Composition and features of graphics cards

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History of graphics cards

- MDA (Monochrome Display Adapter) – 1981 *IBM*
- CGA (Color Graphics Adapter) – 1981 *IBM*
- HGC (Hercules Graphics Card) – 1982 *HCT* pre *IBM*
- EGA (Enhanced Graphics Adapter) – 1984 *IBM*
- VGA (Video Graphics Array) – 1987 *IBM* PS/2
- SVGA (Super Video Graphics Array) – 1989

- XGA (1024×768)
  SXGA (1280×1024)
  UXGA (1600×1200)
  QXGA (2048×1536)
  …
  WHUXGA (7680×4800)

History of graphics cards (according to their functions)

- 1981 MDA (*IBM*) – text mode only
- 1981 CGA (*IBM*) – first graphics card, 4 colors with 2 LUT
- 1984,87 EGA/VGA (*IBM*) – 16/256 colors, workings with LUT
- 1990 (*Tseng*) – paging, zoom, scroll, windows
- 1991 (*S3, Tseng*) – acceleration of Windows (bitmaps, 2D)
- 1994 (*Tseng*, *S3, CL*) – video acceleration (MPEG)
- 1996 (...) – 3D graphic implementation (textures), slow
- 1996 (*3dfx*) – better 3D acceleration, 2D card was also needed
- 1997 (*nVidia*) – DirectX & OpenGL implementation
- 1998 (*3dfx*) – more than one GPU, SLI introducing
- 1999 (*nVidia*) – Transform & Lighting implementation

History of graphics cards (according to their functions)

- 2000 (*3dfx, ...*) – fullscreen antialiasing
- 2001 (*nVidia*) – programmable vertex and pixel shader
- 2002 (*Ageia*) – physics (particle systems, dynamics)
- 2008 (*nVidia*) – CUDA, parallel computations
- 2008 (*AMD, nVidia, Intel, ...*) – OpenCL, parallel computations
- 2013 (*nVidia*) – GameWorks = realtime effects SDK for:
  VisualFX (face, hair, wave, flow, shadows, …)
  PhysX (physics, destruction, particle, fluid simulations)
  OptiX (ray tracing)
- 2013 (*AMD*) – TressFX Hair (realtime hair dynamics)
- 2014 (*nVidia*) – Turf Effects (simulate and render massive grass simulations with physical interaction) is part of VisualFX
- 2015 (*AMD*) – GPUOpen open-source GameWorks alternative
- 2018 (*nVidia*) – Real-Time Ray Tracing

History of graphics cards

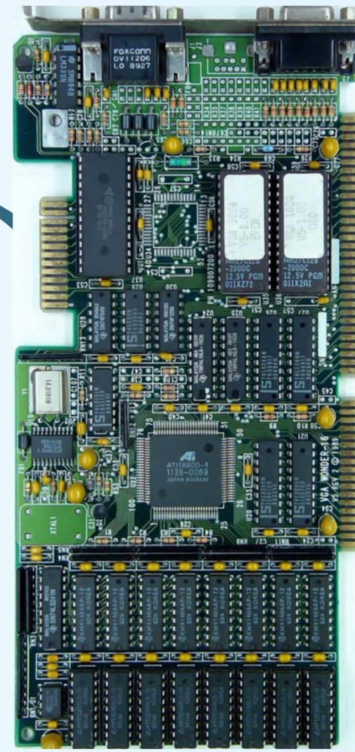
	Year	Resolution	Number of colors	Memory
MDA	1981	-	2	4 kB
HGC	1981	720×348	2	4 kB
CGA	1982	640×200	4	16 kB
EGA	1984	640×350	16	256 kB
VGA	1987	640×480	256	256 kB
SVGA	1989	800×600	256	512 kB
XGA	1990 1991	1024×768	65536 16777216	2048 kB 4096 kB

