Grundlagen der Spieleprogrammierung

Teil I: 3D-Graphik

Kapitel 8: Hardware

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Outline

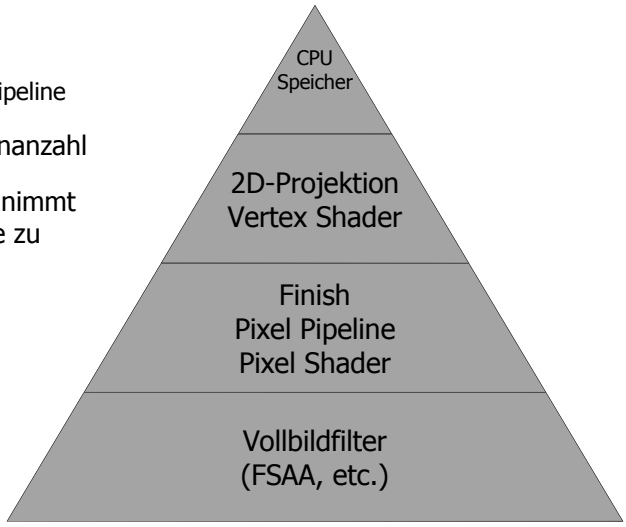
1. Übersicht und Motivation
2. Mathematische Grundlagen
3. Das Ideal: Photorealistisch (Raytracing, Radiosity)
4. Die Realität: DirectX und OpenGL (Übersicht)
5. Schritt 1: Modellierung und Drahtgitter
6. Schritt 2: Texturen
7. Schritt 4: Licht, Filter, etc.
8. Schritt 5: Fortgeschrittene Techniken (Vertex-, Pixel-Shader, …)
9. 3D-Hardware
10. 3D-Engines im Überblick, Cg von nvidia
11. Spielekonsolen
12. Zusammenfassung und Ausblick

Motivation

- Ursprung im professionellen Bereich
  - CAD und Filmentwicklung
  - Random Scan Display Processing Unit
  - Silicon Graphics war Marktführer
  - Ganze Rechner sind „Graphikkarte"
- Siegeszug von 3dfx
  - Beschleuniger-Hardware für den PC
- Aktuelle Firmen
  - nvidia
  - ATI

Umfeld

- 3D-Modell
  - Dreiecke
  - Programmierbare Pipeline
- Erhöhung der Polygonanzahl
- Parallelisierungsgrad nimmt innerhalb der Pipeline zu



Aktuelles im professionellen Bereich

- SGI (2002)

SGI Onyx 3000
InfiniteReality4

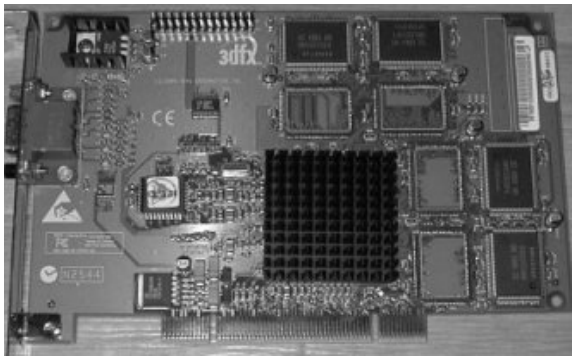
The ultimate solution for the most challenging demands, this system's combination of high-performance computing and advanced visualization provides faster time to insight. This product can scale up to 16 InfiniteReality4 pipelines and up to 128 CPUs with up to 1TB of system memory and 716GB per second of I/O. All of that horsepower can be harnessed to solve one "grand-challenge" class problem or it can be partitioned to support an entire department's computational and graphics needs.

