SIGGRAPH2007

The Mobile 3D Ecosystem

SIGGRAPH2007

Kari Pulli	**Nokia Research Center**
Jani Vaarala	**Nokia**
Ville Miettinen	**NVIDIA**
Robert Simpson	**AMD**
Tomi Aarnio	**Nokia Research Center**
Mark Callow	**HI Corporation**

Today's program: Morning

- Start at 8:30
- Intro & OpenGL ES overview
  45 min, Kari Pulli
- Using OpenGL ES 1.x
  50 min, Jani Vaarala
- OpenGL ES on PyS60
  10 min, Kari Pulli
- Break 10:15 – 10:30
- OpenGL ES performance considerations
  45 min, Ville Miettinen
- OpenGL ES 2.0
  60 min, Robert Simpson
- N95 raffle
- Break 12:15

Today's program: Afternoon

- Start at 13:45
- M3G Intro
  10 min, Kari Pulli
- M3G API overview
  65 min, Tomi Aarnio
- M3G in the Real World 1
  30 min, Mark Callow
- Break 15:30 – 15:45
- M3G in the Real World 2
  60 min, Mark Callow
- M3G 2.0
  30 min, Tomi Aarnio
- Closing & Q&A
  15 min, Kari Pulli
- N95 raffle
- Finish at 17:30

Course Evaluations

http://www.siggraph.org/courses_evaluation

4 Random Individuals will win an ATI Radeon^{tm} HD2900XT

N95 raffle

2 Random Individuals will win a Nokia N95

- OpenGL ES 1.1 and M3G 1.1 HW
- 5 Megapixel camera
- GPS, mapping
- MP3 player
- W-LAN
- …

Put a card with name, affiliation, and feedback to a box, one phone is raffled in the morning session, one in the afternoon.

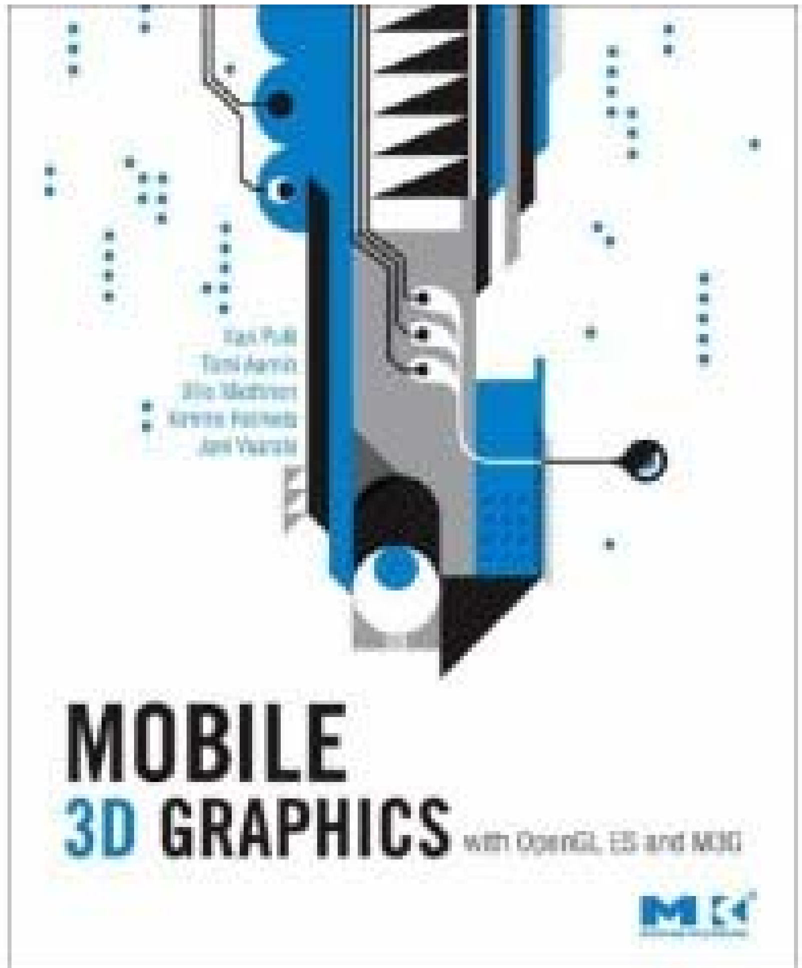
NOKIA
Connecting People

Special Issue of IEEE CGA: Mobile Graphics

- The July-August 2008 issue, the abstracts are due Oct 31, 2007. We are looking for research or system papers in any areas of mobile graphics, including:
    - Mobile gaming
    - Graphics hardware
    - User interface toolkits and design tools
    - Augmented reality
    - Interaction design
    - Input techniques and technologies
    - Multimodal interfaces (such as speech, haptics, and sensors)
    - Programming languages and file formats (such as vector graphics)
    - Software architectures and service approaches
    - Visualization on small displays
    - Adapting multimedia to mobile clients
    - Techniques for rendering and browsing the Web
    - Design principles for information presentation
    - Research into particular domains (health care, developing world)

Mobile 3D Graphics: with OpenGL ES and M3G

- Book on mobile 3D APIs coming out soon
- Pulli, Vaarala, Miettinen, Aarnio, Roimela
- Can already pre-order from Amazon
- Morgan Kaufmann booth should have more information



Evolution of the Computer

Mainframe computer

Mini computer

Personal computer

Laptop computer

Multimedia Computer

Pervasive Mobile Computing

- Mobile phones are the largest and fastest growing market - ever
  - The largest ever market opportunity for the graphics industry
- Handsets are becoming personal computing platform
  - Not “just” phones: A real computer in your hand
- Sophisticated media processing is a key
  - Just like it has been on the PC
  - Games are one of the first handheld media applications

Current expectation:

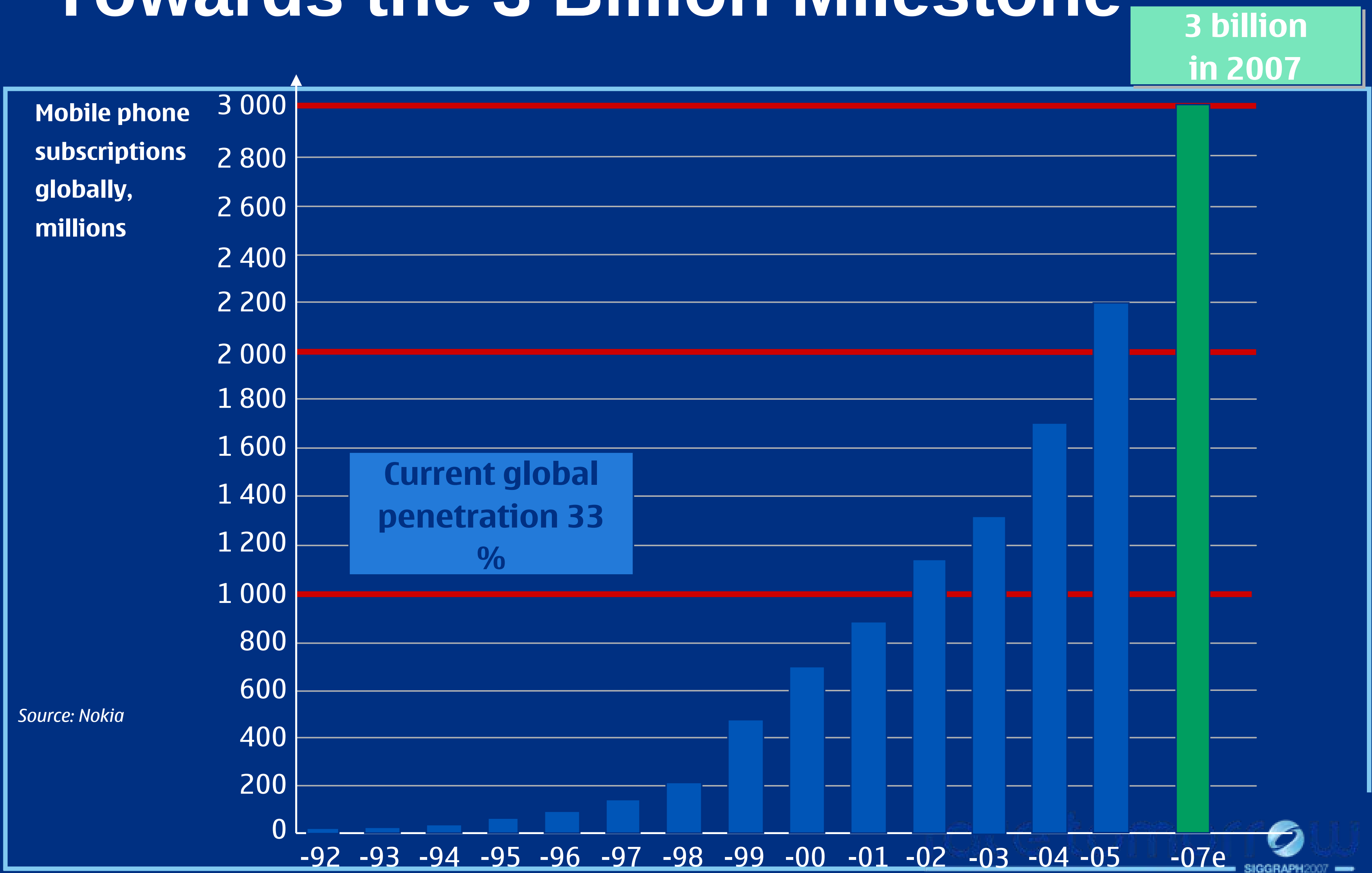
3 billion mobile subscribers by 2007.

Over 1 billion wireless broadband subscribers by 2009.

Up to 90% of the 6 billion will have mobile coverage by 2010.

Sources: Nokia 2005 & 2006, GSM Association 2006

Towards the 3 Billion Milestone



Challenge? Power!

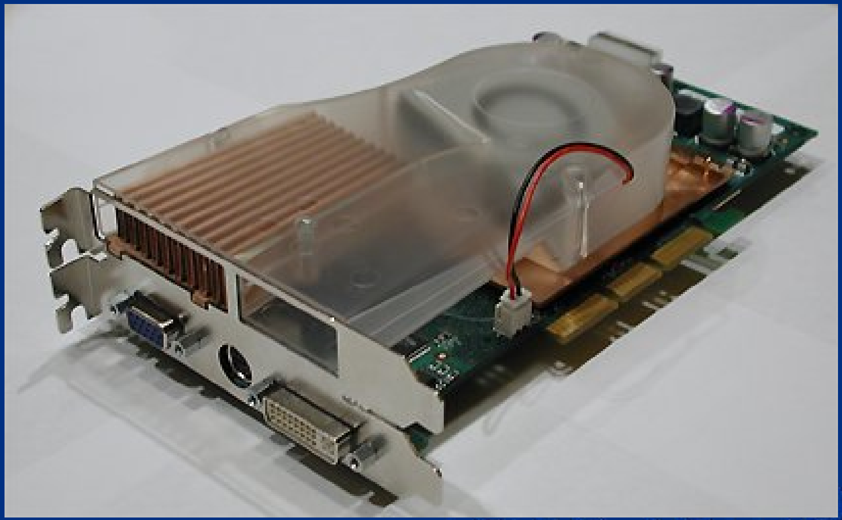
- Power is the ultimate bottleneck
  - Usually not plugged to wall, just batteries
- Batteries don’t follow Moore’s law
  - Only 5-10% per year

Challenge?   Power!

- Gene’s law
  - "power use of integrated circuits decreases exponentially" over time => batteries will last longer
    - Since 1994, the power required to run an IC has declined 10x every 2 years
  - But the performance of 2 years ago is not enough
    - Pump up the speed
    - Use up the power savings

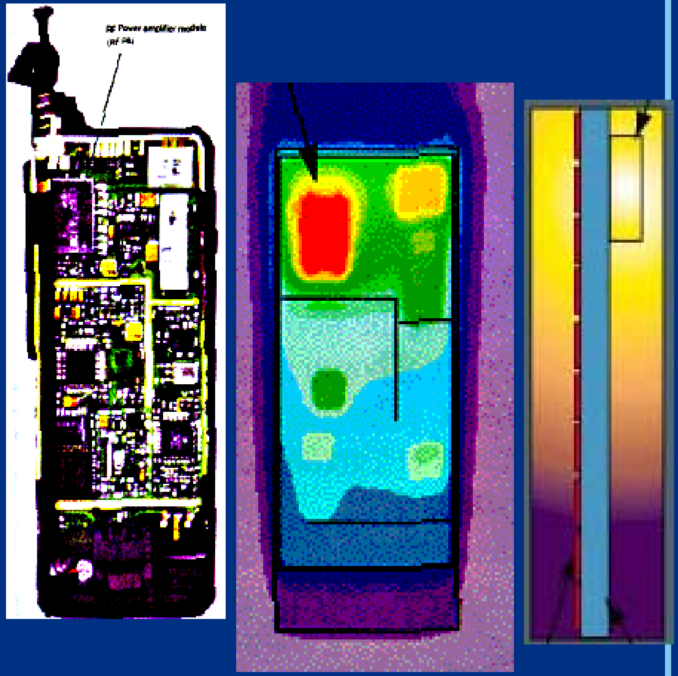
Challenge? Thermal mgt!

- But ridiculously good batteries still won't be the miracle cure
  - The devices are small
  - Generated power must get out
  - No room for fans



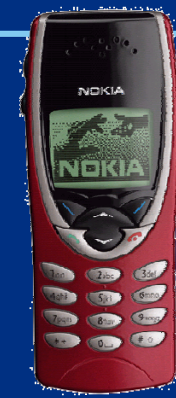
Challenge? Thermal mgt!

- Thermal management must be considered early in the design
  - Hot spot would fry electronics
    - Or at least inconvenience the user…
  - Conduct the heat through the walls, and finally release to the ambient



Changed? Displays!

- Resolution
  - S60: 320 x 240
  - Communicators: 640 x 200
  - Internet tablets like N800: 800 x 480
- Color depth
  - Not many new B/W phones
  - 12 / 16 / 18 / … bit RGB

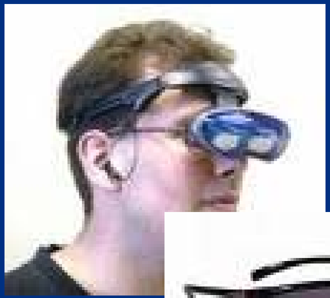




Future? Displays!

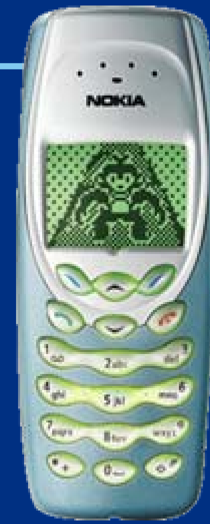
- Physical size remains limited
  - TV-out connection
  - Near-eye displays?
  - Projectors?
  - Roll-up flexible displays?

allaboutsymbian.com



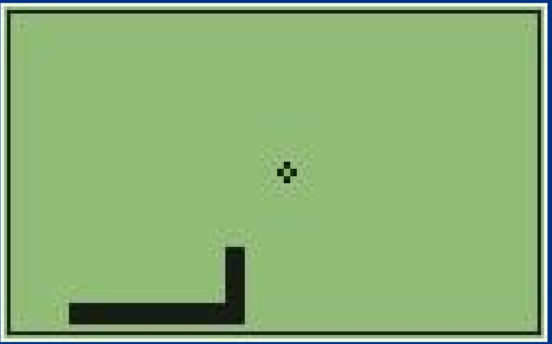
Changed? Computation!