History of graphics cards

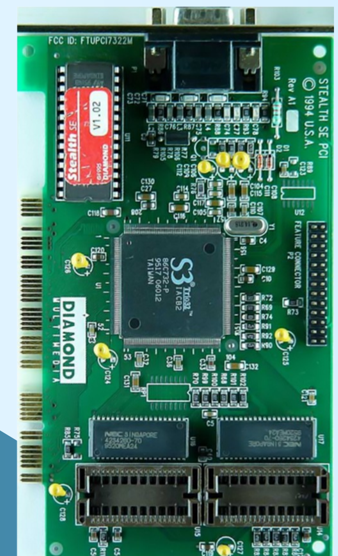
CGA 1984
IBM EC 429

EGA 1986
Prisma PEGA

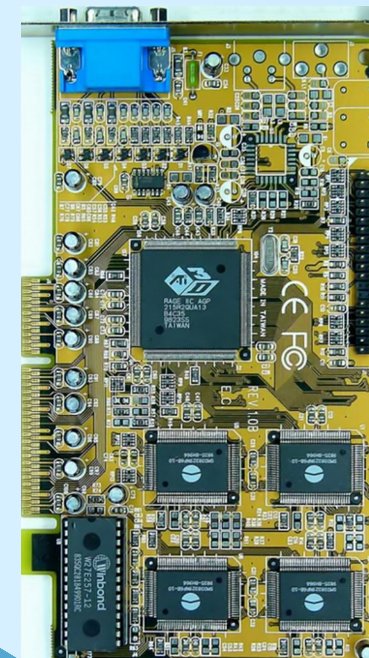
VGA 1989
ATI Wonder



SVGA 1994
S3 Trio32



SVGA 1998
ATI 3D Rage



… and present (in figures)