Specs

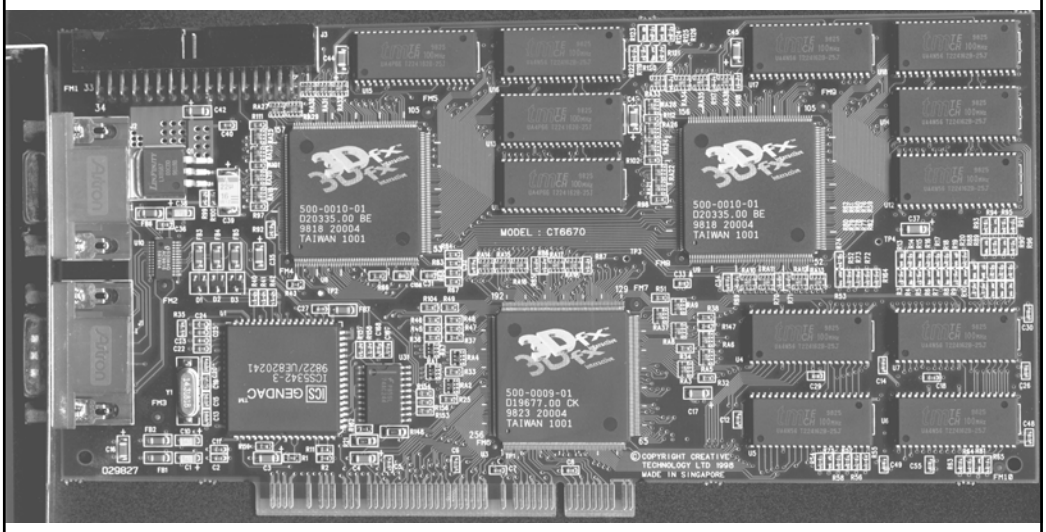
Category	Feature
Architecture	InfiniteReality® with Geometry Engine® processor, Raster Manager, and Display Generator subsystems
Host connection	XIO™ hardware channel--dedicated 1.6Gbyte/sec/pipe
Scalability	1, 2, or 4 Raster Managers
Texture memory	1Gbyte of dedicated 2D/3D texture memory/pipe
Frame Buffer	2.5Gbytes of dedicated frame buffer per Raster Manager, up to 10Gbytes/pipe
Display resolution	Up to 8.3M pixels/pipe and 65M pixels/system
Display	2-channel RGBHV output, one S-Video output, genlock with internal or external sync, hardware swap synchronization for multiple graphics pipes
Display options	6 additional RGBHV output channels (8 total), high-definition and standard-definition graphics-to-video output with real-time colorspace conversion, digital-video multiplexer, hardware-in-the-loop interface
Anti-aliasing	True 4 or 8 subsample full-scene anti-aliasing selected from a 64-element grid with per-pixel samples variations to maximize image quality
Color fidelity	48-bit RGBA for up to 68 billion colors
Stereo	Quad-buffered active and passive stereo with stereo emitter connections
Image-based rendering	Eyepoint-independent photo-realistic rendering
Clip-mapping	Hardware-accelerated clip-mapping
Volume rendering	Interactive volume rendering using texture lookup tables and 1Gbyte volumes from texture memory or unlimited volume sizes when paged from system memory or disk
Imaging	Hardware-accelerated convolutions

3dfx

- Siegeszug beginnt mit der Voodoo 1 (1996)
  - 50 MHz Taktfrequenz
  - 2 bis 4 MByte Videospeicher
- Voodoo 2 (1998)
  - Träume werden wahr
- Voodoo 3 und danach wenig erfolgreich
- nvidia kauft 3dfx (Nov 2000)



