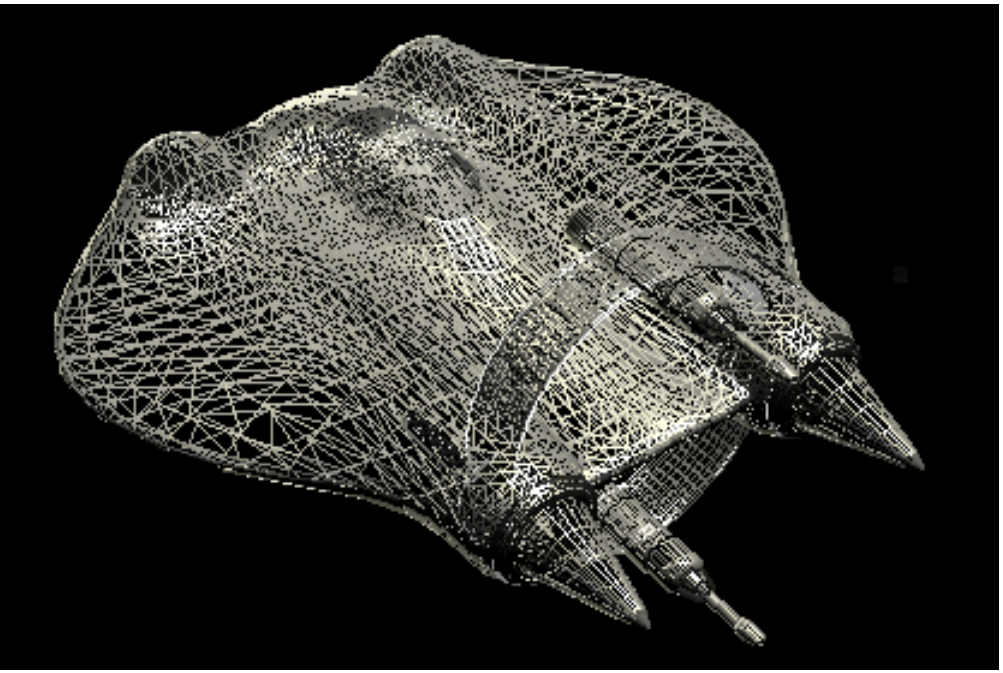
- Performance
  - Triangles / second
  - Pixel fragments / second
  - Shader ops / second
- Features
  - Hidden surface elimination
  - Image (texture) mapping
  - Programmable shading
- Quality
  - Numeric precision (8/10/16 bit, 16/24/32/128 bit FP)
  - Texture filters, antialiasing