- Moore's law in action
  - 3410: ARM 7 @ 26MHz
    - Not much caching, narrow bus
  - 6600: ARM 9 @ 104MHz
    - Decent caching, better bus
  - 6630: ARM 9 @ 220MHz
    - Faster memories
  - N93: ARM 11 @ 330MHz
    - HW floating-point unit
    - 3D HW



State-of-the-art in 2001: GSM world

- The world's most played electronic game?
  - According to The Guardian (May 2001)

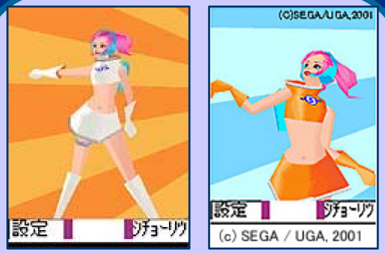


- Communicator demo 2001
  - Remake of a 1994 Amiga demo
  - <10 year from PC to mobile

State-of-the-art in 2001: Japan

GENKI 3D Characters

(C) 2001 GENKI



ULALA

(c)SEGA/UGA.2001

Space Channel 5

©SEGA/UGA,2001 ©SEGA/UGA,2002

Snowboard Rider

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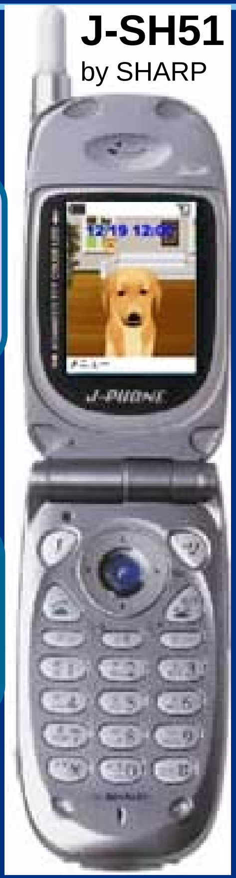


- High-level API with skinning, flat shading / texturing, orthographic view

State-of-the-art in 2002: GSM world

- 3410 shipped in May 2002
  - A SW engine: a subset of OpenGL including full perspective (even textures)
  - 3D screensavers (artist created content)
  - FlyText screensaver (end-user content)
  - a 3D game

State-of-the-art in 2002: Japan

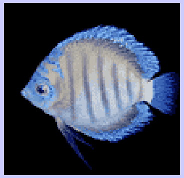
- Gouraud shading, semi-transparency, environment maps


I-3D PolyGame Boxing

@ Hi Vanguard· REZO, BNW

Ulala Channel J

©SEGA/UGA,2001 ©SEGA/UGA,2002



KDDI Au 3D Launcher

©SAN-X+GREEN CAMEL

3d menu

State-of-the-art in 2003: GSM world

- N-Gage ships
- Lots of proprietary 3D engines on various Series 60 phones

Fathammer's Geopod on XForge

State-of-the-art in 2003: Japan

- Perspective view, low-level API

Ridge Racer

@ Namco

Mission Commander

Multi player Fps Game

© IT Telecom

Mobile 3D in 2004

- 6630 shipped late 2004
  - First device to have both OpenGL ES 1.0 (for C++) and M3G (a.k.a JSR-184, for Java) APIs
- Sharp V602SH in May 2004
  - OpenGL ES 1.0 capable HW but API not exposed
  - Java / MascotCapsule API

2005 and beyond: HW

Mobile graphics evolution snapshot

Spider-Man 2: The Hero Returns
Sony Pictures

2D

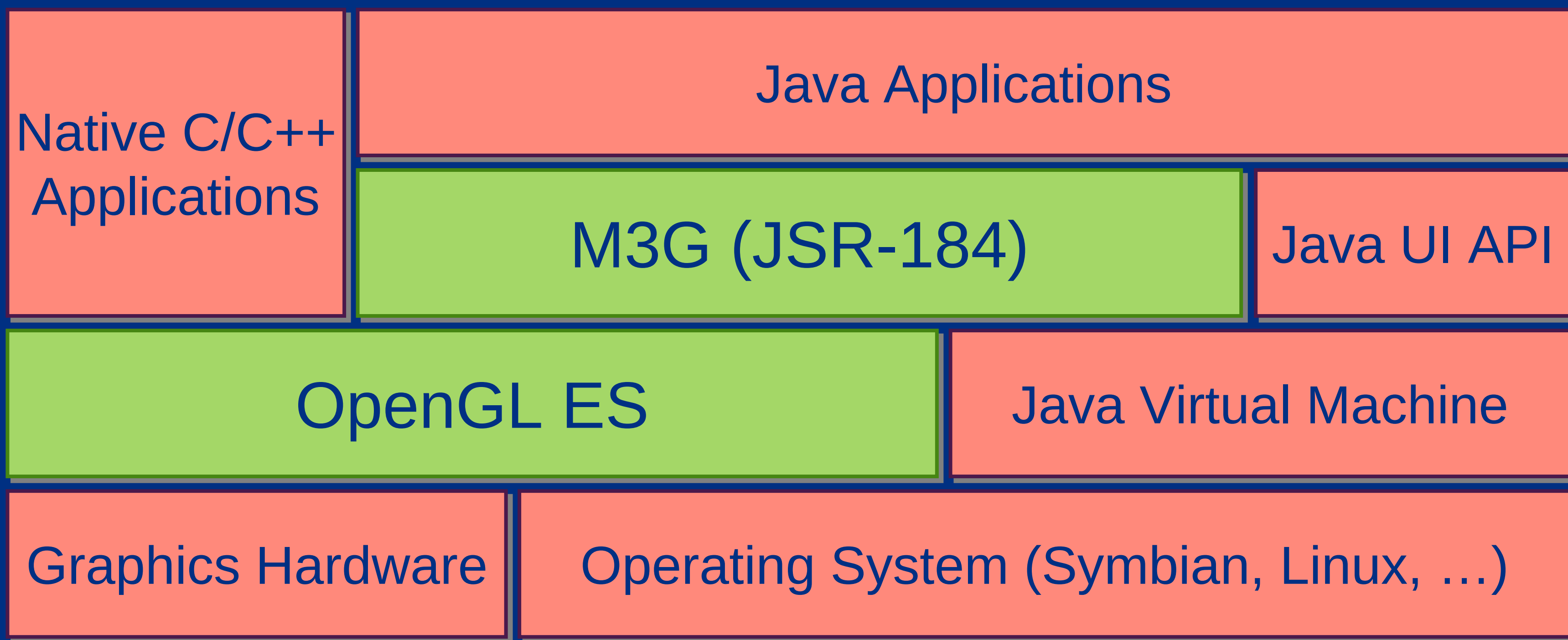
Spider-Man 2 3D: NY Subway
Sony Pictures

Software 3D

Spider-Man 2
Activision

Accelerated 3D

Mobile 3D APIs

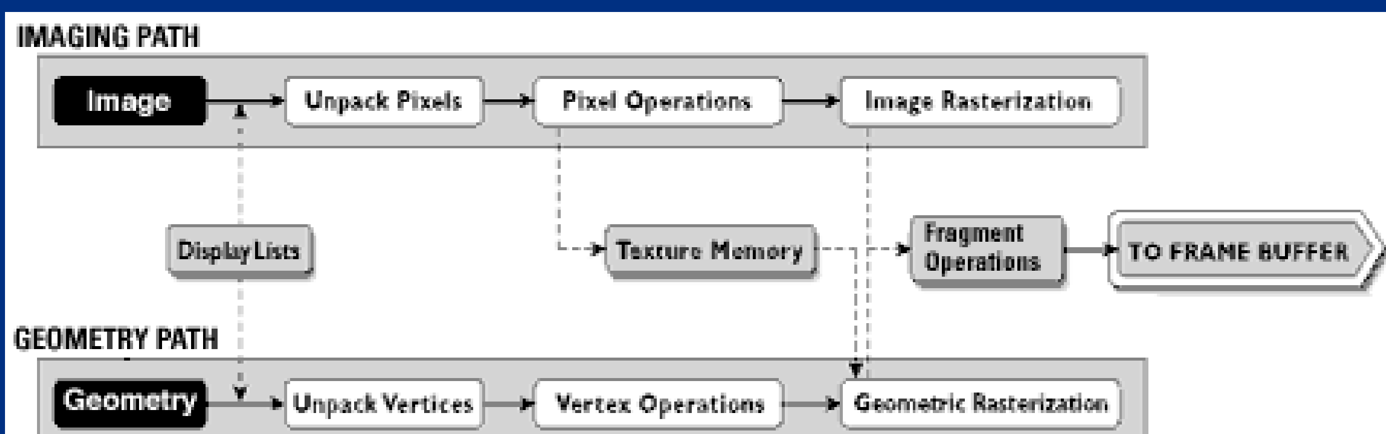


Overview: OpenGL ES

- Background: OpenGL & OpenGL ES
- OpenGL ES 1.0
- OpenGL ES 1.1
- EGL: the glue between OS and OpenGL ES
- How can I get it and learn more?

What is OpenGL?

- The most widely adopted graphics standard
  - most OS's, thousands of applications
- Map the graphics process into a pipeline
  - matches HW well



modeling
⇩
projecting
⇩
clipping
⇩
lighting & shading
⇩
texturing
⇩
hidden surface
⇩
blending
⇩
pixels to screen

- A foundation for higher level APIs
  - Open Inventor; VRML / X3D; Java3D; game engines

What is OpenGL ES?

- OpenGL is just too big for Embedded Systems with limited resources
  - memory footprint, floating point HW
- Create a new, compact API
  - mostly a subset of OpenGL
  - that can still do almost all OpenGL can

OpenGL ES 1.0 design targets

- Preserve OpenGL structure
- Eliminate un-needed functionality
  - redundant / expensive / unused
- Keep it compact and efficient
  - <= 50KB footprint possible, without HW FPU
- Enable innovation
  - allow extensions, harmonize them
- Align with other mobile 3D APIs (M3G / JSR-184)

Adoption

- Symbian OS, S60
- Brew
- PS3 / Cell architecture

Sony's arguments: Why ES over OpenGL

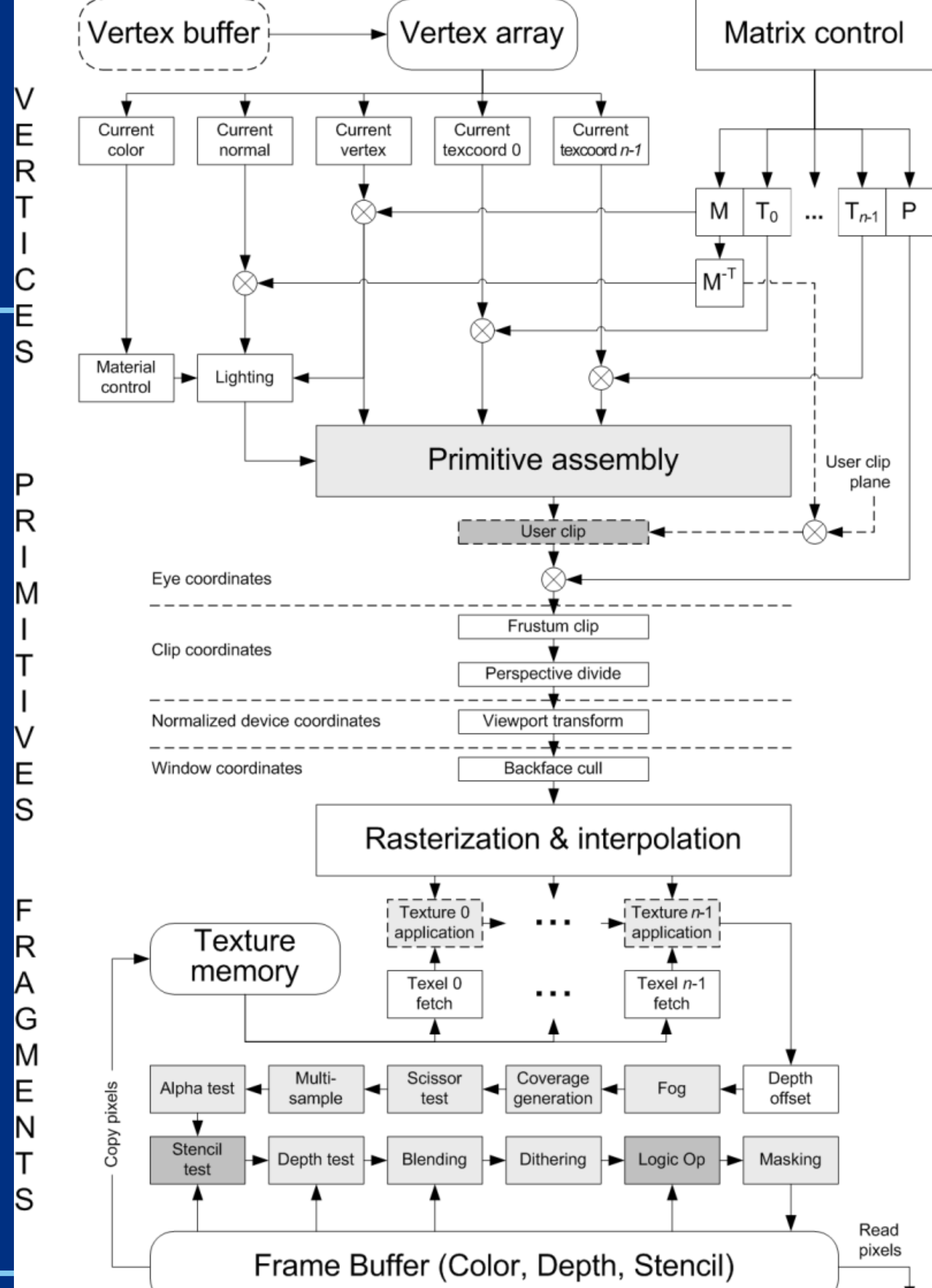
- OpenGL drivers contain many features not needed by game developers
- ES designed primarily for interactive 3D app devs
- Smaller memory footprint

Outline

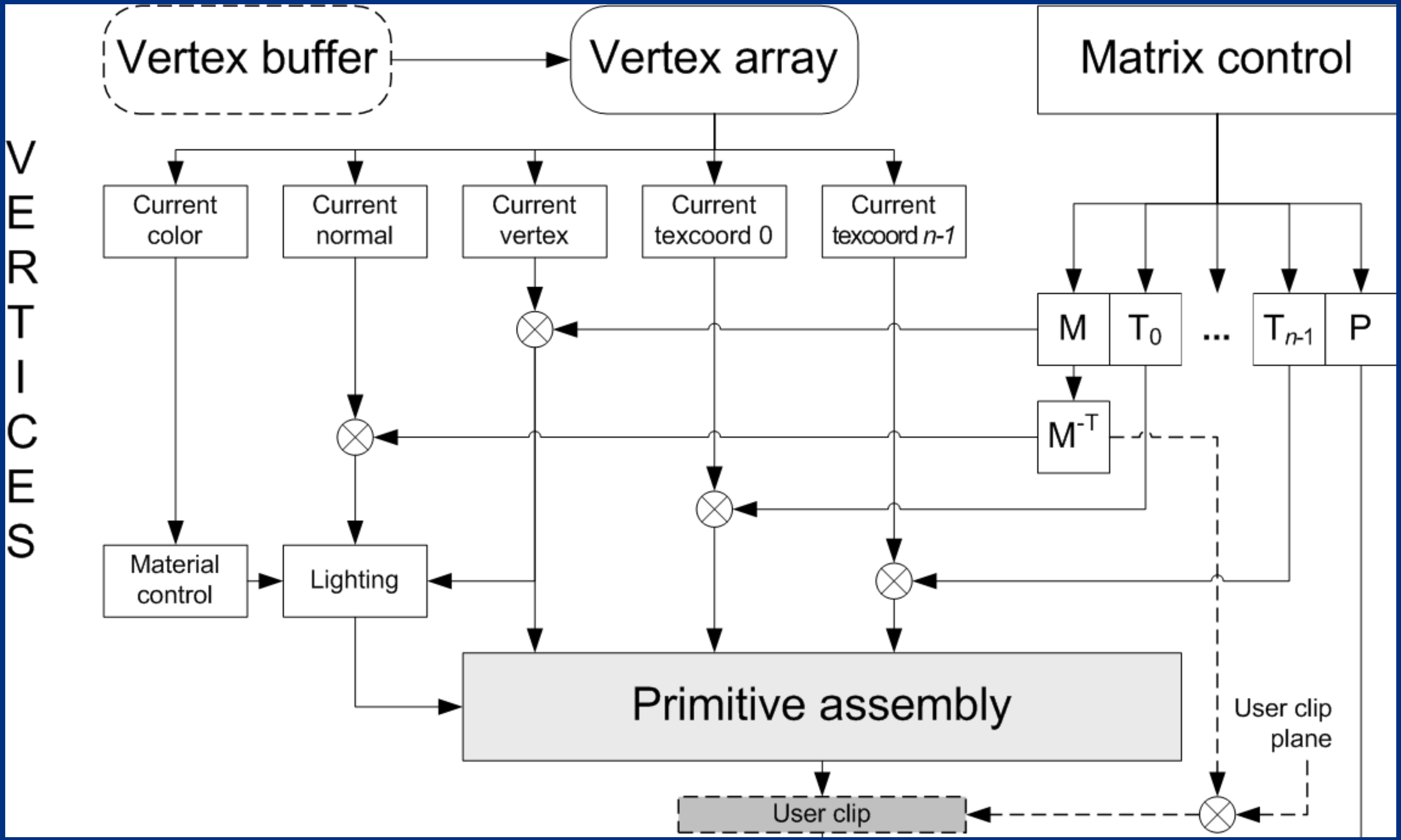
- Background: OpenGL & OpenGL ES
- OpenGL ES 1.0
- OpenGL ES 1.1
- EGL: the glue between OS and OpenGL ES
- How can I get it and learn more?