3dfx Voodoo 2

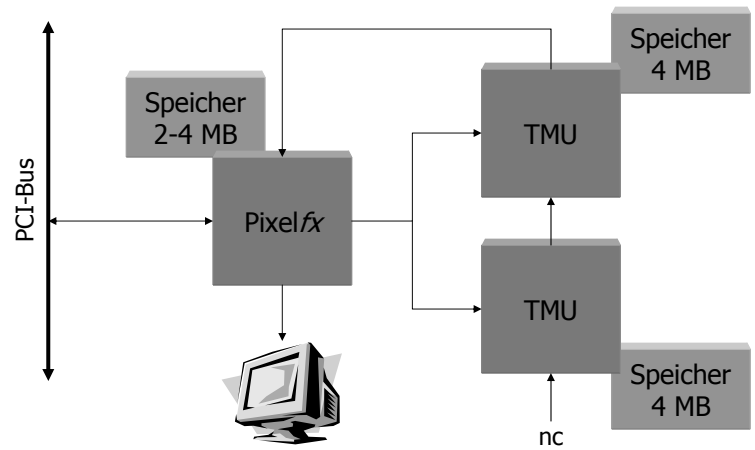


3dfx Voodoo 2: Zahlen

- 2-4 Prozessoren pro Karte
  - 1 Pixelprozessor
  - 1-3 Texturprozessoren
  - 90 MHz Taktfrequenz
- 12-16 Mbyte Speicher
  - 2.1 Gbyte Speicherbandbreite (intern)
- Leistungsdaten
  - 3 Millionen Dreiecke/s (gemessen: 25 Pixel Dreiecke)
  - 90 Mpixel/s
  - 180 Mpixel/s im Doppelpack (SLI)
- Maximal 1024x768 Pixel Auflösung
- 24 Bit Farben (Ausgabe 16 Bit Dithered)
- 16 bpp Z-Buffer

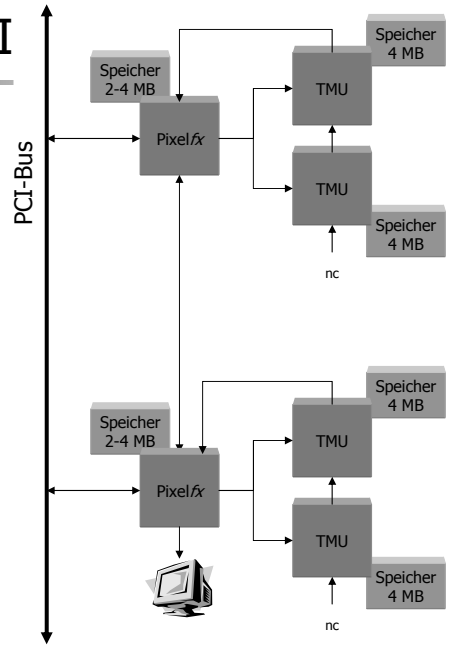
3dfx Voodoo 2: Architektur

- Ziel: Möglichst viele Operationen pro Pixel in einem Zyklus

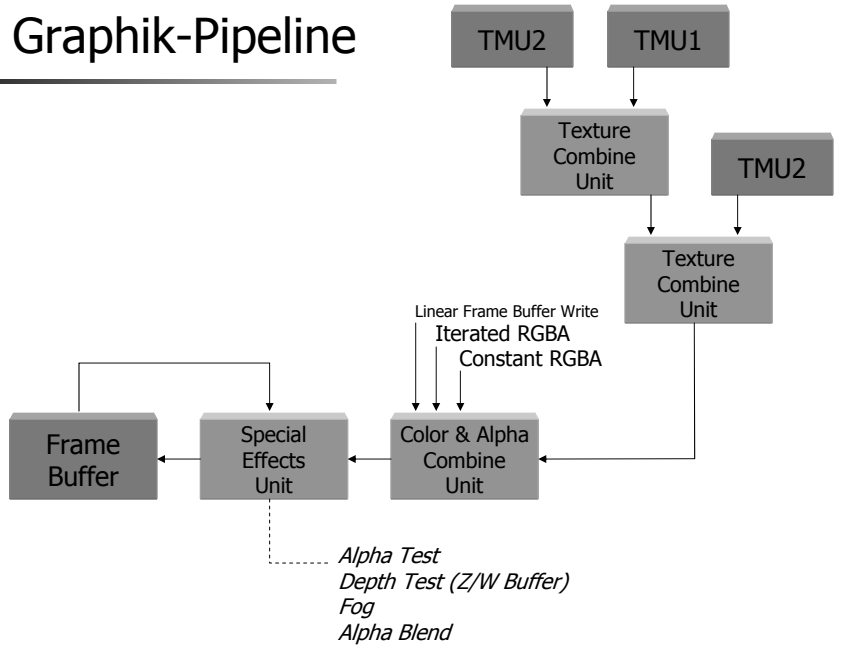


3dfx Voodoo 2: SLI

- Scan Line Interface
  - Gerade Zeilen
  - Ungerade Zeilen
- 2 PCI-Slots
- „Traum jedes Spielers"
  - Schnell
  - Vergleichsweise Teuer