2003 ATI Radeon 9800

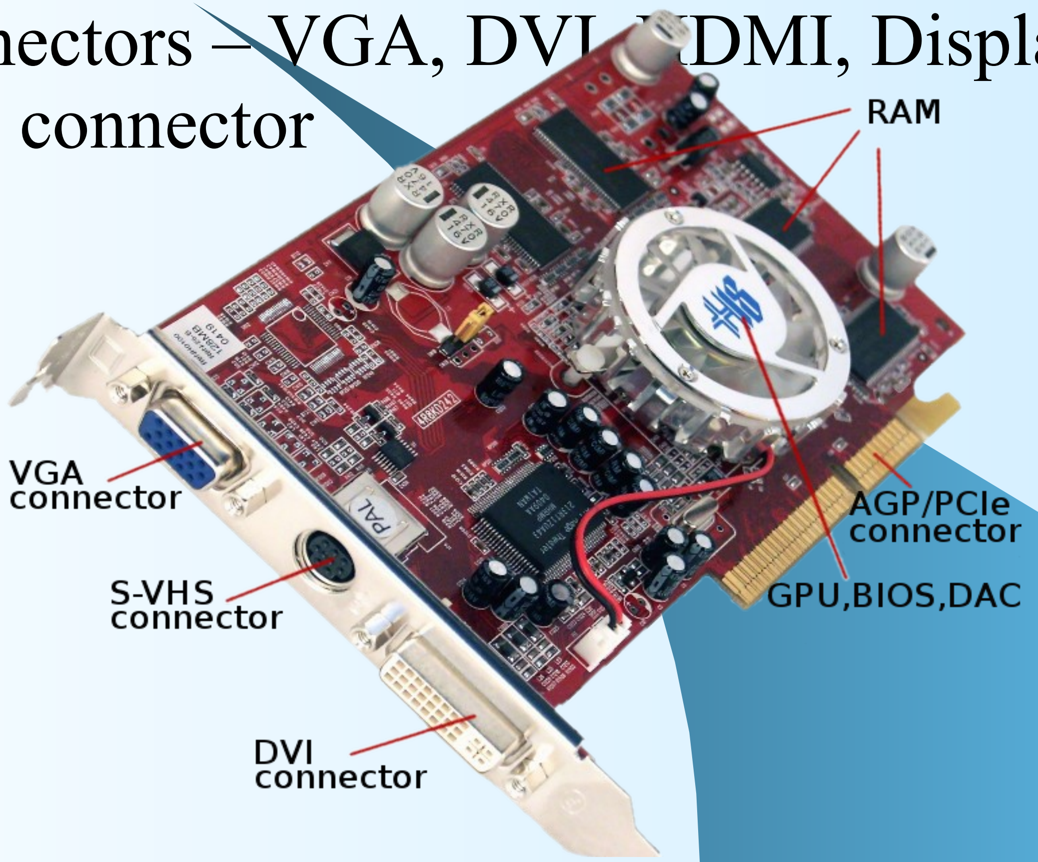
2003 nVidia GeForce FX5200

2018 AMD Radeon™ RX 580X

2018 nVidia Gforce GTX 1080

Graphics card structure

- Processor – GPU (Graphics Processing Unit)
- Video BIOS (Basic Input Output System)
- Videomemory – RAM (DDR, GDDR)
- RAMDAC (Digital-to-Analog Converter)
- Video connectors – VGA, DVI, HDMI, Display port
- AGP, PCIe connector



Graphic card features

- Working with bitmaps, 2D graphics, windows acceleration
- Video acceleration
- 3D graphics: transformation & lighting
- Working with textures – texture mapping
- Texture filtering (bilinear, anisotropic, …) layer textures, bump mapping, etc.
- Determining visibility (z-buffering)
- Transparency, application of fog (alpha blending, fog)
- Picture smoothing (antialiasing)
- Working with shadows (shadow mapping, soft shadows)
- HD video acceleration
- Programmable pixel and vertex shader
- Physical simulations, particle systems, body collisions, ...

Working with bitmaps, 2D graphics and video acceleration

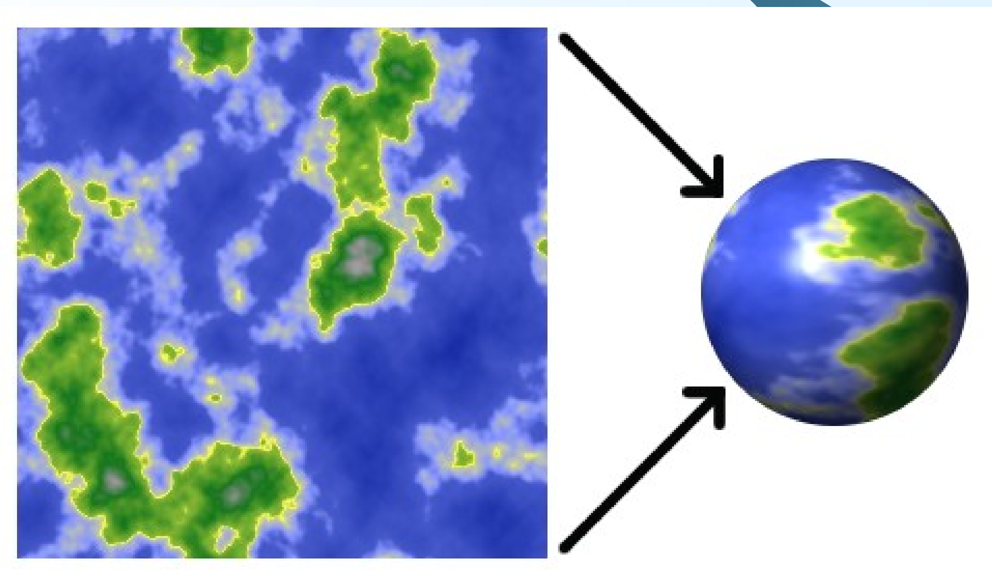
- **Basic bitmap operations**:
  copy, move (bitblt), mask,
  AND, OR, XOR, …
  HW drawing of mouse and small bitmaps.
- **Basic Operations in 2D Graphics**:
  2D primitives rasterization (line, curve, polygon, text, ...), clipping with respect to a window.
- **Video acceleration**:
  decompression, interpolation, IDCT, image scaling, trimming, copying to buffer frame, conversion between YCbCr and RGB color models.