OpenGL ES Pipe

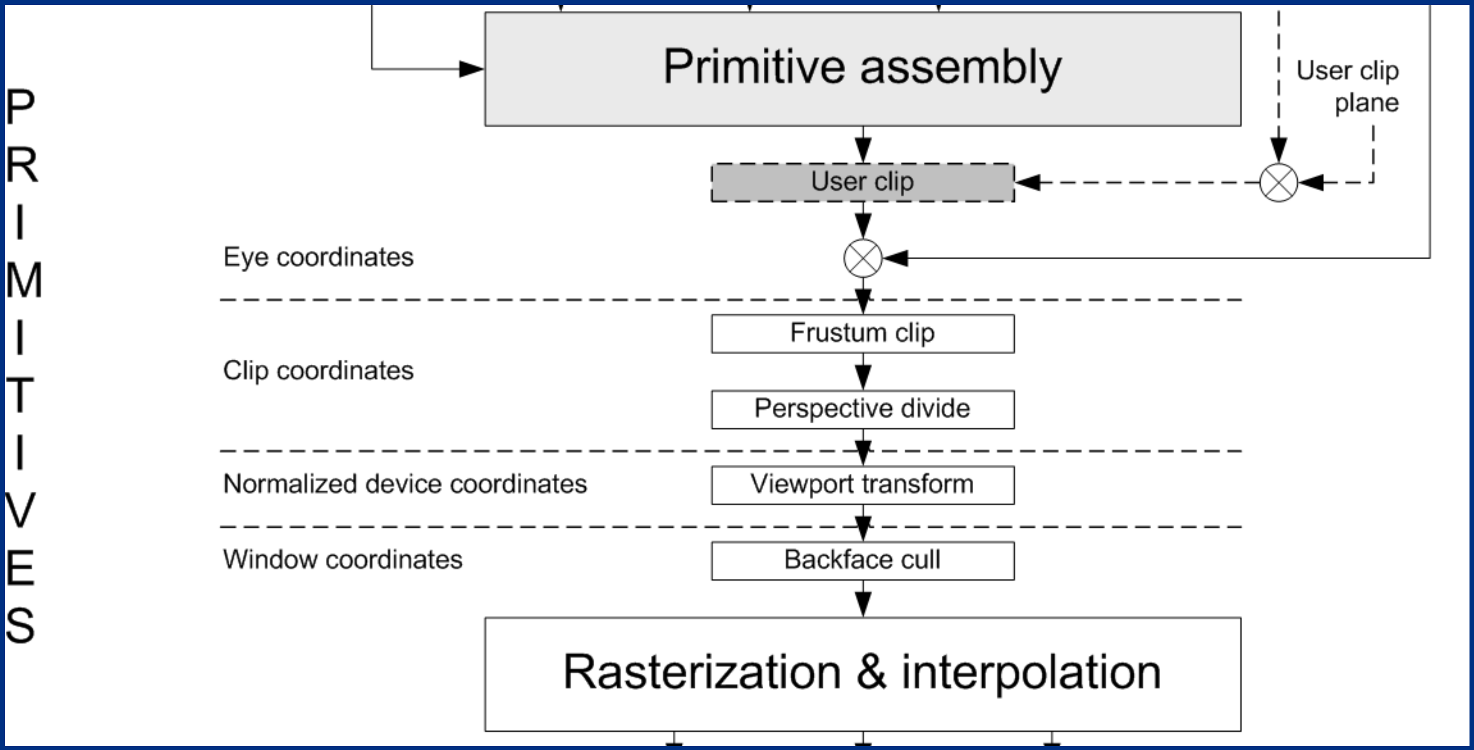
- Here's the OpenGL ES pipeline stages
  - vertices
  - primitives
  - fragments



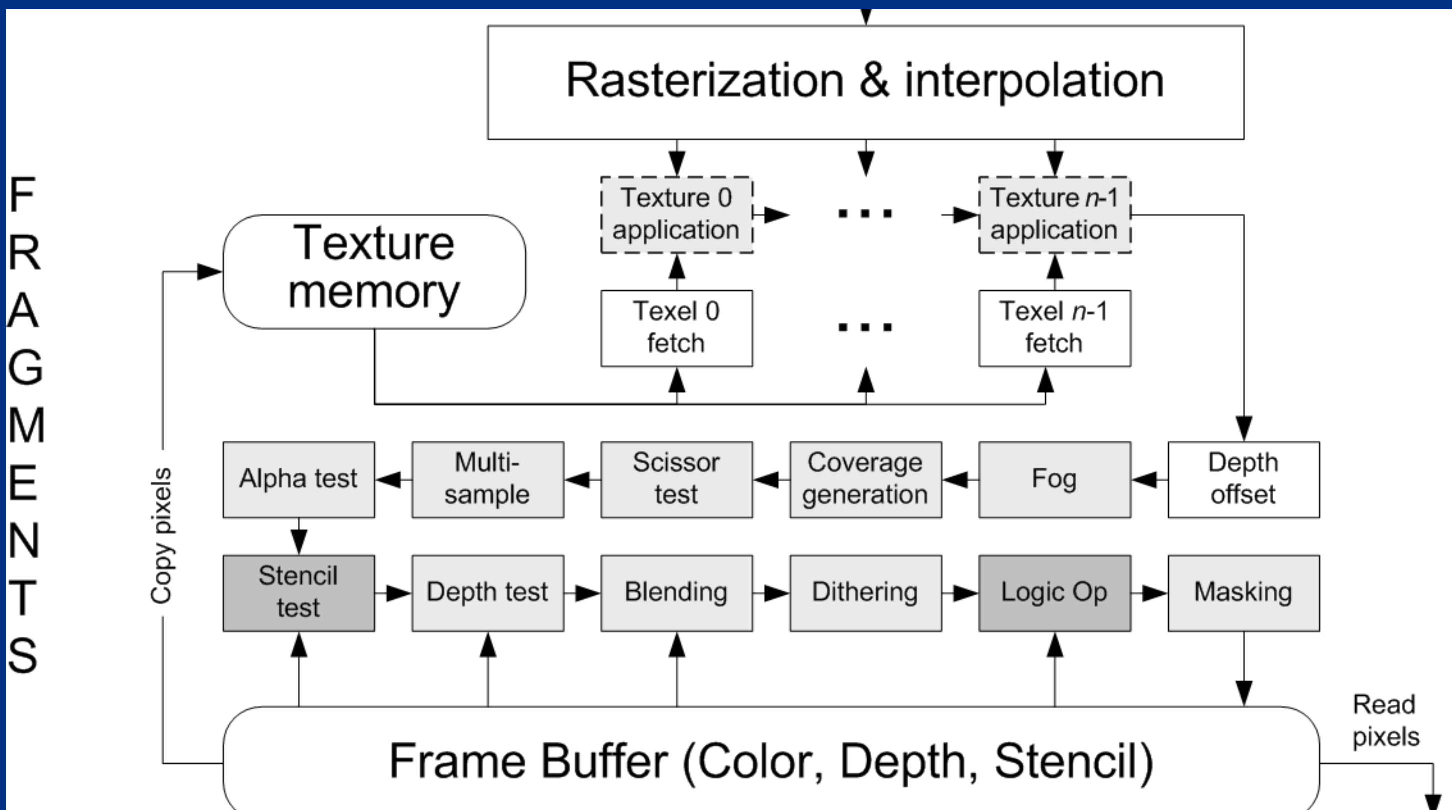
Vertex pipeline



Primitive processing



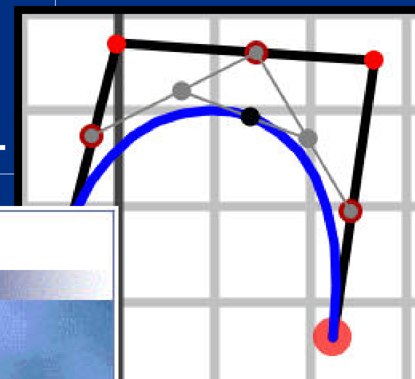
Fragment pipeline

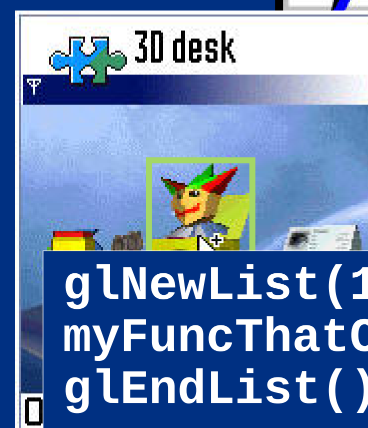


Functionality: in / out? (1/7)

- Convenience functionality is <u>OUT</u>
  - GLU
    (utility library)
  - evaluators
    (for splines)
  - feedback mode
    (tell what would draw without drawing)
  - selection mode
    (for picking, easily emulated)
  - display lists
    (collecting and preprocessing commands)

```
gluOrtho2D(0,1,0,1)
vs.
glOrtho(0,1,0,1,-1,1
```






```
glNewList(1, GL_COMPILE)
myFuncThatCallsOpenGL()
glEndList()
…
glCallList(1)
```

Functionality: in / out? (2/7)

- Remove old complex functionality
  - glBegin – glEnd (**OUT**); vertex arrays (**IN**)
  - new: coordinates can be given as bytes

```
glBegin(GL_POLYGON);
glColor3f (1, 0, 0);
glVertex3f(-.5, .5, .5);
glVertex3f( .5, .5, .5);
glColor3f (0, 1, 0);
glVertex3f( .5,-.5, .5);
glVertex3f(-.5,-.5, .5);
glEnd();
```

```
static const GLbyte verts[4 * 3] =
{    -1,  1,  1,       1,  1,  1,
      1, -1,  1,      -1, -1,  1 };
static const GLubyte colors[4 * 3] =
{   255,  0,  0,     255,  0,  0,
      0,255,  0,       0,255,  0 };
glVertexPointer( 3,GL_BYTE,0, verts );
glColorPointerf( 3,GL_UNSIGNED_BYTE,
                 0, colors );
glDrawArrays( GL_TRIANGLE_STRIP,
              0, 4 );
```

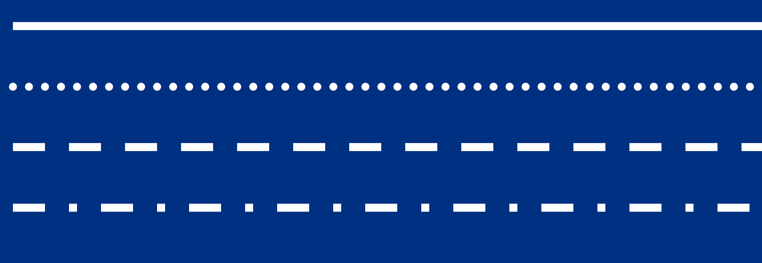
Functionality: in / out? (3/7)

- Simplify rendering modes
  - double buffering, RGBA, no front buffer access
- Emulating back-end missing functionality is expensive or impossible
  - full fragment processing is **IN**

    alpha / depth / scissor / stencil tests,
    multisampling,
    dithering, blending, logic ops)

Functionality: in / out? (4/7)

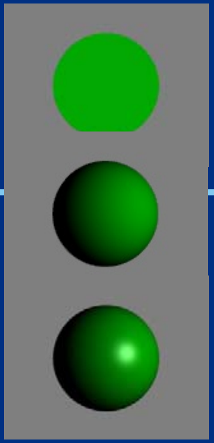
- Raster processing
  - ReadPixels **IN**, DrawPixels and Bitmap **OUT**
- Rasterization
  - **OUT:** PolygonMode, PolygonSmooth, Stipple



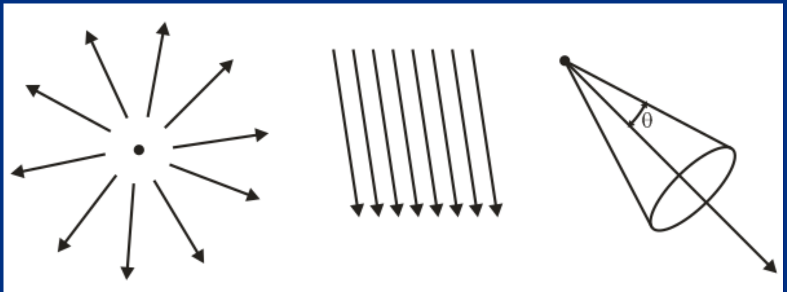
Functionality: in / out? (5/7)

- 2D texture maps <u>**IN**</u>
  - 1D, 3D, cube maps **OUT**
  - borders, proxies, priorities, LOD clamps **OUT**
  - multitexturing, texture compression **IN** (optional)
  - texture filtering (incl. mipmaps) **IN**
  - new: paletted textures **IN**

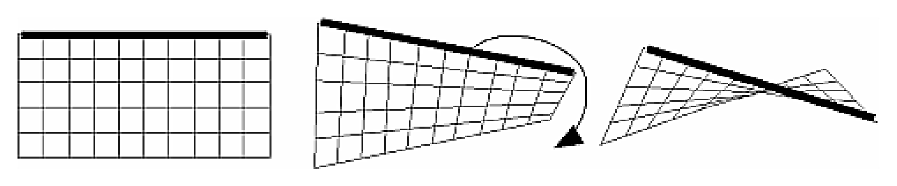
Functionality: in / out? (6/7)

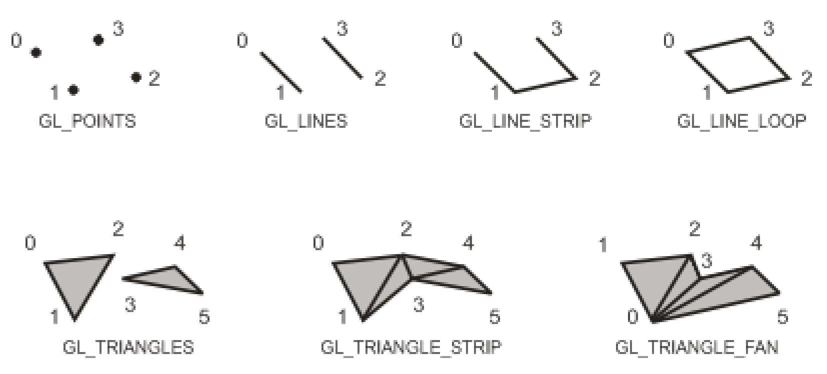


- Almost full OpenGL light model **IN**
  - back materials, local viewer, separate specular **OUT**



- Primitives
  - **IN:** points, lines, triangles
  - **OUT:** quads & polygons





Functionality: in / out? (7/7)

- Vertex processing
  - **IN:** transformations
  - **OUT:** user clip planes, texcoord generation
- Support only static queries
  - **OUT:** dynamic queries, attribute stacks
    - application can usually keep track of its own state

Floats vs. fixed-point

- Accommodate both
  - integers / fixed-point numbers for efficiency
  - floats for ease-of-use and being future-proof
- Details
  - 16.16 fixed-point: add a decimal point inside an int

```
glRotatef( 0.5f,    0.f   , 1.f,    0.f    );
                    vs.
glRotatex( 1 << 15,    0   , 1 << 16,    0    );
```

  - get rid of doubles

Outline

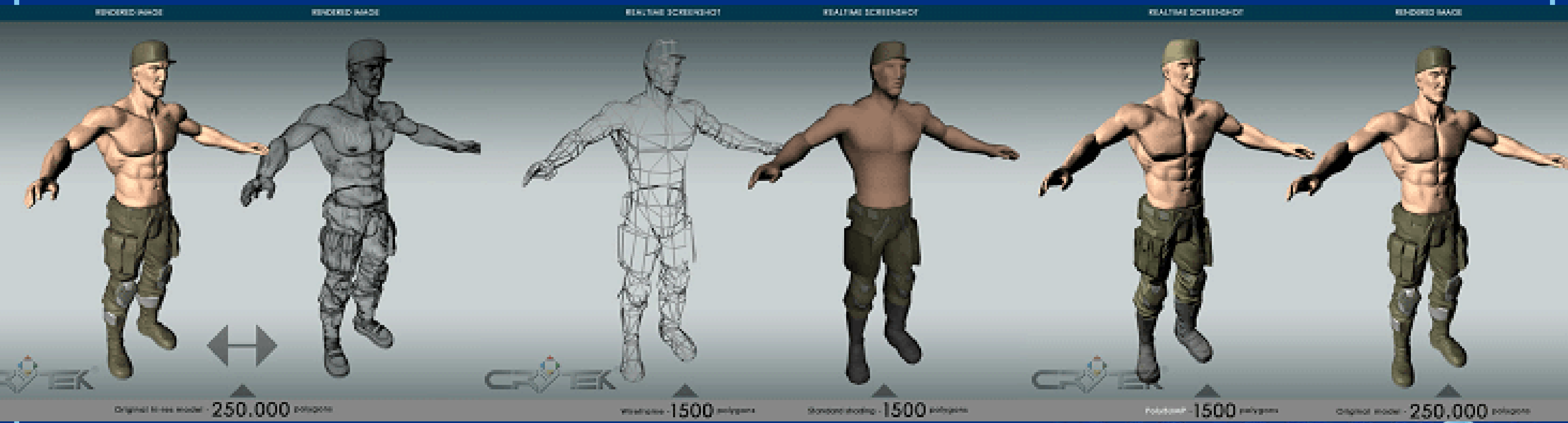
- Background: OpenGL & OpenGL ES
- OpenGL ES 1.0
- OpenGL ES 1.1
- EGL: the glue between OS and OpenGL ES
- How can I get it and learn more?

OpenGL ES 1.1: core

- Buffer Objects
  - allow caching vertex data
- Better Textures
  - >= 2 tex units, combine (+,-,interp), dot3 bumps, auto mipmap gen.
- User Clip Planes
  - portal culling (>= 1)
- Point Sprites
  - particles as points not quads, attenuate size with distance
- State Queries
  - enables state save / restore, good for middleware

Bump maps

- Double win
  - increase realism
  - reduce internal bandwidth -> increase performance



OpenGL ES 1.1: optional

- Draw Texture

  fast drawing of pixel rectangles
  using texturing units
  (data can be cached),
  constant Z, scaling

- Matrix Palette

  vertex skinning
  (>= 3 matrices / vertex, palette >= 9)

Outline

- Background: OpenGL & OpenGL ES
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EGL glues OpenGL ES to OS

- EGL is the interface between OpenGL ES and the native platform window system
  - similar to GLX on X-windows, WGL on Windows
  - facilitates portability across OS's (Symbian, Linux, …)
- Division of labor
  - EGL gets the resources (windows, etc.) and displays the images created by OpenGL ES
  - OpenGL ES uses resources for 3D graphics

EGL surfaces

- Various drawing surfaces, rendering targets
  - *windows* – on-screen rendering ("graphics" memory)
  - *pbuffers* – off-screen rendering (user memory)
  - *pixmaps* – off-screen rendering (OS native images)

EGL context

- A rendering context is an abstract OpenGL ES state machine
  - stores the state of the graphics engine
  - can be (re)bound to any matching surface
  - different contexts can share data
    - texture objects
    - vertex buffer objects
    - even across APIs (OpenGL ES, OpenVG, later others too)

Main EGL 1.0 functions

- Getting started
  - eglInitialize() / eglTerminate(), eglGetDisplay(), eglGetConfigs() / eglChooseConfig(), eglCreate**X**Surface() (**X** = Window | Pbuffer | Pixmap), eglCreateContext()
- eglMakeCurrent(display, drawsurf, readsurf, context)
  - binds context to current thread, surfaces, display

Main EGL 1.0 functions

- eglSwapBuffer(display, surface)
  - posts the color buffer to a window
- eglWaitGL( ), eglWaitNative(engine)
  - provides synchronization between OpenGL ES and native (2D) graphics libraries
- eglCopyBuffer(display, surface, target)
  - copy color buffer to a native color pixmap

EGL 1.1 enhancements

- Swap interval control
  - specify # of video frames between buffer swaps
  - default 1; 0 = unlocked swaps, >1 save power
- Power management events
  - PowerMgmnt event => all Context lost
  - Display & Surf remain, Surf contents unspecified
- Render-to-texture [optional]
  - flexible use of texture memory

Outline

- Background: OpenGL & OpenGL ES
- OpenGL ES 1.0 functionality
- OpenGL ES beyond 1.0
- EGL: the glue between OS and OpenGL ES
- How can I get it and learn more?