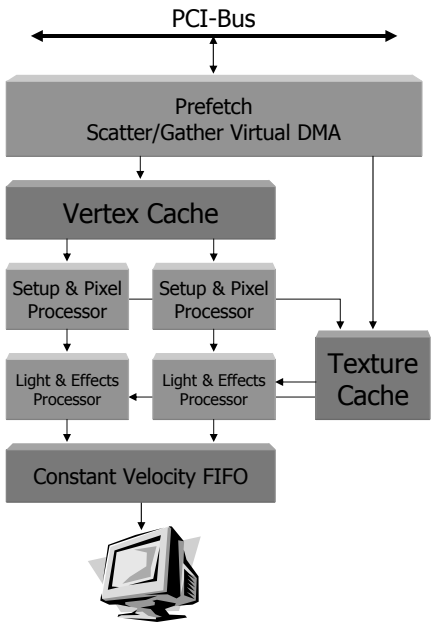


Die Graphik-Pipeline



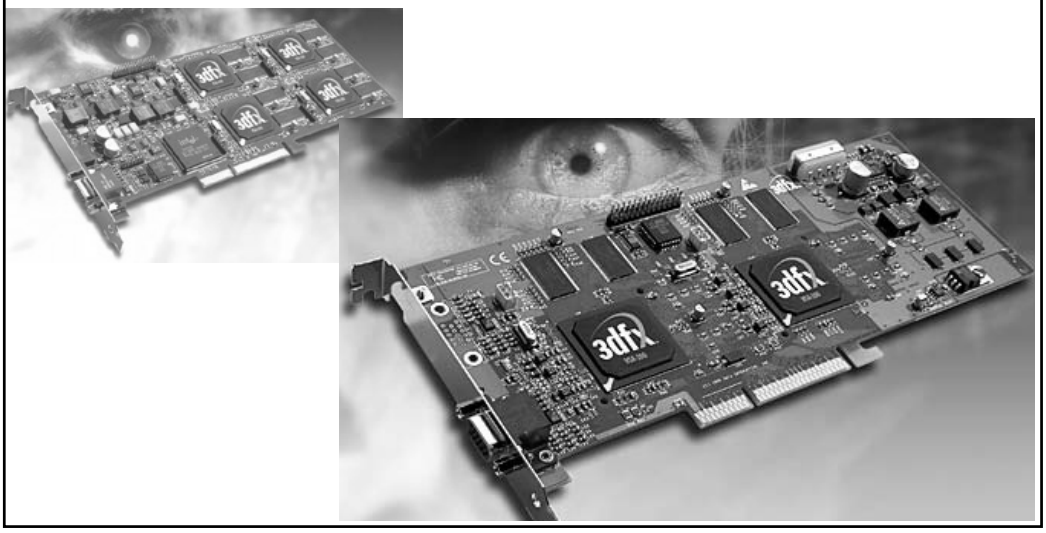
nVidia RivaTNT

- 1 Prozessor
  - 90 Mhz Taktfrequenz
  - 7 Millionen Transistoren
  - 12 Kbyte Cache
- 16 Mbyte Speicher
  - 128 Bit Speicherbreite
  - 1.8 Gbyte Speicherbandbreite
- Leistungsdaten
  - 6 Millionen Dreiecke/s
  - 180 Mpixel/s Füllrate
- Maximal 1920x1200 Auflösung
- 24 Bit Farben
- 16/24 bpp Z-Buffer



3dfx Voodoo 3 und danach

- 3dfx ist seiner Zeit voraus und wird zu ambitioniert

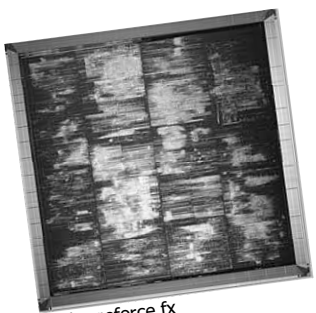


GPUs (Anfang 2003)