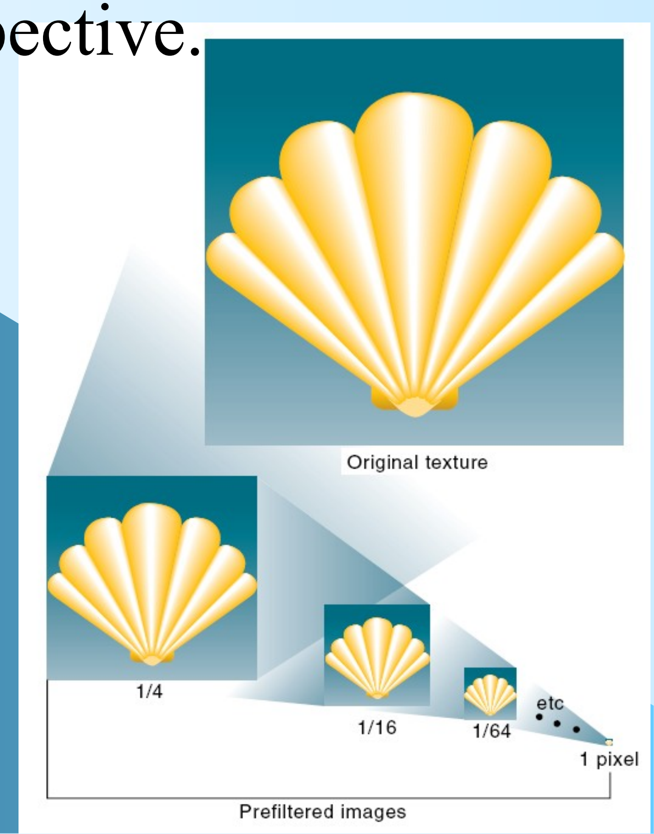
3D transformations & lighting

- 3D transformations:
  world coordinates to camera coordinates transformation, clipping and 3D to 2D projection.
- Transformation often involves *tessellation* and removal of invisible polygons (occlusion culling).
- In lighting, the object colors are calculated for the actual location of the lights and the camera in the scene. *Phong illumination* model and *Gouraud* or *Phong shading* are commonly used.

Texture mapping

- Mapping means transformation of texture pixels to the object surface. For 3D textures, the transformation is also applied to the inside of the object.
- Mip mapping is often used to remove the artifacts of the displayed textures when using a perspective.