SW Implementations

- Gerbera from Hybrid
  - Free for non-commercial use
  - http://www.hybrid.fi

- Vincent
  - Open-source OpenGL ES library
  - http://sourceforge.net/projects/ogl-es
- Reference implementation
  - Wraps on top of OpenGL
  - http://www.khronos.org/opengles/documentation/gles-1.0c.tgz

HW implementations

- There are many designs
- The following slides gives some idea
  - rough rules of thumb
    - 1-5 M Tri / sec
    - 1 pixel / clock
    - clock speeds 50MHz – 200+MHz
    - power consumption should be < 100 mW

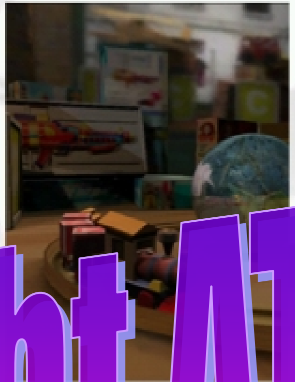
Bitboys

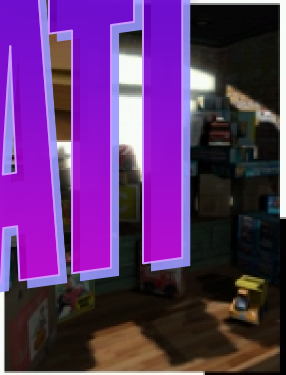
- Graphics processors
  - **G12:** OpenVG 1.0
  - **G34:** OpenGL ES 1.1
    vertex shader
  - **G40:** OpenGL ES 2.0, GLSL
    OpenVG 1.0
    vertex and pixel shader
  - Flipquad antialiasing
  - Max clock 200MHz
- Partners / Customers
  - NEC Electronics
  - Hybrid Graphics (drivers)

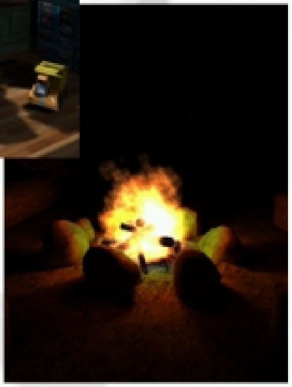
ATI bought BB

ATI

AMD bought ATI







- Imageon 2300
  - OpenGL ES 1.0
  - Vertex and raster HW
    - 32-bit internal pipe
    - 16-bit color and Z buffers
    - Integrated QVGA buffer
    - Imaging / Video codecs
- Imageon 3D (for Qualcomm)
  - OpenGL ES 1.1
  - 3M Tri/s,100M Pix/s @ 100 MHz
- 2nd gen. Imageon 3D adds
  - OpenGL ES 1.1 extension pack
  - Vertex shader
  - HyperZ
  - Audio codecs, 3D audio
- Partners, customers
  - Qualcomm
  - LG SV360, KV3600
  - Zodiac

AMD Handheld Graphics

AMD Smarter Choice

1st generation (Imageon 2300)

- OpenGL ES 1.0 (1st conformant implementation)
- Vertex and raster HW
- 32-bit internal pipe, 16-bit color and Z buffers
- Integrated QVGA buffer
- Imaging / Video codecs
- 1 Mtri/s, 100 Mpix/s

2nd generation (Imageon 2380)

- OpenGL ES 1.1
- Vertex shader, HyperZ
- Audio codecs, 3D audio
- 3.5 Mtri/s, 125 Mpix/s

3rd generation (to be announced)

- OpenGL ES 2.0
- Full HW OpenVG 1.1
- Unified Shaders
- OpenGL ES 2.0 and OpenVG cores are also available as IP

Falanx

- **Mali 110**
  - OpenGL ES 1.1 + extensions
  - 4x / 16x full screen anti-aliasing
  - Video codecs (e.g., MPEG-4)
  - 170-40
  - 2.8M
- **Mali 20**
  - Open
    Mob.
  - 5M Tri / s, 100M Pix / s, 11 instr. / cycle
- **Partners / Customer**
  - Zoran

ARM bought Falanx

CORE SELECTION GUIDE

	MALI55	MALI110	MALI200	MALIGP
Core Function	Pixel Shader	Pixel Shader	Programmable Pixel Shader	Programmable Vertex Shader
Gate Count	190K	230K	400K-500K	150K
Max Clock	200MHz	200MHz	200MHz	150MHz
Anti-Aliasing	4X / 16X	4X / 16X	4X / 16X	4X / 16X
OpenGL ES 1.1	Yes	Yes	Yes	Yes
OpenGL ES 2.0	No	No	Yes	Yes
OpenVG 1.0	Yes	Yes	Yes	Yes
DirectX w/Vista Extensions	No	No	Yes	No
Deferred Vertex Shading	No	No	Yes	No
MPEG-4/H.264*	Yes	Yes	Yes	Yes
FPS Encode H.264*	15fps	15ps	30fps	30fps
FPS Decode H.264*	15fps	30fps	30fps	30fps
OpenMAX*	No	No	Yes	No

available in Mal ali110V and Mali200V Configuration

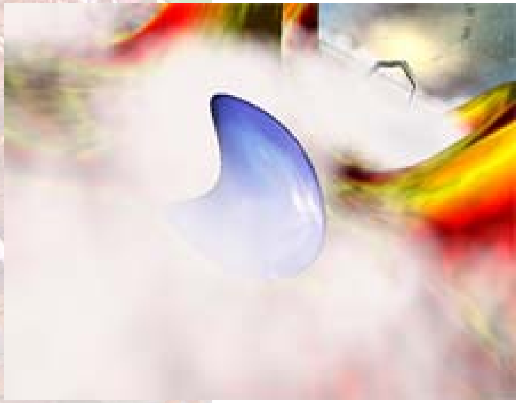
falanx MICROSYSTEMS

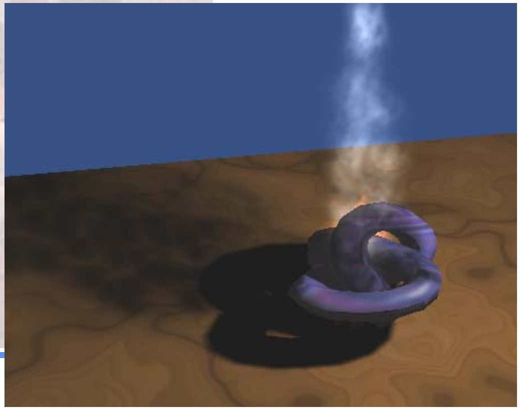
ARM® Mali™ Architecture

- Compared to traditional immediate mode renderer
  - 80% lower per pixel bandwidth usage, even with 4X FSAA enabled
  - Efficient memory access patterns and data locality: enables performance even in high latency systems
- Compared to traditional tile-based renderer
  - Significantly lower per-vertex bandwidth
  - Impact of scene complexity increases is substantially reduced
- Other architectural advantages
  - Per frame autonomous rendering
  - No renderer state change performance penalty
  - On-chip z / stencil / color buffers
    - minimizes working memory footprint
- Acceleration beyond 3D graphics (OpenVG etc.)

	Mali200	MaliGP2	Mali55
Anti-Aliasing	4X / 16X	4X / 16X	4X / 16X
OpenGL®ES 1.x	YES	YES	YES
OpenGL®ES 2.x	YES	YES	NO
OpenVG 1.x	YES	NA	YES
Max CLK	275MHz	275MHz	200MHz
Fill rate Mpix / s	275	NA	100
Triangles / s	9M	9M	1M

- **PICA200 graphics core**
  - 3D Features
    - OpenGLES 1.1
    - DMP's proprietary "Maestro" extensions
      - **Very high quality graphics with easier programming interface**
      - **Per-fragment lighting,**
      - **Shadow-mapping,**
      - **Procedural texture,**
      - **Polygon subdivision (Geo shader), and**
      - **Gaseous object rendering.**
  - Hardware Features
    - » **Performance: 20Mtri/s, 400Mpixel/s@100MHz**
    - » **Core size: 500Kgate – 4Mgate**
    - » **Power consumption: 0.5-2mW/MHz**
    - » **Max. clock freq. 200MHz (90nm and 130nm)**





Imagination Technologies POWERVR MBX & SGX 2D/3D Acceleration

- **5th Generation Tile Based Deferred Rendering**
  - Market Proven Advanced Tiling Algorithms
  - Order-independent Hidden Surface Removal
  - Lowest silicon area, bandwidth and power
  - Excellent system latency tolerance
- **POWERVR SGX: OpenGL ES 2.0 in Silicon Now**
  - Scalable from 1 to 8 pipelines and beyond
  - Programmable multi-threaded multimedia GPU
  - Optimal load balancing scheduling hardware
  - Vertex, Pixel, Geometry shaders + image processing
- **Partners/Customers**
  - TI, Intel, Renesas, Samsung, NXP, NEC, Freescale, Sunplus, Centrality & others unannounced

POWERVR MBX: The de-facto standard for mobile graphics acceleration, with >50 PowerVR 3D-enabled phones shipping worldwide

www.powervrinsider.com
Market-leading Ecosystem with more than 1650 members

	PowerVR MBX Family	PowerVR SGX Family
OpenGL	ES1.1	2.0, ES1.1 and ES2.0
Direct3D	Mobile	Mobile, 9L and 10.1
OpenVG	1.0	1.0.1 and 1.1
Triangles/Sec	1.7M … 3.7M	1M … 15.5M
Pixels/Sec	135M … 300M	50M … 500M

Performance quoted at 100MHz for MBX, MBX Lite and for SGX510 to SGX545.
Peak SoC achievable performance not quoted, e.g. <50% Shader load for Tri/Sec.
Performance scales with clock speeds up to 200MHz and beyond.
Planned future cores will offer higher performance levels.

Mitsubishi

- Z3D family
  - Z3D and Z3D2 out in 2002, 2003
    - Pre-OpenGL ES 1.0
    - Embedded SRAM architecture
  - Z3D3 in 2004
    - OpenGL ES 1.0, raster and vertex HW
    - Cache architecture
    - @ 100 MHz: 1.5M vtx / s, 50-60 mW, ~250 kGates
  - Z3D4 in 2005
    - OpenGL ES 1.1
- Partners / Customers
  - Several Japanese manufacturers

Z3D
First mobile 3D HW?

Z3D Graphics Engine

GiPump™ Series

GiPump™ NX1005
; Mobile 3D graphics acc. with camera control functions
- OpenGL ES 1.1 / GIGA / JSR184
- 5M poly/s, 80M pix/s @ 80MHz, JPEG codec (3M pixel), ~QVGA display
- Cellular phone, smart phone, etc.

GiPump™ NX1007
; High end 3D graphics acc. for mobile
- OpenGL ES 1.1 + Ext. / GIGA / JSR184
- 12.5M poly/s, 200M pix/s @ 100MHz, ~SVGA display, PIP supports
- PND, PMP, game device, mobile device, etc.

GiPump™ NX1008
; Mobile 3D graphics acc. with stereoscopic display
- OpenGL ES 1.1 / GIGA / JSR184
- 5M poly/s, 80M pix/s @ 80MHz, ~QVGA display, stereoscopic display
- Cellular phone, smart phone, etc.

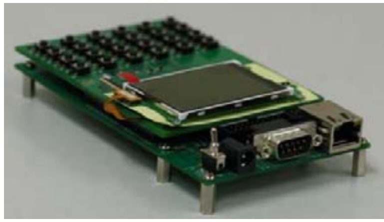
GiPump™ NX1009
; Economical mobile 3D graphics accelerator
- OpenGL ES 1.1 + Ext. / GIGA / JSR184
- 12.5M poly/s, 200M pix/s @ 100MHz, ~SVGA display, boost mode
- Cellular phone, Smart phone, etc.

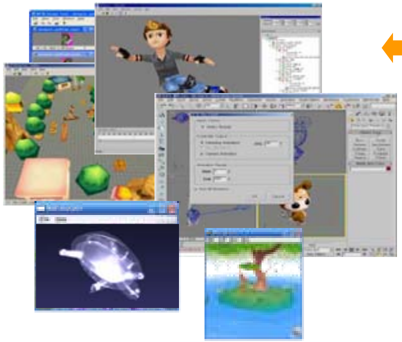
GiPump™ NX2001
; 3D Graphics enhanced multimedia processor
- OpenGL ES 2.0 / 1.1 Ext. / JSR184 / D3DM
- 10M poly/s, 200M pix/s @ 200MHz, ~SVGA display
- PND, PMP, game device, mobile device, etc.

Service Solutions

Nexus Mobile Platform™
Gaming Device Platform
(OS: WinCE, Linux, RTOS, etc.)
To: Game Device Maker

NX1008TK™
3D Reference B/D
GiPump™ Integration Platform
To: Device Developer





GiPump™ SDK
NXsdk with Emulator
NXsdk Shader+
NXm3g Engine
NX3D Engine & Tools

GiPump™ Partners : Samsung, SKT, Other Device Manufactures

* GiPump™ : Pronounced, "G", "I", "Pump".   It means "Graphics / Image Pump".
* GIGA (Giga Instruction Giga Acceleration) : SK Telecom's mobile 3D graphics platform

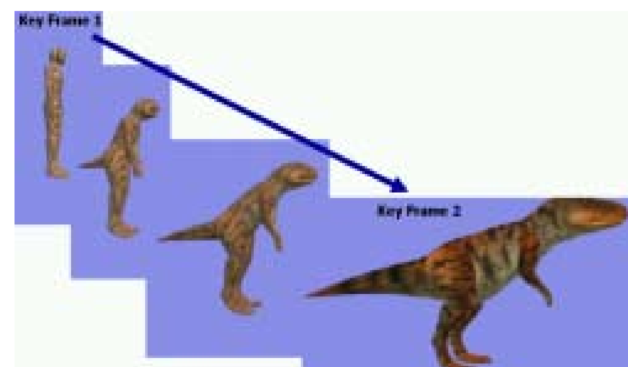
NVidia

- GoForce 5500 handheld GPU
  - 3D geometry and rasterization HW
  - OpenGL ES 1.1, D3D Mobile, OpenVG 1.0
  - 1.3M tri / s, 100M pix / s (@ 100 MHz)
  - Programmable pixel micro shaders
  - 40 bit signed non-int (overbright) color pipeline
  - Dedicated 2D engine (bitblt, lines, alpha blend)
  - Supersampled anti-aliasing, up to 6 textures
  - <50mW avg. dynamic power cons. for graphics
  - 10MPxl camera support, XGA LCD, MPEG-4 video, audio

- Partners / Customers
  - Motorola, Sony Ericsson, Samsung, LG, Kyocera, O2, HTC, Marvell, Freescale, ...

Sony PSP

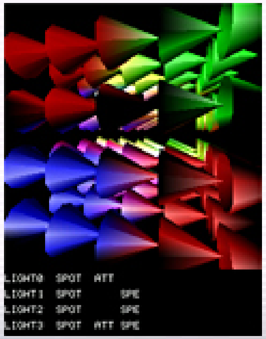
- Game processing unit
  - Surface engine
    - tessellation of Beziers and splines
    - skinning (<= 8 matrices), morphing (<= 8 vtx
    - HW T&L
    - 21 MTri / s (@ 100 MHz)
  - Rendering engine
    - basic OpenGL-style fixed pipeline
    - 400M pix / s (@ 100 MHz)
  - 2MB eDRAM
- Media processing engine
  - 2MB eDRAM
  - H.264 (AVC) video up to 720x480 @ 30fps



TAKUMI

- **GSHARK-TAKUMI Family**
  - **GP**
    - OpenGL ES 1.0
    - 0.5M tri/s @100MHz, 170Kgate
  - **GT**
    - OpenGL ES 1.1
    - 1.4M tri/s @100MHz, < 30mW
  - **G2**
    - OpenGL ES 1.1
    - 5M tri/s @100MHz
- Partners / Customers
  - NEC Electronics

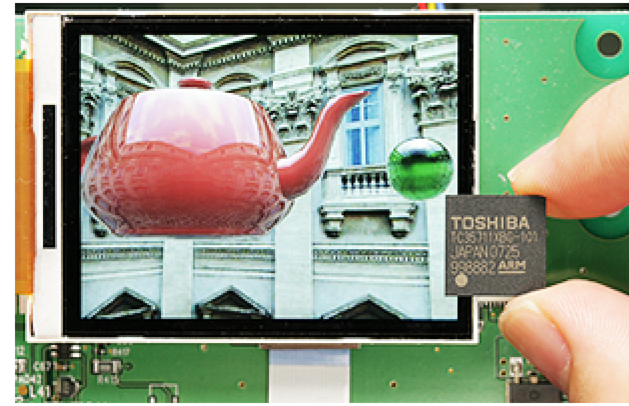
- Concepts & Architecture
  - Small Gate Counts
  - Low Power Consumption
  - Vertex Processor (T&L)
  - Dedicated 2D Sprite Engine
  - Target Application
    - Mobile Phone and Digital AV Equipments such as DTV, STB, DSC, PMP, etc.