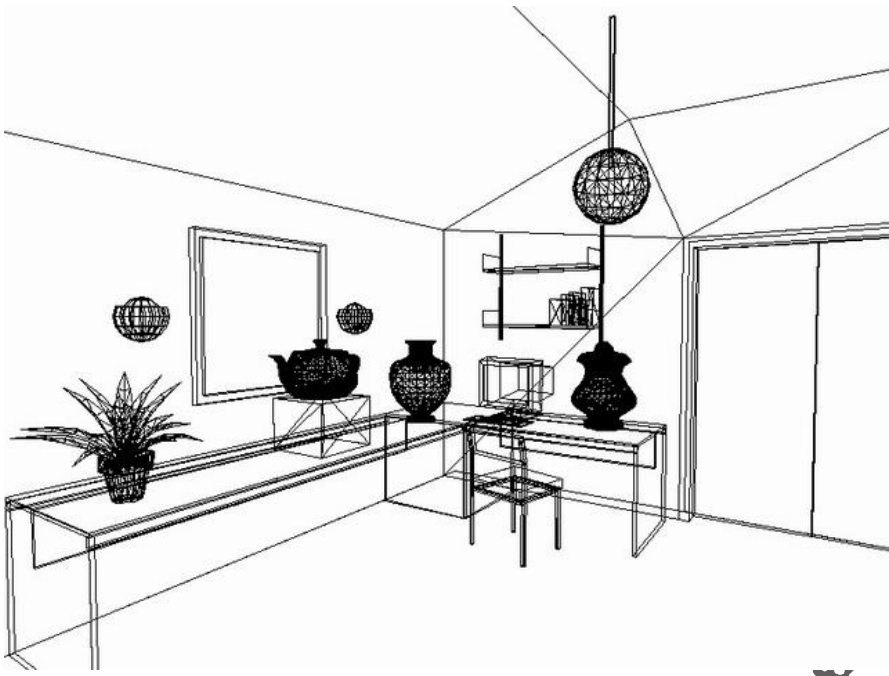
Evolution of Real-Time Graphics

- Some important phases
  - Early research
  - Flight simulation
  - SGI workstations
  - PC
- Hardware generations
  - Different development track for SGI/PC
  - Defined by feature set, but:
  - Any feature can be implemented in hardware
    - Early SGIs: hardware geometry, no texturing
    - Early PCs: hardware texturing, no geometry

First Generation – Wireframe

- Vertex: transform, clip, project
- Pixel: color interpolation of lines
- Frame buffer: overwrite
- When: prior to 1987





Second Generation – Shaded Solids

- Vertex: lighting calculations
- Pixel: depth interpolation, triangles
- Frame buffer: depth buffer, color blending
- Dates: 1987-1992

Third Generation – Texture Mapping

- Vertex: texture coordinate transformation
- Pixel: texture coordinate interpolation
  texture evaluation and filtering
- Dates: 1992-2000

Fourth Generation – Programmable Pipeline

- Programmable shading
  - Vertex shading
  - Pixel shading
  - Geometry shading
  - Tessellation
- Heavily used for other calculations (GPGPU)

Date: 2001-2008

Fourth Generation – Programmability

- Real-time photorealistic rendering kind of possible…

- But a lot of highly specialized methods/fakes
- Realism mostly due to artist tuning/content creation (100 artists, ~3 years for AAA titles)

Fifth Generation – General Programmability

- Starts 2009:
  - IBM: **Cell** (already in use in PS3, though not primarily for graphics)
  - Intel: **Larabee** (16 x86 'mini-cores‘) (-> Xeon Phi)
  - AMD: **Fusion** (CPU+GPU on a chip, low-end)
  - NVIDIA: **CUDA: FERMI, KEPLER, MAXWELL**
- Better surface representations (subdivision surfaces, true displacements, true B-reps)
- Real-time raytracing/pathtracing, radiosity
- Might make many state-of-the-art methods useless!
- **But**: Exciting new research areas!!!