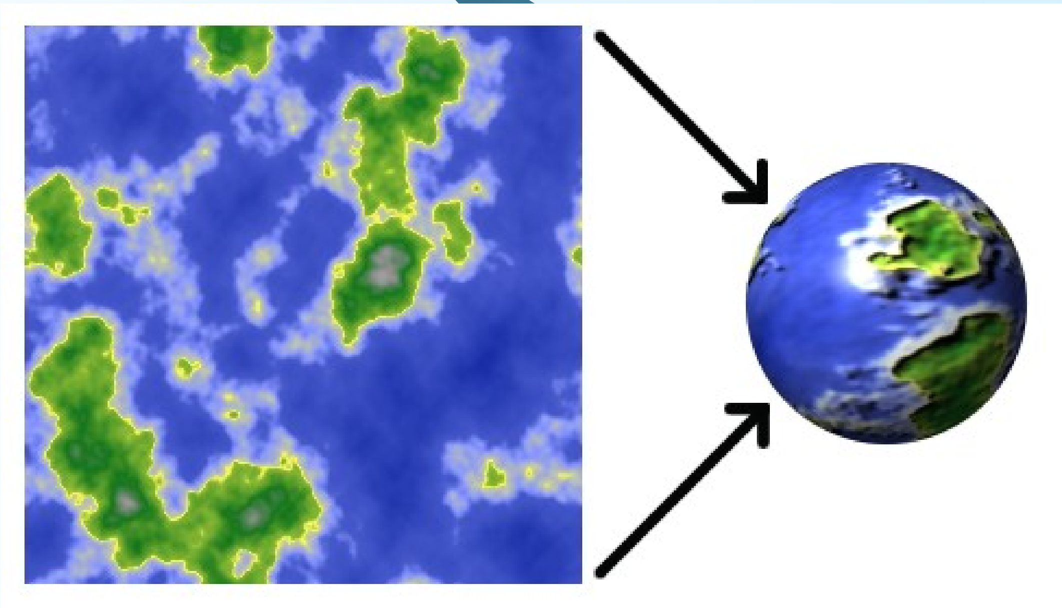


Texture filtering

- Removes the aliasing effect that occurs when applying small textures to a large object.
- Can be used either a simple *bilinear* or *trilinear* filter or *anisotropic filtering*.

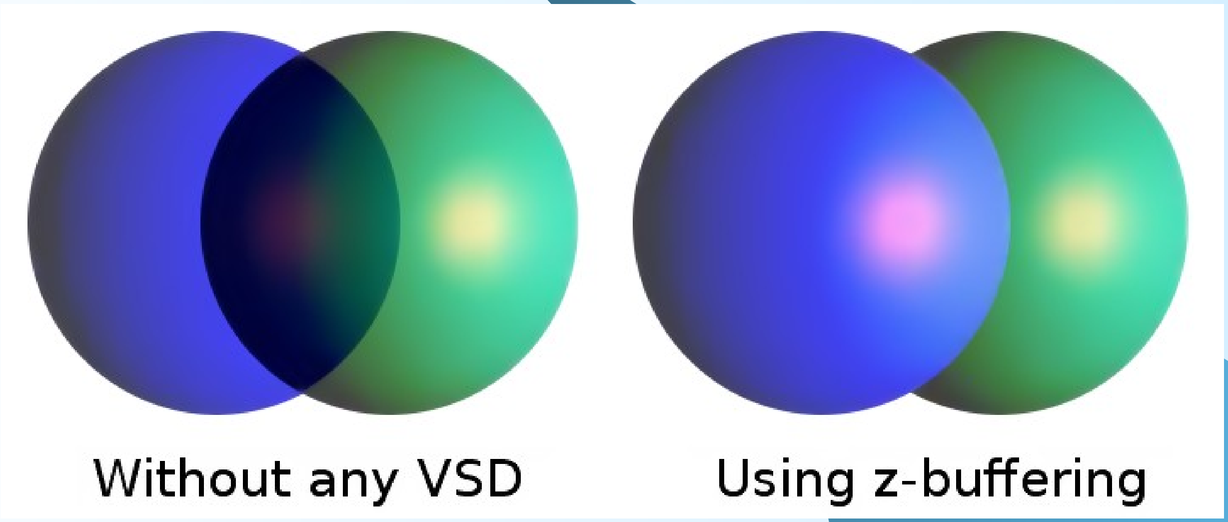
Bump mapping

- It gives the objects a more realistic look.
- It creates a visually uneven surface on objects that are completely smooth.
- It uses the prepared height map that is applied to the texture.