TAKUMI CORPORATION

Toshiba

- TC35711XBG
  - Programmable shader
  - Plan to support OpenGL ES2.0
  - Large embedded memory for
    - Color and Z buffer
    - Caches for vertex arrays, textures
    - Display lists (command buffer)
  - 50M vtx / sec, 400M pix / sec (@ 100 MHz)
  - WVGA LCD controller
  - 13mm x 13mm x 1.2mm 449Ball BGA



Vivante GPU for Handheld

- OpenGL ES 1.1 & 2.0 and D3D 9.0
- Unified vertex & pixel shader
- Anti-Aliasing
- AXI/AHB interface
- GC500
  - 3 mm^2 die area in 65nm (1.8mm x 1.2mm)
  - 10 MPolygons/s and 100 MPixel/s at 200 MHz
  - 50mW GPU core power
- Scalable solution to 50 MPolygons/s and 1 GPixels/s (GC1000, GC4000)
- **Silicon proven solution**
- Designed into multiple 65nm SoCs

VIVANTE

SDKs

- Nokia S60 SDK (Symbian OS)
  - http://www.forum.nokia.com
- Imagination SDK
  - http://www.pvrdev.com/Pub/MBX
- NVIDIA handheld SDK
  - http://www.nvidia.com/object/hhsdk_home.html
- Brew SDK & documentation
  - http://brew.qualcomm.com

OpenGL ES 1.1 Demos

Questions?

SIGGRAPH2007

Using OpenGL ES

SIGGRAPH2007

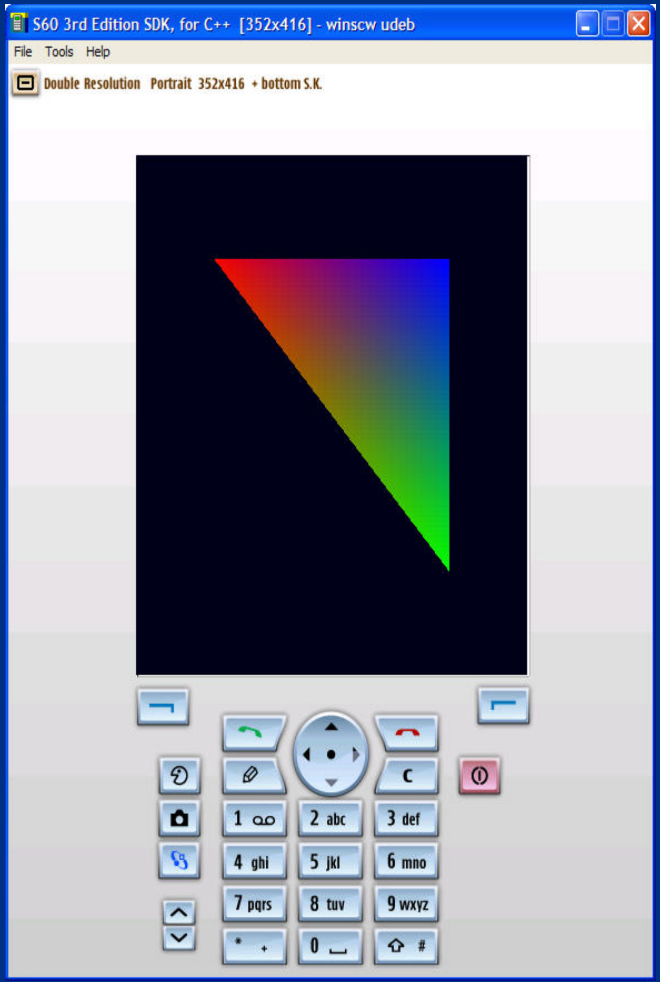
Jani Vaarala

Nokia

Using OpenGL ES

- Simple OpenGL ES example
- EGL configuration selection
- Texture matrix example
- Fixed point programming
- Converting existing code

"Hello OpenGL ES"



Hello OpenGL ES, EGL initialization

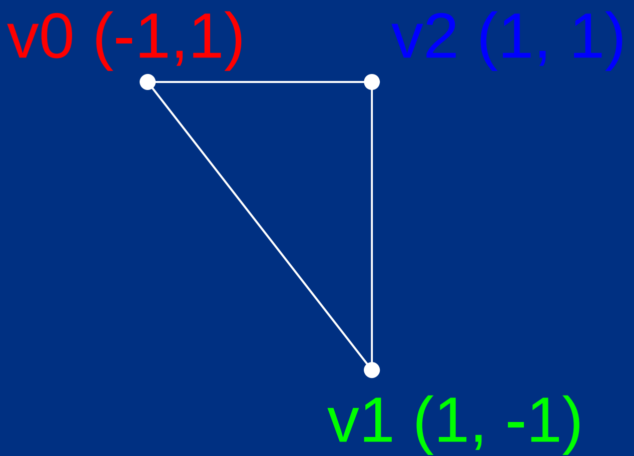
```
/* ============================================================
 *  "Hello OpenGL ES" OpenGL ES code.
 *
 *  Siggraph 2007 course on mobile graphics.
 *
 *  Copyright: Jani Vaarala
 * ============================================================
*/

#include <GLES/gl.h>
#include <GLES/egl.h>

EGLDisplay          display;
EGLContext          context;
EGLSurface          surface;
EGLConfig           config;
```

Hello OpenGL ES, EGL initialization

```
EGLint attrib_list[] =
{
    EGL_BUFFER_SIZE,   16,
    EGL_DEPTH_SIZE,    15,
    EGL_SURFACE_TYPE,    EGL_WINDOW_BIT,
    EGL_NONE
};

void init_egl(void)
{
    EGLint numOfConfigs;

    display = eglGetDisplay( EGL_DEFAULT_DISPLAY );
    eglInitialize( display, NULL, NULL );
    eglChooseConfig( display, attrib_list, &config, 1 , &numOfConfigs );
    surface = eglCreateWindowSurface( display, config, WINDOW( ), NULL );
    context = eglCreateContext( display, config, EGL_NO_CONTEXT, NULL );
    eglMakeCurrent( display, surface, surface, context );
}
```

Hello OpenGL ES, OpenGL ES part

```
#include <GLES/gl.h>

static const GLbyte vertices[3 * 3] =
{
    -1,   1,   0,
     1,  -1,   0,
     1,   1,   0
};

static const GLubyte colors[3 * 4] =
{
        255,   0,     0,     255,
        0,     255,   0,     255,
        0,     0,     255,   255
};
```



Hello OpenGL ES, OpenGL ES part

```
void init( )
{
    glClearColor            ( 0.f, 0.f, 0.1f, 1.f );
    glMatrixMode            ( GL_PROJECTION );
    glFrustumf              ( -1.f, 1.f, -1.f, 1.f, 3.f, 1000.f );
    glMatrixMode            ( GL_MODELVIEW );
    glShadeModel            ( GL_SMOOTH );
    glDisable               ( GL_DEPTH_TEST );
    glVertexPointer         ( 3, GL_BYTE, 0, vertices );
    glColorPointer          ( 4, GL_UNSIGNED_BYTE, 0, colors );
    glEnableClientState     ( GL_VERTEX_ARRAY );
    glEnableClientState     ( GL_COLOR_ARRAY );
    glViewport              ( 0, 0, GET_WIDTH(), GET_HEIGHT() );

    INIT_RENDER_CALLBACK(drawcallback);
}
```

Hello OpenGL ES, OpenGL ES part

```
void drawcallback(void)
{
    glClear          ( GL_COLOR_BUFFER_BIT );
    glLoadIdentity   ( );
    glTranslatef     ( 0.f, 0.f, -5.f );
    glDrawArrays     ( GL_TRIANGLES, 0, 3 );

    eglSwapBuffers( display, surface );
}
```

EGL config sorting

ATTRIBUTE	DEFAULT VALUE	SELECTION RULE	SORT PRIORITY	SORT ORDER
EGL_BUFFER_SIZE [16]	0	AtLeast	3	Smaller
EGL_DEPTH_SIZE [15]	0	AtLeast	6	Smaller
…				

- Selection rule: minimum requirement
- Sort priority: which attrib is sorted first
- Sort order: how attrib is sorted
- One way of sorting
- Not optimal for all applications

Example of sorted list of configs

EGL_CONFIG_ID	EGL_BUFFER_SIZE (Sort priority = 3)	EGL_DEPTH_SIZE (Sort priority = 6)
5	16	15
2	16	32
40	24	15
11	32	15
3	32	32
30	32	32

Sorted first, smaller comes first

Sorted next, smaller comes first

Sorted last (if otherwise no unique order exists), smaller comes first

Example EGL config selection

```
EGLConfig select_config(int type, int color_bits, int depth_bits, int stencil_bits)
{
	EGLBoolean		err;
	EGLint			amount, attrib_list[5*2];   /* fits 5 attribs */
	EGLConfig		best_config, configs[64]; /* max 64 configs considered */
	EGLint *ptr;

	ptr = &attrib_list[0];

	/* Make sure that the config supports target surface type */
	*ptr++ = EGL_SURFACE_TYPE;
	*ptr++ = type;

	/* For color, we require minimum of <color_bits> bits */
	*ptr++ = EGL_BUFFER_SIZE;
	*ptr++ = color_bits;

	/* For depth, we require minimum of <depth_bits> bits */
	if(depth_bits)
	{
		*ptr++ = EGL_DEPTH_SIZE;
		*ptr++ = depth_bits;
	}
```

Real-world EGL config selection

```
if(stencil_bits)
{
        ptr[0] = EGL_STENCIL_SIZE;
        ptr[1] = stencil_bits;
        ptr[2] = EGL_NONE;
}
else
{
        ptr[0] = EGL_NONE;
}

err = eglChooseConfig( display, &attrib_list[0], &configs[0], 64, &amount );

if(amount == 0)
{
        /* If we didn't have get any configs, try without stencil */
        ptr[0] = EGL_NONE;
        err = eglChooseConfig( display, &attrib_list[0], &configs[0], 64, &amount );
}
```

Real-world EGL config selection

```
    if(amount > 0)
    {
        /* We have either configs w/ or w/o stencil, not both. Find one with best AA */
        int i,best_samples;
        best_samples     = 0;
        best_config      = configs[0];

        for(i=0 ; i<amount ; i++)
        {
                int samp;
                eglGetConfigAttrib( display, configs[i], EGL_SAMPLES, &samp );
                if(samp > best_samples)
                {
                        best_config  = configs[i];
                        best_samples = samp;
                }
        }
    }
    else    best_config = (EGLConfig)0;                /* no suitable configs found */

    return best_config;
}
```

Texture matrix example

```
void appinit_glass(void)
{
    GLint texture_handle;

    /* View parameters */
    glMatrixMode            ( GL_PROJECTION );
    glFrustumf              ( -1.f, 1.f, -1.f, 1.f, 3.f, 1000.f );
    glMatrixMode            ( GL_MODELVIEW );

    /* Reset state */
    glEnable                ( GL_DEPTH_TEST );
    glClearColor            ( 0.f, 0.f, 0.1f, 1.f );

    /* Enable vertex arrays */
    glEnableClientState  ( GL_VERTEX_ARRAY );
    glEnableClientState  ( GL_TEXTURE_COORD_ARRAY );
```

Texture matrix example

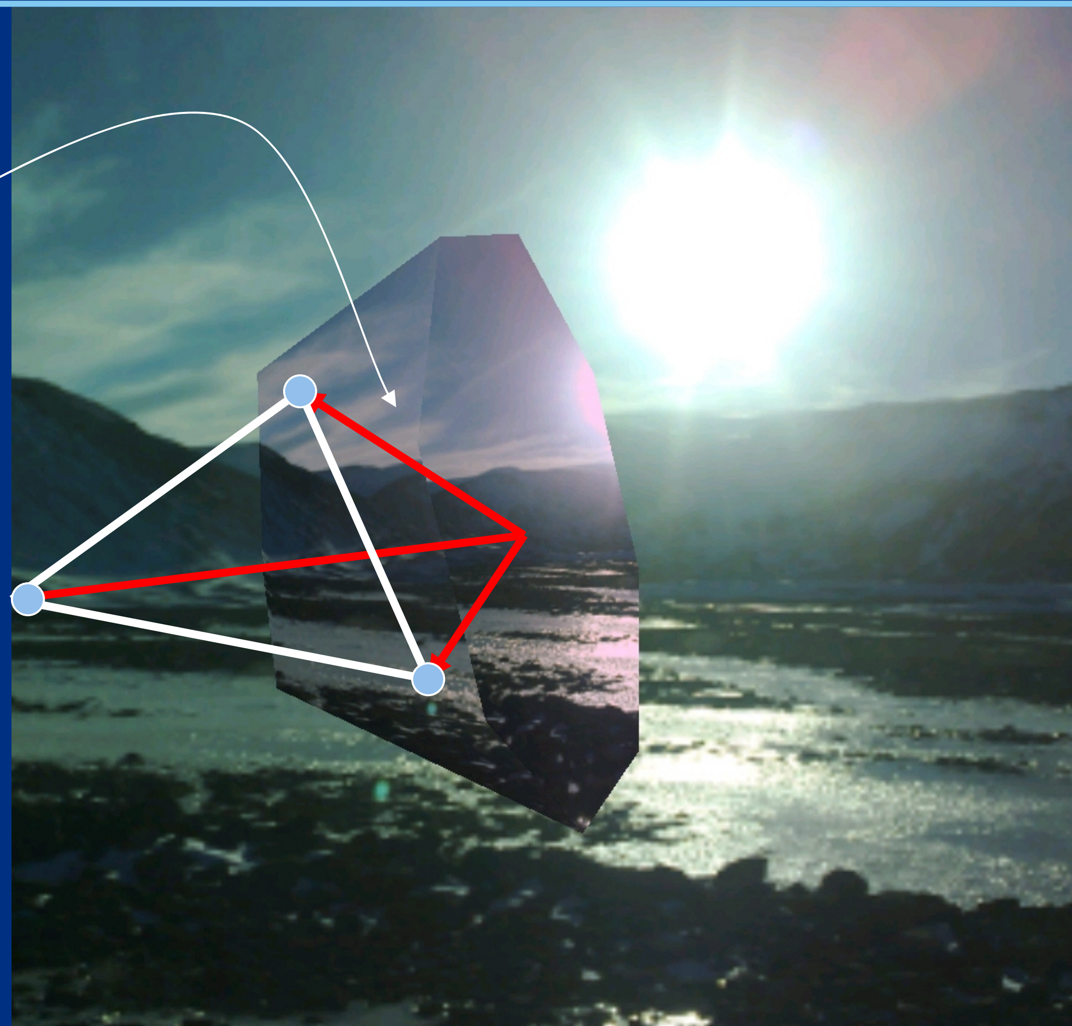
```
/* Setup texture */
glEnable              ( GL_TEXTURE_2D );

glGenTextures         ( 1, texture_handle );
glBindTexture         ( GL_TEXTURE_2D,  texture_handle );
glTexImage2D          ( GL_TEXTURE_2D,  0, GL_RGB, 256, 256, 0,
                        GL_RGB, GL_UNSIGNED_BYTE, texture_data );
glTexEnvi             ( GL_TEXTURE_ENV, GL_TEXTURE_ENV_MODE,
                        GL_MODULATE );
glTexParameteri       ( GL_TEXTURE_2D,  GL_TEXTURE_MIN_FILTER,
                        GL_LINEAR );
glTexParameteri       ( GL_TEXTURE_2D,  GL_TEXTURE_MAG_FILTER,
                        GL_LINEAR );
glTexParameteri       ( GL_TEXTURE_2D,  GL_TEXTURE_WRAP_S,
                        GL_CLAMP_TO_EDGE );
glTexParameteri       ( GL_TEXTURE_2D,  GL_TEXTURE_WRAP_T,
                        GL_CLAMP_TO_EDGE );
}
```

Texture matrix example

```
int render(float time)
{
    glClear          ( GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT );

    /* draw background with two textured triangles */
    glMatrixMode          ( GL_TEXTURE );
    glLoadIdentity        ( );
    glMatrixMode          ( GL_PROJECTION);
    glLoadIdentity        ( );
    glMatrixMode          ( GL_MODELVIEW);
    glLoadIdentity        ( );
    glColor4ub            ( 255, 255, 255, 255 );
    glScalef              ( 2.f, -2.f, 0.f );
    glTranslatef          ( -0.5f, -0.5f, 0.f );
    glVertexPointer       ( 2, GL_BYTE, 0, back_coords );
    glTexCoordPointer     ( 2, GL_BYTE, 0, back_coords );
    glDrawArrays          ( GL_TRIANGLE_STRIP, 0, 4 );
```