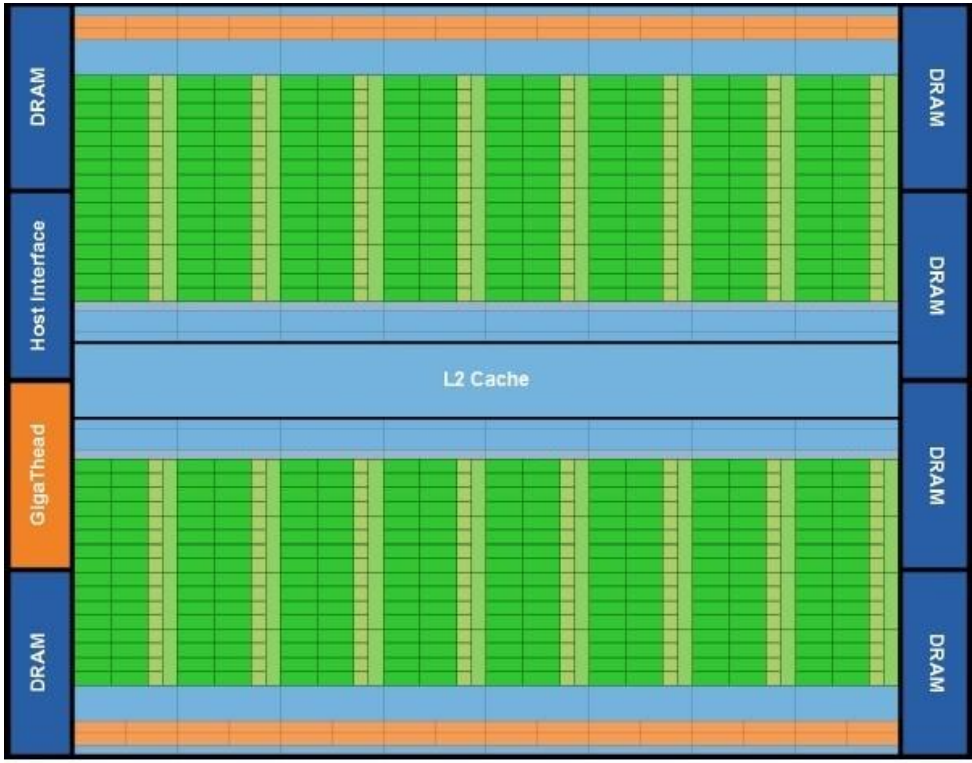
Fifth Generation – Global Evaluation

- Paradigm shift to heterogeneous architectures
  - Merging CPU and GPU on one chip
    - Often seen in mobile GPUs
  - GPU is treated as a parallel streaming PU
- High bandwidth interconnect of CPU and GPU
  - CPU and streaming units working together
- New: algorithm decomposition, dynamic data structures, efficient data structure traversal and adaptive refinement…

- **Good-bye to the one way graphics pipeline!**

Fifth Generation – General Purpose GPU

- Intel Larrabee
  - x86 cores
- NVIDIA Fermi/Kepler/…
  - streaming cores
- Extremely powerful multi-core processors
  - Usually 8-16 cores
  - Optimized for SIMD instructions
  - Synchronized caches for communication
  - C++ programmability