	ATI Radeon 9700 PRO	NVIDIA GeForce4 Ti4800	NVIDIA GeForceFX 5800	NVIDIA GeForceFX 5800 Ultra
Chip Technology	256-bit	256-bit	256-bit	256-bit
Process	0.15 Micron	0.15 Micron	0.13 Micron	0.13 Micron
Transistors	~107 Million	63 Million	125 Million	125 Million
Memory Bus	256-bit DDR	128-bit DDR	128-bit DDR2	128-bit DDR2
Memory Bandwidth	19.8 GB/s	10.4 GB/s	12.8 GB/s	16 GB/s
Pixel Fillrate	2.6 Gigapixel/s	1.24 Gigapixel/s	~3.2 Gigapixel/s	~4 Gigapixel/s
Anti Aliased Fillrate	15.6 Billion AA Samples/s	4.8 Billion AA Samples/s	~12.8 Billion AA Samples/s	~16 Billion AA Samples/s
Max FSAA Mode	6x	4x	8x	8x
Triangle Transform Rate	325 M Triangles/s	69 M Triangles/s	280 M Triangles/s	350 M Triangles/s
AGP Bus	1x/2x/4x/8x	1x/2x/4x/8x	1x/2x/4x/8x	1x/2x/4x/8x
Memory	128/256MB	128MB	128/256MB	128/256MB
GPU Clock	325 MHz	300 MHz	~400 MHz	~500 MHz
Memory Clock	310 MHz (620 DDR)	325 MHz (650 DDR)	400 MHz (800 DDR2)	500 MHz (1000 DDR2)
Memory	BGA 2.9 ns	BGA 2.8ns	?	BGA 2.0ns
Vertex Shader	4	2	FP Array	FP Array
Pixel Pipelines	8	4	8	8
Texture Units Per Pipe	1	2	1	1
Textures per Texture Unit	8	4	16	16
Vertex S. Version	2	1.1	2.0+	2.0+
Pixel S. Version	2	1.3	2.0+	2.0+
DirectX Generation	9	8	9.0 (+)	9.0 (+)
FSAA Modi	MultiSampling	MultiSampling	MultiSampling	MultiSampling
Memory Optmizations	Hyper Z III	LMA II	LMA II Optimized Color Compression	LMA II Optimized Color Compression
Display Outputs	2	2	2	2

Aktuelle GPUs (2003)

	ATI Radeon 9800 PRO	NVIDIA GeForceFX 5800 Ultra	NVIDIA GeForceFX 5900 Ultra
Chip-Technologie	256 Bit	256 Bit	256 Bit
Prozess	0.15 Micron	0.13 Micron	0.13 Micron
Transistors	~107 Million (?)	125 Million	130 Million
Speicherbus-Weite	256 Bit DDR/DDR2	128 Bit DDR2	256 Bit DDR
Speicherbandbreite	21.8 GB/s	16 GB/s	27.2 GB/s
Pixel Fillrate	3.04 Gigapixel/s	- Texelrate (Color+Z): 2000 texel/s - Z-rate (Z): 4000/s - Stencilrate: 4000/s - Texturerate: 4000/s	- Texelrate (Color+Z): 1800 texel/s - Z-rate (Z): 3600/s - Stencilrate: 3600/s - Texturerate: 3600/s
Anti Aliased Fillrate	18.2 Billion AA Samples/s	~16 Billion AA Samples/s	~27.2 Billion AA Samples/s
Max FSAA Mode	6x	4x	4x
Triangle Transform Rate	380 M Triangles/s	350 M Triangles/s	315 M Triangles/s
AGP-Bus	1x/2x/4x/8x	1x/2x/4x/8x	1x/2x/4x/8x
Speicherbestückung	128/256MB	128/256MB	128/256MB
Chiptakt	380 MHz	500 MHz	450 MHz
Speichertakt	340 MHz (680 DDR)	500 MHz (1000 DDR2)	425 MHz (850 DDR)
Speichermodule	?	BGA 2.0ns	BGA 2.0ns
Vertex Shader	4	FP Array	FP Array
Pixel Pipelines	8	4 for color & Z 8 for z 8 for stencil 8 for texture	4 for color & Z 8 for z 8 for stencil 8 for texture