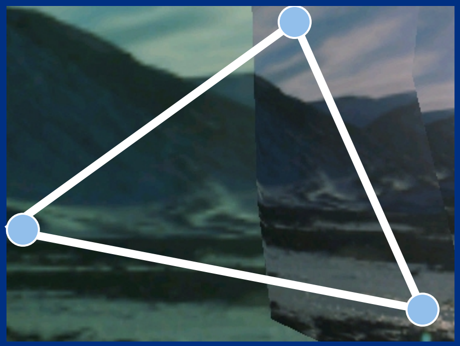
Texture matrix example, coordinates

Texture ”normals”



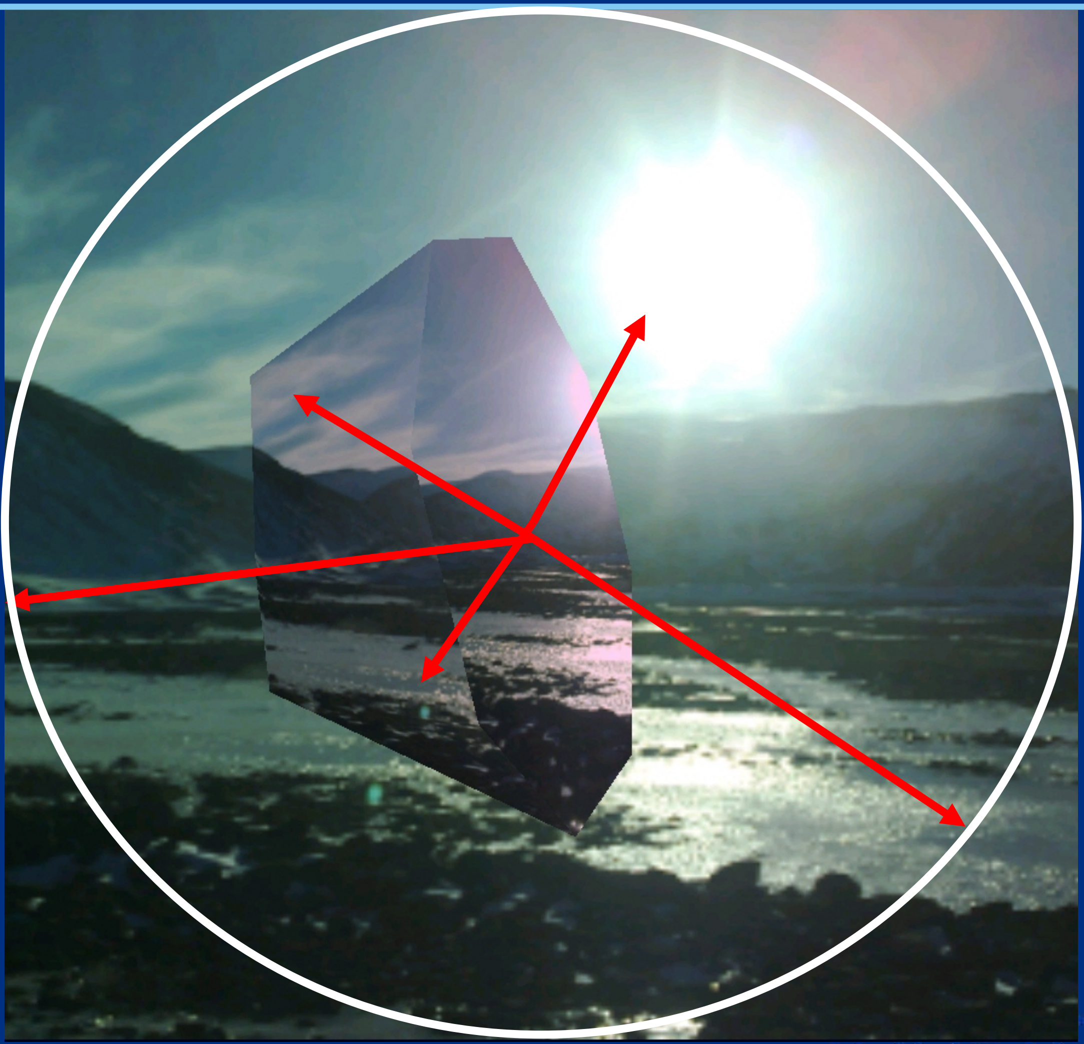
Vertex coordinates

Texture matrix example, coordinates

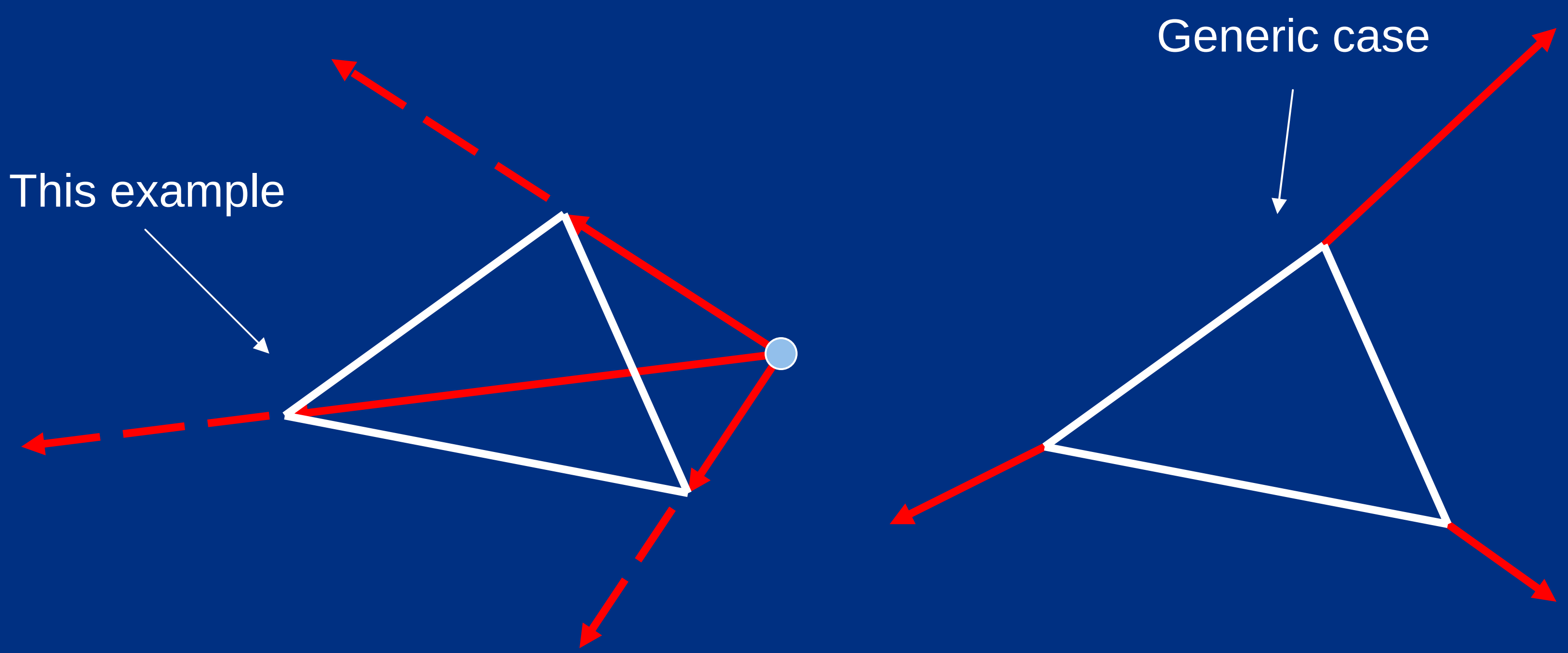


We just take the (x,y) of the texture coordinate output

Texture matrix example, coordinates



Texture matrix example, coordinates



In this example we use the same data for vertex and texture ”normals” as the object is cut away from roughly tesselated sphere (all coordinates unit length)

This is NOT possible for general objects. You should use separate normalized normals for other objects

Texture matrix example

```
glMatrixMode     ( GL_PROJECTION );
glLoadIdentity   ( );
glFrustumf       ( -1.f, 1.f, -1.f, 1.f, 3.f, 1000.f );

glMatrixMode     ( GL_MODELVIEW );
glLoadIdentity   ( );
glTranslatef     ( 0, 0, -5.f );
glRotatef        ( time*25, 1.f, 1.f, 0.f );   /* (1) */
glRotatef        ( time*15, 1.f, 0.f, 1.f );

glMatrixMode     ( GL_TEXTURE );
glLoadIdentity   ( );
glTranslatef     ( 0.5f, 0.5f, 0.f );        /* [-0.5,0.5] -> [0,1]     */
glScalef         ( 0.5f, -0.5f, 0.f );       /* [-1,1]   -> [-0.5,0.5] */
glRotatef        ( time*25, 1.f, 1.f, 0.f );  /* identical rotations! */
glRotatef        ( time*15, 1.f, 0.f, 1.f );  /* see (1) */
```

Texture matrix example

```
    /* use different color for the (glass) object vs. the background */
    glColor4ub          ( 255, 210, 240, 255 );
    glVertexPointer     ( 3,GL_FIXED, 0, vertices );
    glTexCoordPointer   ( 3,GL_FIXED, 0, vertices );
    glDrawArrays        ( GL_TRIANGLES, 0, 16*3 );
}
```

Texture matrix example

Fixed point programming

- Why should you use it?
  - Most mobile handsets don't have a FPU
- Where does it make sense to use it?
  - Where it makes the most difference
  - For per-vertex processing: morphing, skinning, etc.
  - Per vertex data shouldn't be floating point
- OpenGL ES API supports 32-bit FP numbers

Fixed point programming

- There are many variants of fixed point:
  - Signed / Unsigned
  - 2's complement vs. Separate sign
- OpenGL ES uses 2's complement
- Numbers in the range of [-32768, 32768 [
- 16 bits for decimal bits (precision of 1/65536)
- All the examples here use 16.16 fixed point

Float to fixed and vice versa

- Convert from floating point to fixed point

```
#define float_to_fixed(a)  (int)((a)*(1<<16))   or
#define float_to_fixed(a)  (int)((a)*(65536))
```

- Convert from fixed point to floating point

```
#define fixed_to_float(a)  (((float)a)/(1<<16)) or
#define fixed_to_float(a)  (((float)a)/(65536))
```

Fixed point programming

- Examples:

```
0x0001 0000 =  65536        =     "1.0f"
0x0002 0000 =  2*65536      =     "2.0f"
0x0010 0000 =  16*65536     =     "16.0f"
0x0000 0001 =  1/65536      =     "0.0000152587…"
0xffff ffff = -1/65536(-0x0000 0001)
```

Fixed point operations

- Addition

```
#define add_fixed_fixed(a,b) ((a)+(b))
```

- Multiply fixed point number with integer

```
#define mul_fixed_int(a,b) ((a)*(b))
```

- MUL two FP numbers together

```
 #define mul_fixed_fixed(a,b)                              \
          (int)((((int64)a)*((int64)b)) >> 16)
```

Fixed point operations and scale

Addition:

a & b = original float values

S = fixed point scale (e.g., 65536)

result = (a * **S**) + (b * **S**) = (a + b) * **S**

- **Scaling term keeps the same**
- **Range of the result is 33 bits**
- **Possible overflow by 1 bit**

Fixed point operations and scale

Multiplication:

a & b = original float values

S = fixed point scale (e.g., 65536)

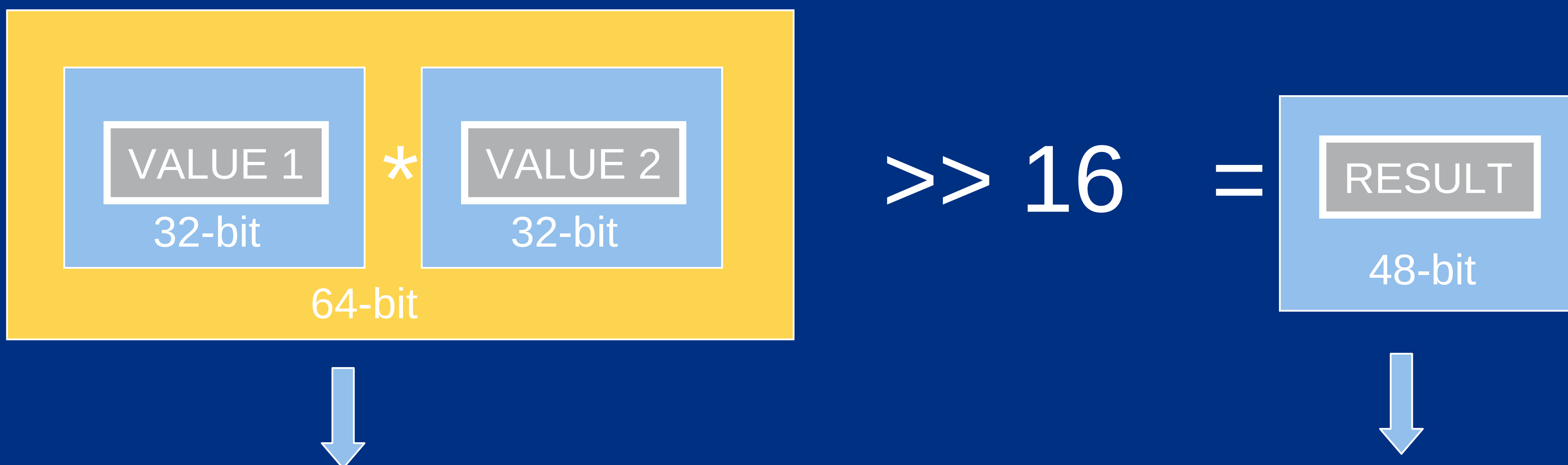
result = (a * S) * (b * S) = ((a * b) * S^2)

final = ((a * b) * S^2) / S = (a * b) * S

- Scaling term is squared (S^2) and takes 32 bits
- Also the integer part of the multiplication takes 32 bits

=> need 64 bits for full s16.16 * s16.16 multiply

Fixed point programming



Intermediate overflow

- Higher accuracy (64-bit)
- Downscale input
- Redo range analysis

Result overflow (48 bits)

- Redo range analysis
- Detect overflow, clamp

Fixed point programming

- Division of integer by integer to a fixed point result

```
#define div_int_int(a,b)                        \
        (int)((((int64)a)*(1<<16))/(b))
```

(a*S)/ b = (a/b)*S

- Division of fixed point by integer to a fixed point result

```
#define div_fixed_int(a,b) ((a)/(b))
```

- Division of fixed point by fixed point

```
#define div_fixed_fixed(a,b)                    \
        (int)((((int64)a)*(1<<16))/(b))
```

(a*S*S)/(b*S) = (a/b)*S

Fixed point programming

- Power of two MUL & DIV can be done with shifts
  - a * 65536 = a << 16,   a / 256 = a >> 8
- Fixed point calculations overflow easily
- Careful analysis of the range requirements is required

=>

Always add validation code to your fixed point code

Fixed point programming

```
#if defined(DEBUG)
int add_fix_fix_chk(int a, int b)
{
  int64 bigresult = ((int64)a) + ((int64)b);
  int smallresult = a + b;
  assert(smallresult == bigresult);
  return smallresult;
}
#endif

#if defined(DEBUG)
#  define add_fix_fix(a,b) add_fix_fix_chk(a,b)
#else
#  define add_fix_fix(a,b) ((a)+(b))
#endif
```

Fixed point math functions

- Complex math functions
  - Pre-calculate for the range of interest

- An example: Sin & Cos
  - Sin table between [0, 90°], fixed point angle (S = 2048)
  - Generate other angles and Cos from the table
  - Store in a short table (16-bit) as s0.16 (S = 32768)
  - Range for shorts is [-32768,32767] ([-1.0, 1.0[for s0.16 FP)
  - Equals to [-1.0, +1.0[for s0.16 FP (+1.0 not included !)
  - Negative values stored in the table (can represent -1.0)

Sin table precalculation

```
void calculate_table(short *out)
{
  int i;

  for(i=0;i<2048;i++)
  {
     float angle = (0.5f*PI*i)/2048.0;
     out[i] = -(int)(sin(angle)*32768);
  }
}
```

Sin function

```
inline int fp_sin(int angle)
{
  int ph    = angle & (2048 + 4096);  /* phase */
  int ang   = angle & 2047;           /* sub-angle */

  /* return negated values (was stored negated) */
  if(ph == 0)          return -((int)table[ang]);
  else if(ph == 2048) return -((int)table[2048-ang]);
  else if(ph == 4096) return  (int)table[ang];
  else                 return  (int)table[2048-ang];
}
```

How to use fp_sin()

```
void do_something(int ang)
{
  int i;

  for( i=0; i<1000; i++)
  {
      int tmp;
      tmp = (vin[i*3] * fp_sin(ang)) >> 15;
      vout[i*3] = tmp;
  }
}
```

- note: fp_sin returns integers
  => it can also return 32768 (1.0)

- it does not fit inside s0.16 fixed point number !