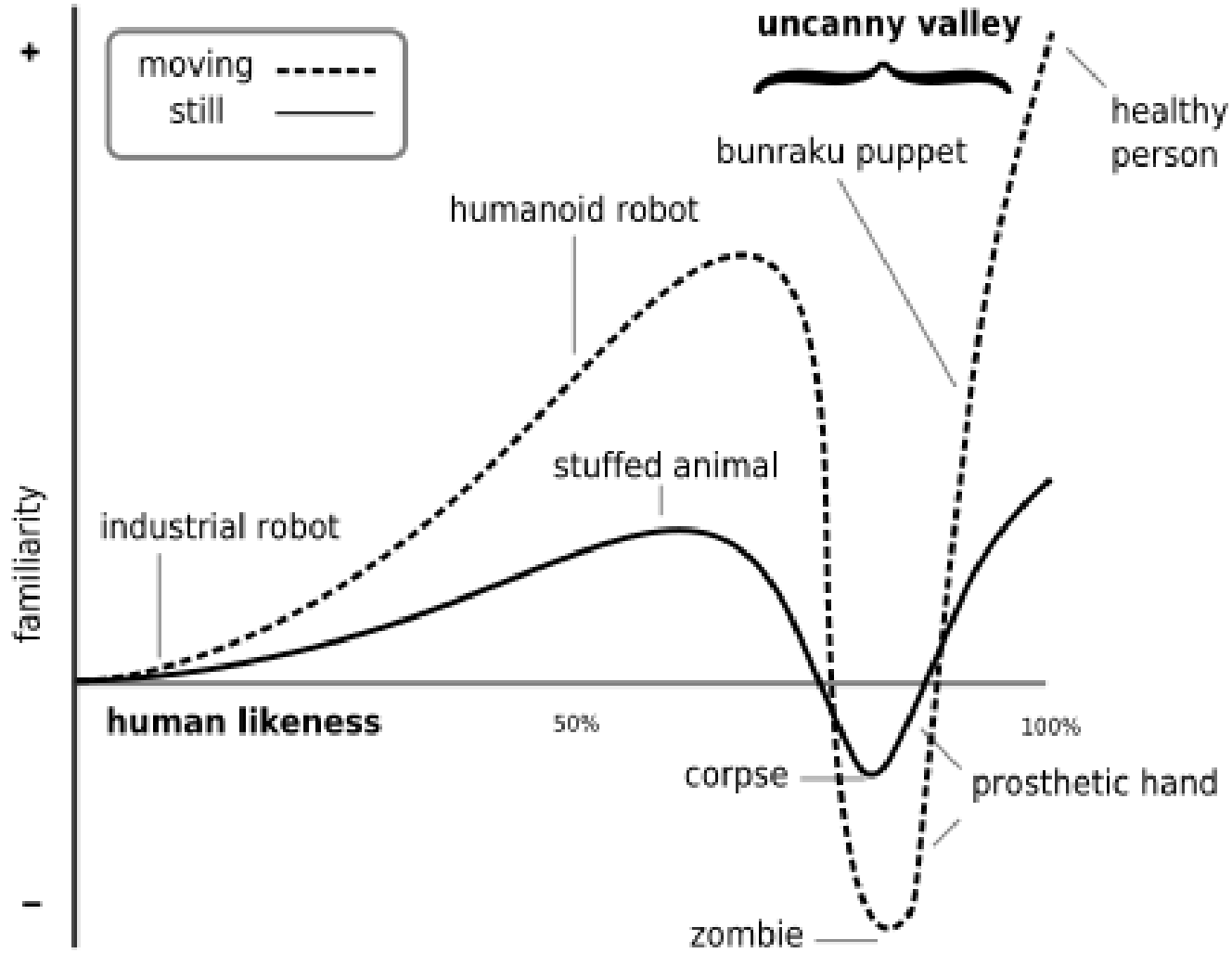


Fermi's 16 SM are positioned around a common L2 cache. Each SM is a vertical rectangular strip that contain an orange portion (scheduler and dispatch), a green portion (execution units), and light blue portions (register file and L1 cache).

Axes of Realism

- Axes of realism:
  - Rendering
  - Content
  - Animation
  - Behavior
- Have to be in equilibrium!
- Current content and animation gap!
- Hard problem: Requires complex simulations/captures or cannot be formulated as equations
- Especially hard for animation (uncanny valley)

Uncanny Valley



Consumer Graphics

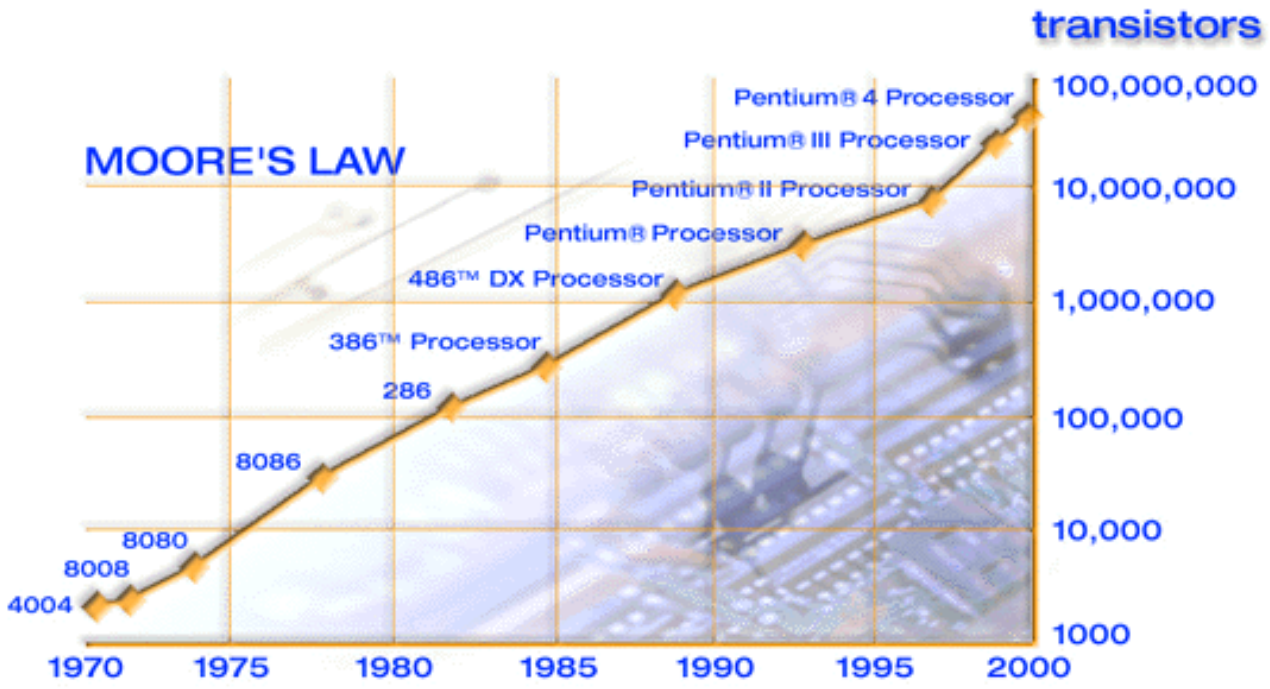
- Started with introduction of 3DFX Voodoo in late 1996
  - First real 3D card (but no 2D)
  - Bilinearly filtered textures
  - No performance hit for texturing
  - 2x performance advantage for over 1 year!
- 3rd generation, minus all vertex capabilities!
- Let's forget about…
  - Matrox Millenium (no textures), S3 Virge (slower than software), NVidia NV-1 (bad architecture)
- Enter NVidia…