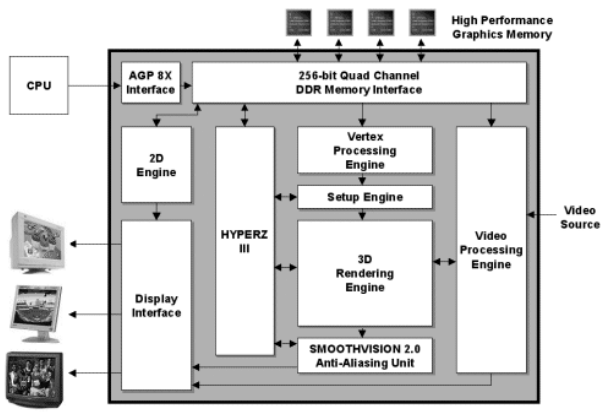
nvidia geforce fx

	ATI Radeon 9800 PRO	NVIDIA GeForceFX 5800 Ultra	NVIDIA GeForceFX 5900 Ultra
Texture Units Per Pipe	1	1	1
Textures per Texture Unit	8	16	16
Vertex S. Version	2	2.0+	2.0+
Pixel S. Version	2	2.0+	2.0+
DirectX Generation	9	9.0 (+)	9.0 (+)
FSAA Modi	MultiSampling	MultiSampling	MultiSampling
Memory Optmizations	Hyper Z III+	LMA II Optimized Color Compression	LMA II Optimized Color Compression
Optimierungen	SmartShader 2.1 SmoothVision 2.1	IntelliSample	IntelliSample HCT
Bildschirmanschlüsse	2	2	2
Chip-interne Ramdacs	2 x 400 MHz	2 x 400 MHz	2 x 400 MHz
externe Ramdacs	-	-	-
Bits per Color Channel	10	10	10
Besonderheiten	TV Encoder On-Chip; FullStream Adaptive Filtering F-Buffer	TV Encoder On-Chip Extended Progammability Adaptive Filtering	TV Encoder On-Chip Extended Progammability Adaptive Filtering UltraShadow
Voraussichtlicher Preis	$399/€399	$399/€399	$399/€399

Trends

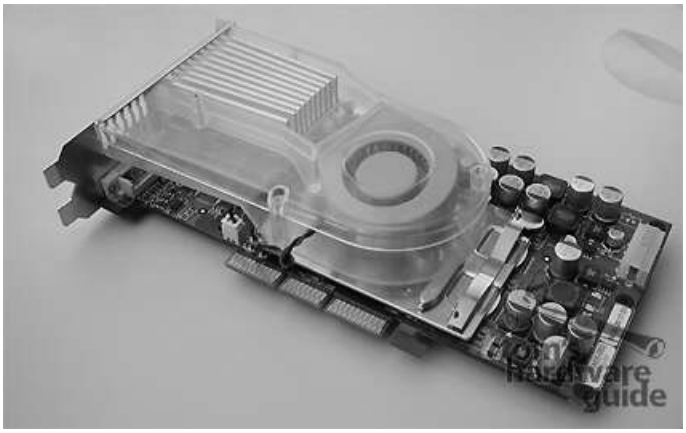
- Anzahl der integrierten Pixel-Pipelines wächst
- CPU-Interface beschleunigen (AGP 8fach)
- Sehr breiter Speicherbus
  - 256 Bit gängig
  - Eklat nvidia mit 128 Bit ganz schnellem Speicher
- Mehr Gags

ATI Radeon 9800



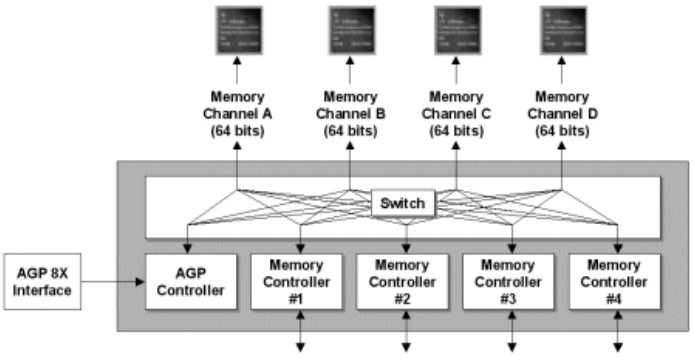
Flop 2003: nVidia NV30

- Extreme Wärmeentwicklung
  - Spezielles Lüfterdesign (Föhn)
  - nVidia: „Lautstärke kein Problem. Power Games spielen allemal mit Kopfhörer"