Performance

- fp_sin() is rather complex
- Simple optimization: calculate 360 degrees
- Downside: takes more memory
- And: to handle 1.0 we have to use S = 16384

Sin table precalculation (360 deg)

```
void calculate_table(short *out)
{
  int i;

  for(i=0;i<2048*4;i++)
  {
     float angle = (2.f*PI*i)/2048.0;
     out[i] = (int)(sin(angle)*16384;
  }
}
```

Sin function (360 deg)

```
inline int fp_sin(int angle)
{
  return ((int)table[angle & 8191]);
}
```

Example: Simple morphing (LERP)

- Simple fixed point morphing loop (16-bit data, 16-bit coeff)

```
#define DOLERP_16(a,b,t) (short)((((b)-(a))*(t))>>16)+(a))

void lerpgeometry(short *out, const short *inA, const short *inB,
   int count, int scale)
{
   int i;

   for(i=0; i<count; i++)
   {
        out[i*3+0] = DOLERP_16(inB[i*3+0], inA[i*3+0], scale);
        out[i*3+1] = DOLERP_16(inB[i*3+1], inA[i*3+1], scale);
        out[i*3+2] = DOLERP_16(inB[i*3+2], inA[i*3+2], scale);
   }
}
```

Converting existing code

- OS/device conversions
  - Programming model, C/C++, compiler, CPU
- Windowing API conversion
  - EGL API is mostly cross platform
  - EGL Native types are platform specific
- OpenGL -> OpenGL ES conversion

Example: Symbian porting

Programming model

- C++ with some changes (e.g., exceptions)
- Event based programming (MVC), no main / main loop
- Three level multitasking: Process, Thread, Active Objects

- ARM CPU
  - Unaligned memory accesses will cause exception (unlike x86)

- OpenC (http://www.forum.nokia.com/openc)

Example: EGL porting

- Native types are OS specific
  - EGLNativeWindowType (RWindow *)
  - EGLNativePixmapType (CFbsBitmap *)
  - Pbuffers are portable
- Config selection
  - Select the color depth to be same as in the display
- Windowing system issues
  - What if render window is clipped by a system dialog?
  - Only full screen windows may be supported

OpenGL porting

- glBegin/glEnd wrappers
  - _glBegin stores the primitive type
  - _glColor changes the current per-vertex data
  - _glVertex stores the current data behind arrays and increments
  - _glEnd calls glDrawArrays with primitive type and length

```
_glBegin(GL_TRIANGLES);
   _glColor4f(1.0,0.0,0.0,1.0);
   _glVertex3f(1.0,0.0,0.0);
   _glVertex3f(0.0,1.0,0.0);
   _glColor4f(0.0,1.0,0.0,1.0);
   _glVertex3f(0.0,0.0,1.0);
_glEnd();
```

OpenGL porting

- Display list wrapper
  - Add the display list functions as wrappers
  - Add all relevant GL functions as wrappers
  - When drawing a list, go through the collected list

OpenGL porting

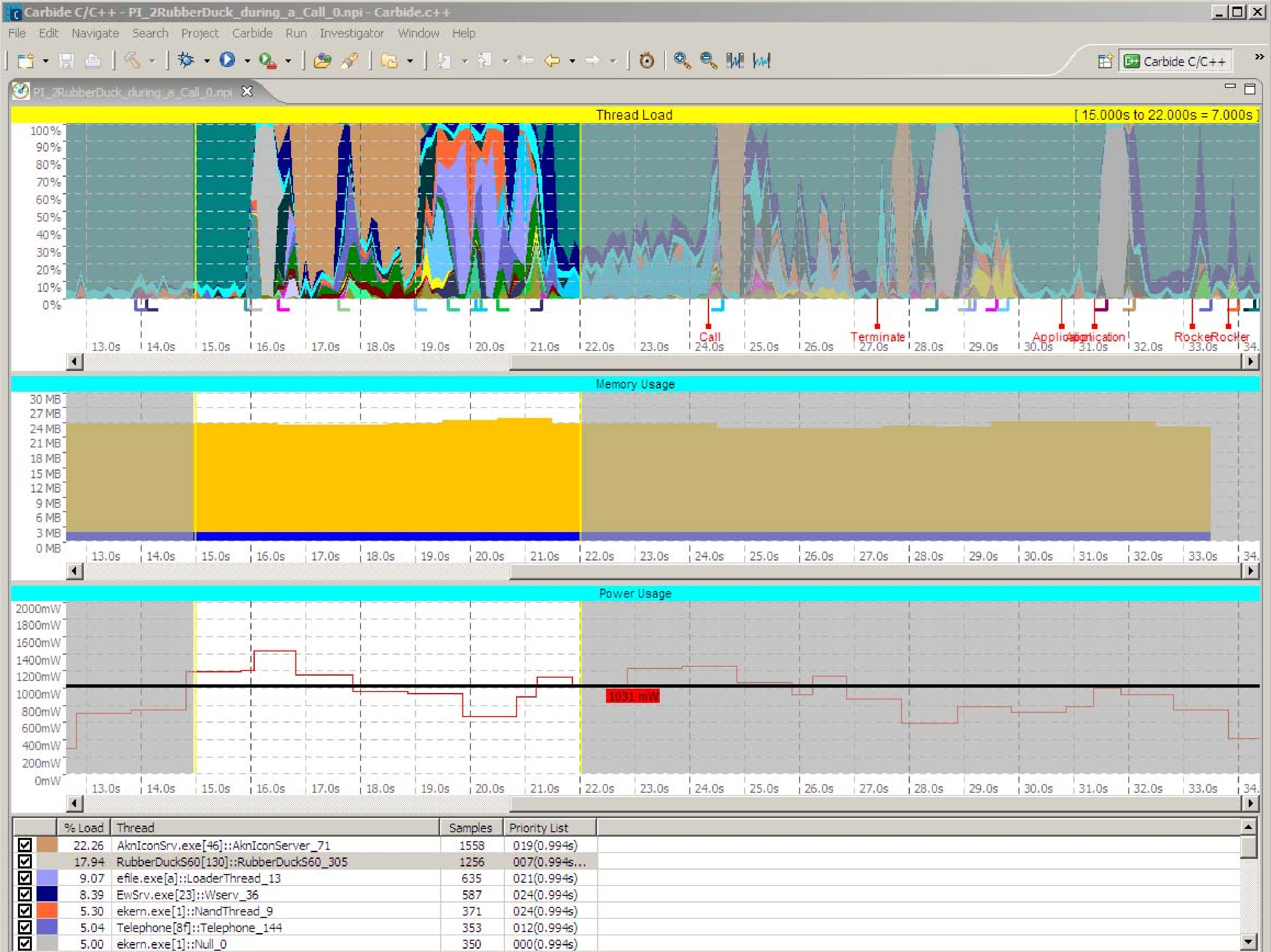
```
void _glEnable( par1, par2 )
{
  if( GLOBAL()->iSubmittingDisplayList )
  {
    *(GLOBAL()->dlist)++ = DLIST_CMD_GLENABLE;
    *(GLOBAL()->dlist)++ = (GLuint)par1;
    *(GLOBAL()->dlist)++ = (GLuint)par2;
  }
  else
  {
    glEnable(par1,par2);
  }
}
```

OpenGL porting

- Vertex arrays
  - OpenGL ES supports only vertex arrays
  - SW implementations get penalty from float data
  - Use as small types as possible (byte, short)
  - For HW it shouldn't make a difference, mem BW
  - With OpenGL ES 1.1 always use VBOs

OpenGL porting

- No quads
  - Convert a quad into 2 triangles
- No real two-sided materials in lighting
  - If you really need it, submit front and back triangles
- OpenGL ES and querying state
  - OpenGL ES 1.0 only supports static getters
  - OpenGL ES 1.1 supports dynamic getters
  - For OpenGL ES 1.0, create own state tracking if needed


Carbide C/C++ - PI_2RubberDuck_during_a_Call_0.npi - Carbide.c++
File Edit Navigate Search Project Carbide Run Investigator Window Help
Carbide C/C++
PI_2RubberDuck_during_a_Call_0.npi
Thread Load
[15.000s to 22.000s = 7.000s]
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Call
Terminate
Application
Application
Rocker
Rocker
13.0s 14.0s 15.0s 16.0s 17.0s 18.0s 19.0s 20.0s 21.0s 22.0s 23.0s 24.0s 25.0s 26.0s 27.0s 28.0s 29.0s 30.0s 31.0s 32.0s 33.0s
Memory Usage
30 MB
27 MB
24 MB
21 MB
18 MB
15 MB
12 MB
9 MB
6 MB
3 MB
0 MB
Power Usage
2000mW
1800mW
1600mW
1400mW
1200mW
1000mW
800mW
600mW
400mW
200mW
0mW
1031 mW
% Load | Thread | Samples | Priority List
22.26 | AknIconSrv.exe[46]::AknIconServer_71 | 1558 | 019(0.994s)
17.94 | RubberDuckS60[130]::RubberDuckS60_305 | 1256 | 007(0.994s...
9.07 | efile.exe[a]::LoaderThread_13 | 635 | 021(0.994s)
8.39 | EwSrv.exe[23]::Wserv_36 | 587 | 024(0.994s)
5.30 | ekern.exe[1]::NandThread_9 | 371 | 024(0.994s)
5.04 | Telephone[8f]::Telephone_144 | 353 | 012(0.994s)
5.00 | ekern.exe[1]::Null_0 | 350 | 000(0.994s)

Demo

- Sequel to game One (Nokia)

Questions?

? ? ?

SIGGRAPH2007

OpenGL ES on PyS60

Kari Pulli

Nokia Research Center

Python: Great for rapid prototyping

- Python
  - designed to be as small, practical, and open as possible
  - easy and fun OO programming
- sourceforge.net/projects/pyS60
  - Python 2.2.2 on Symbian S60
  - wrappers for phone SDK libraries
  - can extend in Symbian C++

Python bindings to OpenGL ES

- Almost direct bindings
- OpenGL ES functions that take in pointers typically take in a Python list
- Next we'll show a full S60 GUI program with OpenGL ES

Import libraries

```
import appuifw    # S60 ui framework
import sys


from glcanvas  import *
from gles      import *
from key_codes import *
```

Application class, data

```
class Hello:
    vertices = array( GL_BYTE, 3,
                      [-1, 1, 0,
                        1,-1, 0,
                        1, 1, 0] )
    colors = array( GL_UNSIGNED_BYTE, 4,
                    [255, 0,   0,  255,
                      0, 255,   0,  255,
                      0,   0, 255,  255] )
```

Initialize the application

```
def __init__(self):                               # class constructor
    self.exiting = False                          # while !exit, run
    self.frame, self.angle = 0, 0                 # set variables
    self.old_body = appuifw.app.body
    try:                                          # create surface
        c = GLCanvas( redraw_callback = self.redraw,
                      resize_callback = self.resize )
        appuifw.app.body = c
        self.canvas = c
    except Exception, e:
        appuifw.note( u"Exception: %s" % (e) )
        self.start_exit()
        return
    appuifw.app.menu = [(u"Exit", self.start_exit)]
    c.bind( EKeyLeftArrow,  lambda:self.left() )
    c.bind( EKeyRightArrow, lambda:self.right() )
    self.initgl()
```

Keyboard and resize callbacks

```
def left(self):
    self.angle -= 10

def right(self):
    self.angle += 10

def resize(self):
    if self.canvas:
        glViewport( 0, 0,
                    self.canvas.size[0],
                    self.canvas.size[1] )
```

Main loop

```
def start_exit(self):
    self.exiting = True

def run(self):
    app = appuifw.app
    app.exit_key_handler = self.start_exit
    while not self.exiting:
        self.canvas.drawNow()
        e32.ao_sleep( 0.01 )
    app.body             = self.old_body
    self.canvas          = None
    app.exit_key_handler = None
```

Initialize OpenGL ES

```
def initgl(self):
    glMatrixMode( GL_PROJECTION )
    glFrustumf  ( -1.0, 1.0, -1.0, 1.0,
                  3.0, 1000.0 )
    glMatrixMode( GL_MODELVIEW )
    glDisable   ( GL_DEPTH_TEST )
    glShadeModel( GL_SMOOTH )
    glClearColor( 0.0, 0.0, 0.1, 1.0 )
    glVertexPointerb( self.vertices )
    glColorPointerub( self.colors )
    glEnableClientState( GL_VERTEX_ARRAY )
    glEnableClientState( GL_COLOR_ARRAY )
```

Draw cycle

```
def redraw(self, frame=None):
    if self.canvas:
        glClear( GL_COLOR_BUFFER_BIT )
        glLoadIdentity()
        glTranslatef( 0.0, 0.0, -5.0 )
        glRotatef   ( self.angle,
                      0.0, 0.0, 1.0 )
        glRotatef   ( self.frame,
                      0.0, 1.0, 0.0 )
        glDrawArrays( GL_TRIANGLES, 0,3 )
        self.frame += 1
```

Using the class

```
appuifw.app.screen = 'full'
try:
    app = Hello()
except Exception, e:
    appuifw.note( u"Cannot start: %s" %
                  (e) )
else:
    app.run()
del app
```

SIGGRAPH2007

High-performance OpenGL ES 1.x

Ville Miettinen

NVIDIA

Targeting the ”mobile platform”

- CPU speed and available memory varies
  - Current range ~30Mhz - 600MHz, ARM7 to ARM11, no FPUs
- Different resolutions
  - QCIF (176x144) to VGA (640x480), antialiasing on higher-end devices
  - Color depths 4-8 bits per channel (12-32 bpp)
- Portability issues
  - Different CPUs, OSes, Java VMs, C compilers, ...
  - OpenKODE from the Khronos Group will help to some extent

Graphics capabilities

- General-purpose multimedia hardware
  - Pure software renderers (all done using CPU & integer ALU)
  - Software + DSP / WMMX / FPU / VFPU
  - Multimedia accelerators
- Dedicated 3D hardware
  - Software T&L + HW tri setup / rasterization
  - Full hardware acceleration
- Performance: 50K – 2M tris, 1M – 100M pixels / sec
- Next gen: 30M+ tris, 1000M pixels / sec

Standards help somewhat

- Act as hardware abstraction layers
  - Provide programming interface (API)
  - Same feature set for different devices
  - Unified rendering model
- Performance cannot be guaranteed

Scalability

- Successful application has to run on hundreds of different phone models
  - No single platform popular enough
- Same game play but can scale video and audio
- Design for lowest-end, add eye candy for high-end
  - Scalability has to be built into the design

3D content is easy to scale

- Separate low and high poly count 3D models
- Different texture resolutions & compressed formats
- Rendering quality can be scaled
  – Texture filtering, perspective correction, blend functions, multi-texturing, antialiasing

Special effects

- Identify special effects
  - Bullet holes, skid marks, clouds, ...
  - Cannot have impact on game play
    - Fog both game play and visual element
    - Multiplayer games have to be fair
- Users can alter performance by controlling effects

Tuning down the details

- Particle systems
  - Number of particles, complexity, visuals
  - Shared rendering budget for all particle systems
- Background elements
  - Collapse into sky cubes, impostors
- Detail objects
  - Models to have “important” and “detail” parts

Profiling

- Performance differences often system integration issues - not HW issues
- Measuring is the only effective way to find out how changes in code affect performance
- Profile on actual target device if possible
- Public benchmark apps provide some idea of graphics performance
- gDEBugger ES for gfx driver profiling

Identifying bottlenecks

- Three groups: application code, vertex pipeline, pixel pipeline
  – Further partitioned into pipeline stages
  – Overall pipeline runs as fast as its slowest stage
- Locate bottlenecks by going through each stage and reducing its workload
  – If performance changes, you have a bottleneck
- Apps typically have multiple bottlenecks

Pixel pipeline bottlenecks

- Find out by changing rendering resolution
  - If performance increases, you have a bottleneck
  - Either texturing or frame buffer accesses
- Remedies
  - Smaller screen resolution, render fewer objects, use simpler data formats, smaller texture maps, less complex fragment and texture processing

Vertex pipeline bottlenecks

- Vertex processing or submission bottlenecks
  - Find out by rendering every other triangle but using same vertex arrays
- Remedies
  - Submission: smaller data formats, cache-friendly organization, fewer triangles
  - Vertex processing: simpler T&L (fewer light sources, avoid dynamic lighting and fog, avoid floating-point data formats)

Application code bottlenecks

- Two ways to find out
  - Turn off all application logic
  - Turn off all rendering calls
- Floating-point code #1 culprit
- Use profiler
  - HW profilers on real devices costly and hard to get
  - Carbide IDE from Nokia (S60 and UIQ Symbian)
  - Lauterbach boards
  - Desktop profiling (indicative only)

Changing and querying the state

- Rendering pipes are one-way streets
- Apps should know their own state
  - Avoid dynamic getters if possible!
- Perform state changes in a group at the beginning of a frame
- Avoid API synchronization
  - Do not mix 2D and 3D libraries!