Determining visibility

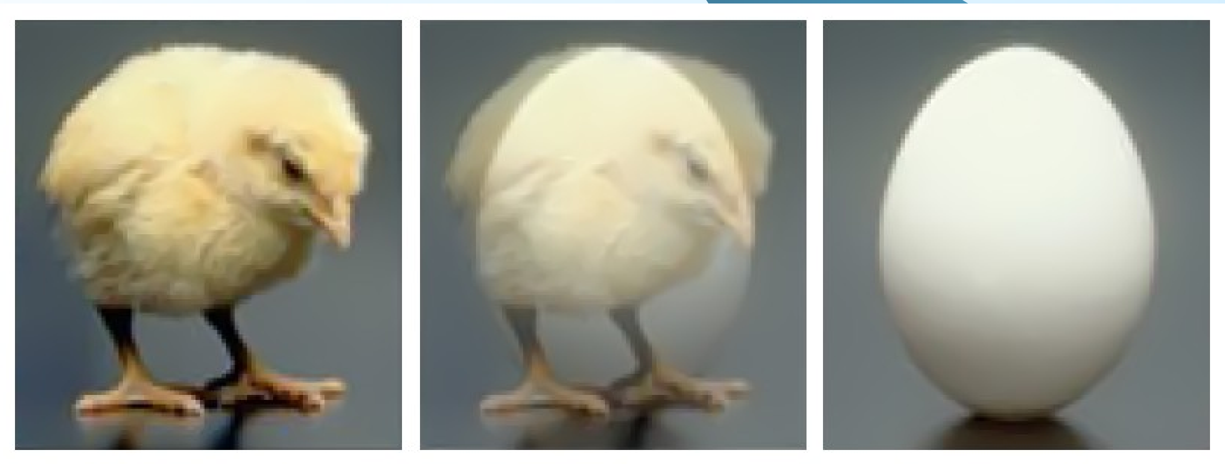
- To determine visibility, the *z-buffering* method is most commonly used.
- It is very simple. It uses only the storage of the *z*-coordinates of the calculated pixels of the scene objects and the comparison with the previous value in the buffer.



Transparency and application of fog

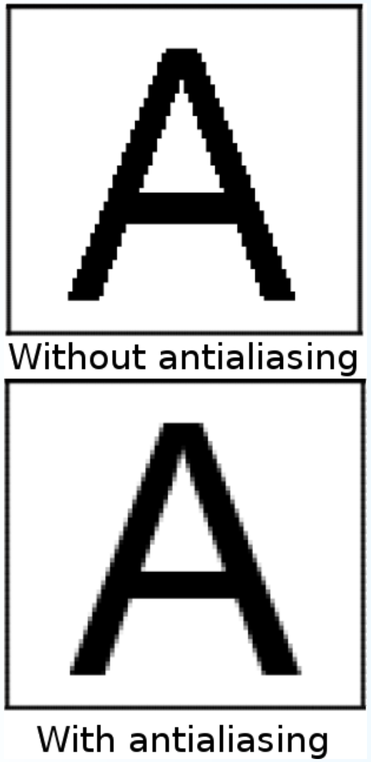
- It creates more realistic scenes.
- Object pixels must have a transparency value in addition to color – α value. This value determines how the point is translucent.
- Most commonly used formula for calculating the resulting pixel value:

$$[r,g,b] = \alpha[r,g,b]_{foreground} + (1-\alpha)[r,g,b]_{background}$$



Antialiasing

- Removes image artifacts – “jagged effect”.
- Most often, it is resolved by *super sampling*. Currently, the *quincunx* supersampling method is almost used.
- Fullscreen, high-resolution antialiasing is a relatively time-consuming operation.



Advanced functions

- Precomputed shadows (shadow mapping).
- Precomputed ilumination (per pixel lighting).
- Precomputed environment texture (environment mapping).
- Multitextures – combination of multiple textures (bump map, light map, environment map, ...).
- Smooth texture blending (texture blending).
- Texture compressing.
- 4k video acceleration.
- Programmable pixel, vertex, and geometry shader.
- *CUDA, OpenCL* – parallel computing on the GPU.
- *VisualFX* – rendering effects such as smoke, fire, water, depth of field, soft shadows, etc.
- *PhysX* – physical simulations: particle systems, objects collision, objects and fluid dynamics, hair and cloth simulation, object decay…
- *OptX* – ray tracing computation.
- Volume rendering.