Speicher-Interface

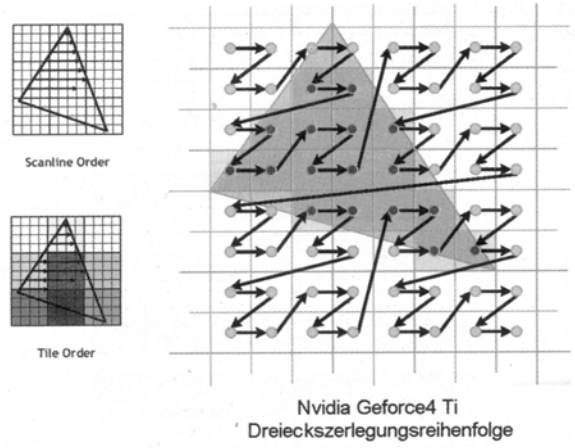
- Beschleunigungsansätze
  - Breiter Speicherbus
  - Höher Takten
  - Parallelisieren (Crossbar-Switch)



ATI Radeon 9800

Cache-Problematik

- Chips verwenden interne schnelle Textur-Caches
  - Zeilenorientierte Umsetzung (Z-Buffer) ist ungünstig



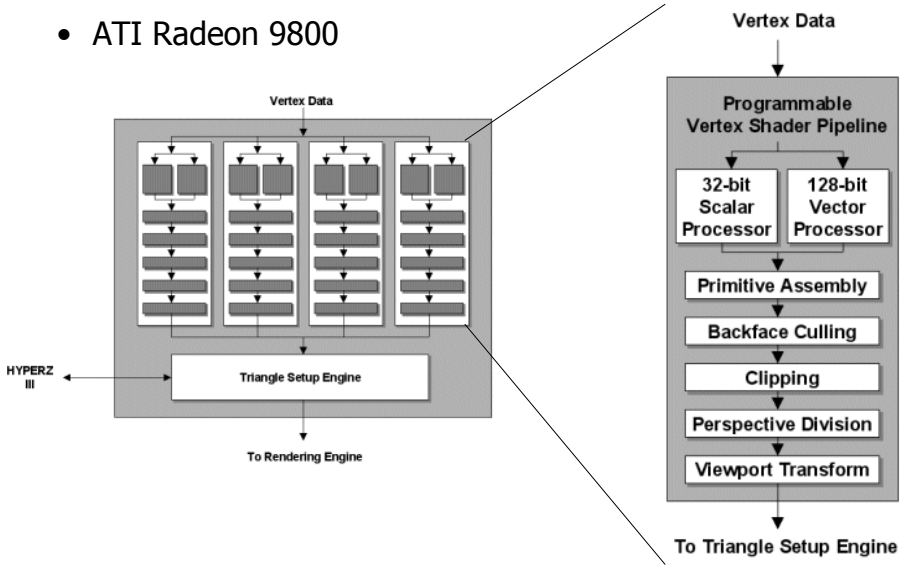
Vertex- und Pixel-Shader

- Mehr und Besser

	DX8.0	DX8.1	DX9
Higher Order Surfaces	Yes	Yes	Yes
N-Patches (TruForm)	Yes	Yes	Yes
Continuous Tessellation	No	No	Yes
Displacement Mapping	No	No	Yes
Vertex Shaders	1.1	1.1	2.0
Max. Instructions	128	128	1024
Max. Constants	96	96	256
Flow Control	No	No	Yes
Pixel Shaders	1.1	1.4	2.0
Texture Maps	4	6	16
Max. Texture Instructions	4	8	32
Max. Color Instructions	8	8	64
Data Type	Integer	Integer	Floating Point
Data Precision	32 bits	48 bits	128 bits

Vertex Shader

- ATI Radeon 9800



Pixel Shader

- ATI Radeon 9800