Consumer Graphics – Major Points

- Up to 1995
  - 2D only (S3, Cirrus Logic, Tseng Labs, Trident)
- 1995 Scanlines (Proprietary APIs)
- 1996 Trapezium rendering (introduction of DX3)
- 1997 Triangle rendering (… DX5)
- 1998 Triangle setup (…DX6)
- 1999 Multi-Pipe, Multitexture (…DX7)
- 2000 Transform and lighting (…DX8)
  - finally caught up to full 3rd generation!
- 2001 Programmable shaders
  - PCs surpass SGI workstations, 4th generation
- 2002 Full floating point
- 2004 Full looping and conditionals (…DX9)
- 2007 Geometry shaders, more flexible programming model (…DX10)

Moore's Law

- Gordon Moore, 1965
- Exponential growth in number of transistors
- Doubles every 18 months (holds for CPUs)
  - → yearly growth: 1.6
    - Not visible in clock speeds anymore
    - Trend: multiple cores…



Nvidia Development

Season	Product	32-bit AA Fill	Yr rate	MPolys	Yr rate
2H97	Riva 128	20M	-	3M	-
1H98	Riva ZX	31M	2.4	3M	1.0
2H98	Riva TNT	50M	2.6	6M	4.0
1H99	TNT 2	75M	2.3	9M	2.3
2H99	GeForce256	120M	2.6	15M	2.8
1H00	GeForce 2 GTS	200M	2.6	25M	2.8
2H00	Geforce 2 Ultra	250M	1.6	31M	1.5
1H01	GeForce 3	416M	2.5	25M	0.6
2H01	GeForce 3 Ti500	500M	1.4	30M	1.4
1H02	GeForce 4	625M	1.6	75M	6.3
1H03	GeForceFX 5800	1041M	1.7	375M	5
2H03	GeForceFX 5900	938M	0.8	338M	0.8
2H04	GeForceFX 6800	~2500M	2.7	600M	1.8
2H05	GF 7800 GTX	~5000M	2	800M	1.4
	(Cost: 500 Euro)	AVG:	2.1	AVG:	2.4

Nvidia Graphics Card Specifications

8800 GTX (2006)	GTX 280 (2008)	GTX 980Ti (2015)
120 cores	240 cores	2816 cores/22 SMM
single precision	single/double precision	
0.5 TeraFLOPs	1 TeraFLOPs	5,6 TeraFLOPs
37 GigaTexels/sec	48 GigaTexels/sec	176 GigaTexels/s

- As fast as fastest Supercomputer in 1995
- Becoming slower than Moore's law
- Used in HPC parallel computers (CUDA,Tesla)
  - Molecular dynamics, climate simulations, fluid dynamics
  - …everything highly parallel computable
- Speedup 10-100x compared to standard processors

A Note on Peak Numbers…

- Beware peak numbers! Usually less due to:
  - State changes, pipeline stalls
  - CPU/driver issues
  - Non-optimal geometry arrangement
  - Memory bandwidth (for geometry!)
  - Non-trivial transform/lighting
  - Cache inefficiencies
  - Non-trivial shading/texturing
- But may sometimes be larger:
  - e.g.: z/texture compression can help
  - no antialiasing

A Note on Peak Numbers…

- Peak numbers not so relevant nowadays…
- More important considerations:
  - Vertex shader instructions
  - Pixel shader instructions
  - Feature set
  - Quality (antialiasing)
  - Single/Double precision Teraflops