”Shaders”

- Combine state changes into blocks (”shaders”)
  - Minimize number of shaders per frame
  - Typical application needs only 3-10 ”pixel shaders”
    - Different 3-10 shaders in every application
    - Enforce this in artists’ tool chain
- Sort objects by shaders every frame
  - Split objects based on shaders

Complexity of shaders

- Software rendering: everything costs!
  - Important to keep shaders as simple as possible
    - Even if introduces additional state changes
    - Example: turn off fog & depth buffering when rendering overlays
- Hardware rendering: Usually more important to keep number of changes small

Model data

- Keep vertex and triangle data short and simple!
  - Better cache coherence, less memory used
- Make as few rendering calls as possible
  - Combine strips with degenerate triangles
- Weld vertices using off-line tool
- Order triangle data coherently
- Use hardware-friendly data layouts
  - Buffer objects allow storing data on server

Transformation pipeline

- Minimize matrix changes
  - Changing a matrix may involve many hidden costs
  - Combine simple objects with same transformation
  - Flatten and cache transformation hierarchies
- ES 1.1: Skinning using matrix palettes
  - CPU doesn’t have to touch vertex data
- ES 1.1: Point sprites for particle effects

Rendering pipeline

- Rendering order is important
  - Front-to-back improves depth buffering efficiency
  - Also need to minimize number of state changes!
- Use culling to speed up rendering pipeline
  - Conservative: frustum culling & occlusion culling
    - Portals and Potentially Visible Sets good for mobile
  - Aggressive culling
    - Bring back clipping plane in, drop detail & small objects

Lighting

- Fixed-function lighting pipelines are so 1990s
  - Drivers implemented badly even in desktop space
  - In practice only single directional light fast
  - OpenGL's attenuation model difficult to use
  - Spot cutoff and specular model cause aliasing
  - No secondary specular color
  - Flat shading sucks
  - Artifacts unless geometry heavily tessellated

Lighting (if you have to use it)

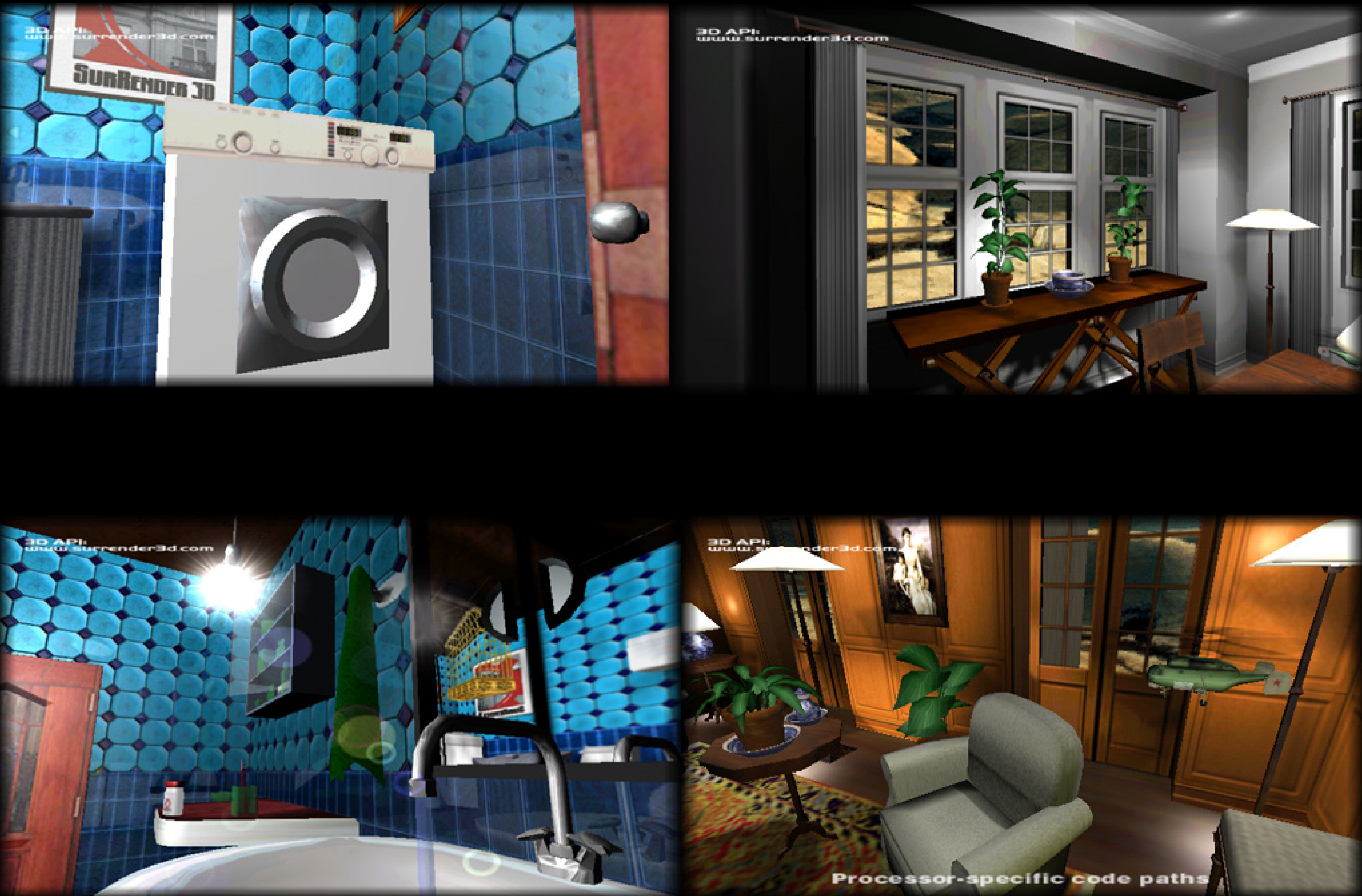
- Single directional light usually accelerated
- Pre-normalize vertex normals
- Avoid homogeneous vertex positions
- Turn off specular illumination
- Avoid distance attenuation
- Turn off distant non-contributing lights

Lighting: the fast way

- While we're waiting for OpenGL ES 2.0 drivers
  - Pre-computed vertex illumination good if slow T&L
  - Illumination using texturing
    - Light mapping
    - ES 1.1: dot3 bump mapping + texture combine
    - Less tessellation required
  - Combining with dynamic lighting: color material tracking

Environment mapping


MOTH

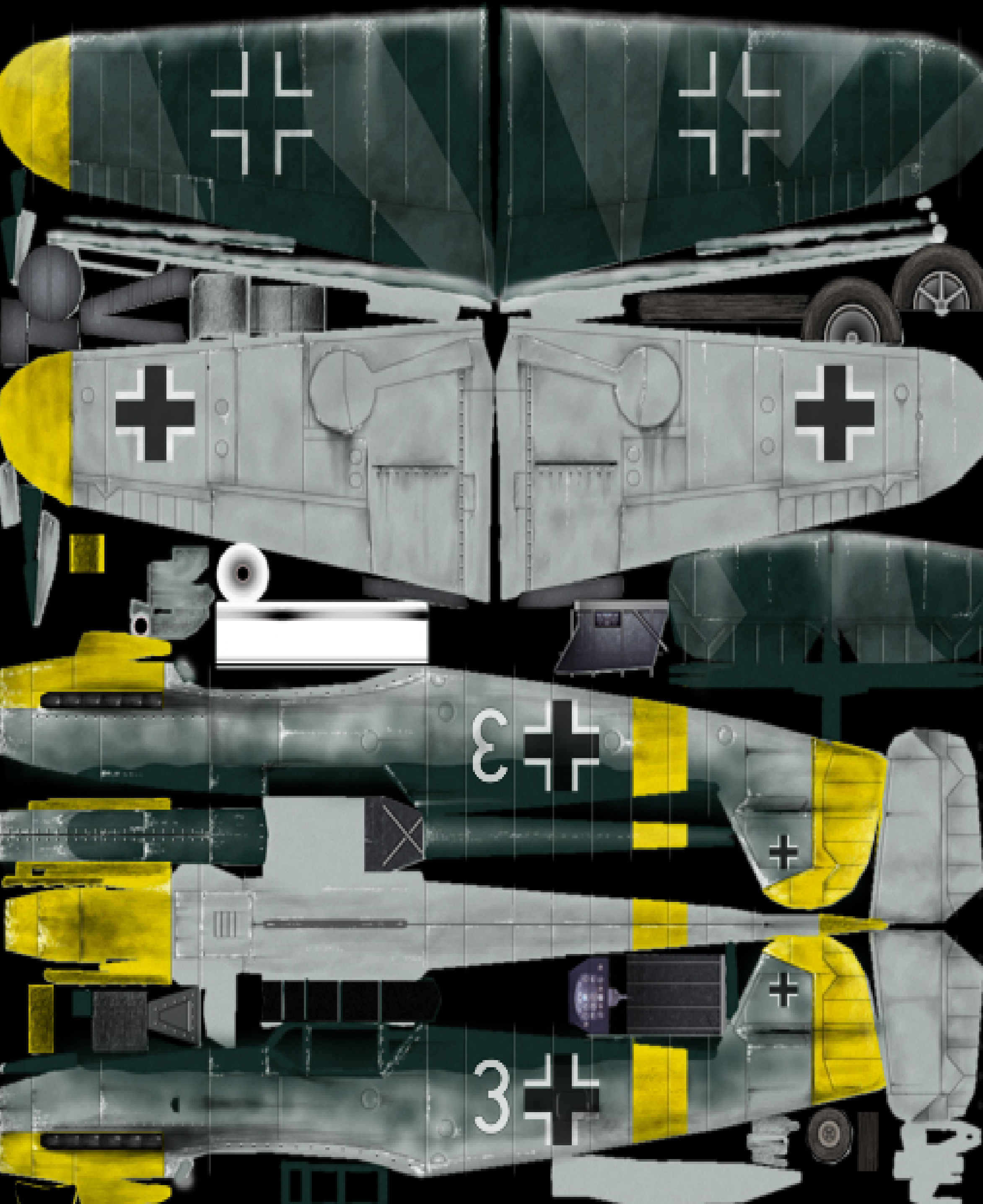

3D API:
www.surrender3d.com
SURRENDER 3D
3D API:
www.surrender3d.com
3D API:
www.surrender3d.com
3D API:
Processor-specific code paths

Textures

- Mipmaps always a Good Thing™
  - Improved cache coherence and visual quality
  - ES 1.1 supports auto mipmap generation
- Avoid modifying texture data
- Keep textures ”right size”, use compressed textures
- Different strategies for texture filtering & perspective correction
  - SW implementations affected

Textures (cont'd)

- Multitexturing
  - Always faster than doing multiple rendering passes
  - ES 1.1: support at least two texturing units
  - ES 1.1: TexEnvCombine neat toy
- Use small & compressed texture formats
- Texture atlases: combining multiple textures
  - Reduces texture state changes



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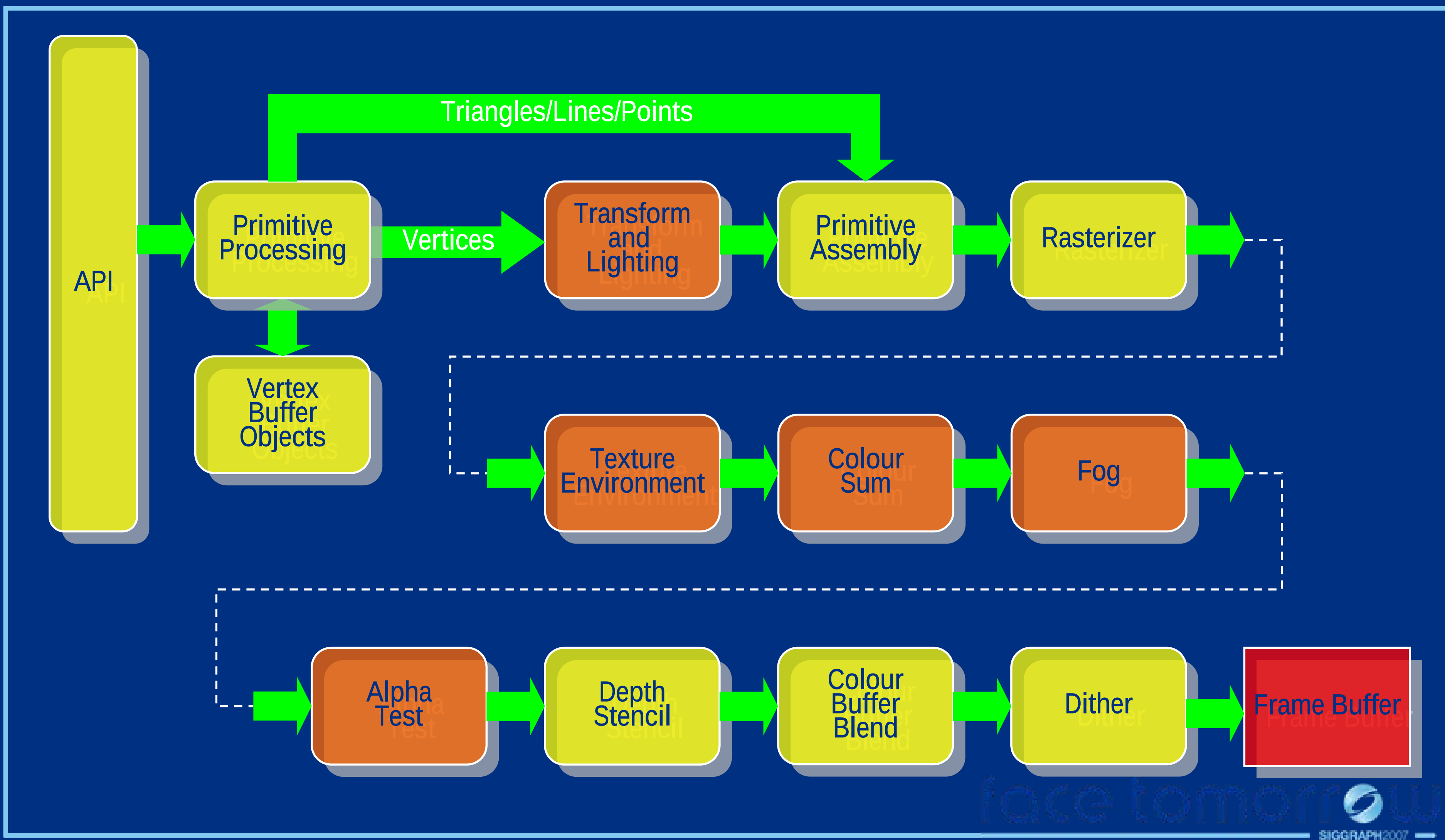
ES 2.0 Overview

SIGGRAPH2007

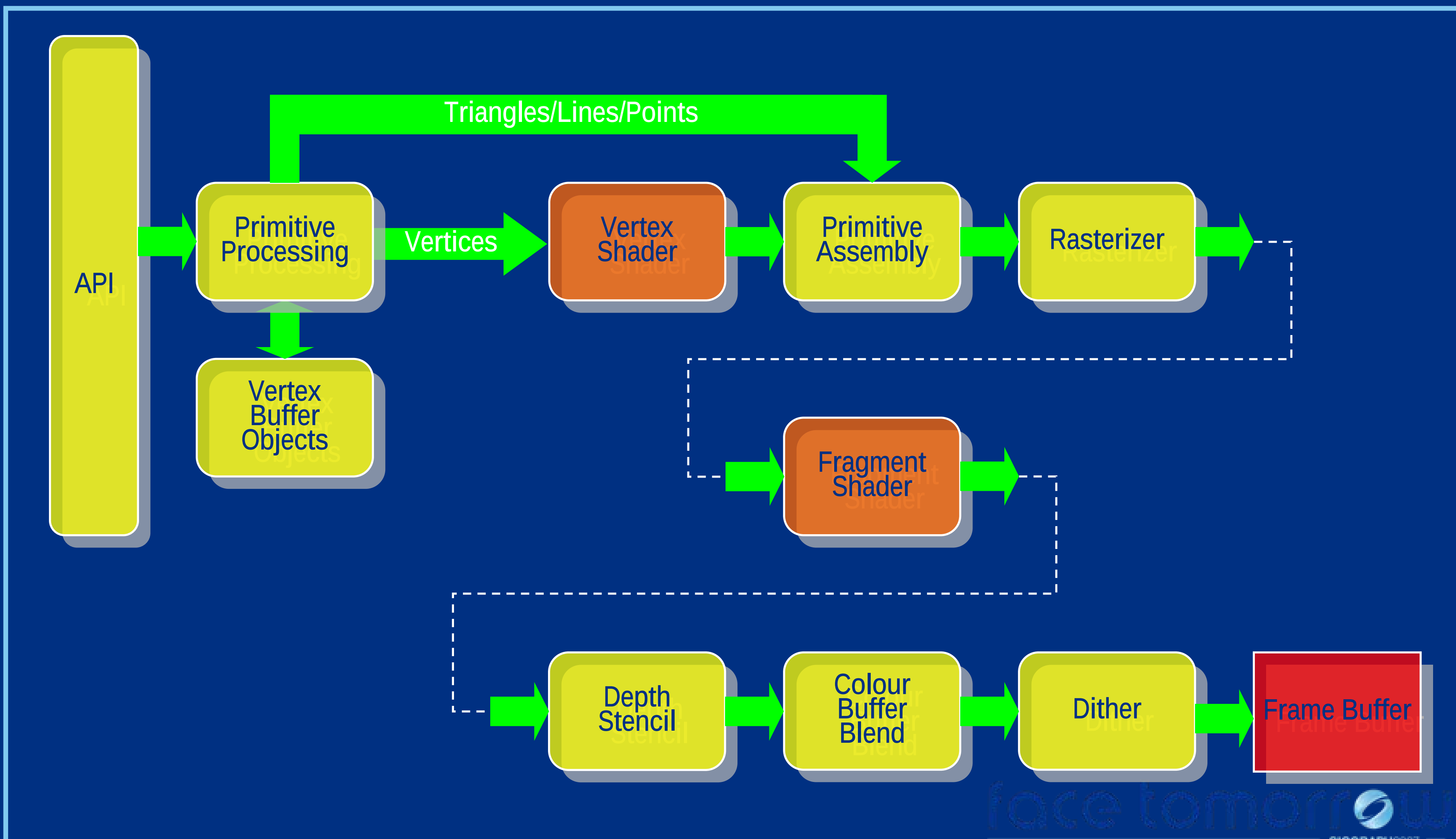
Robert J. Simpson
AMD

Contents

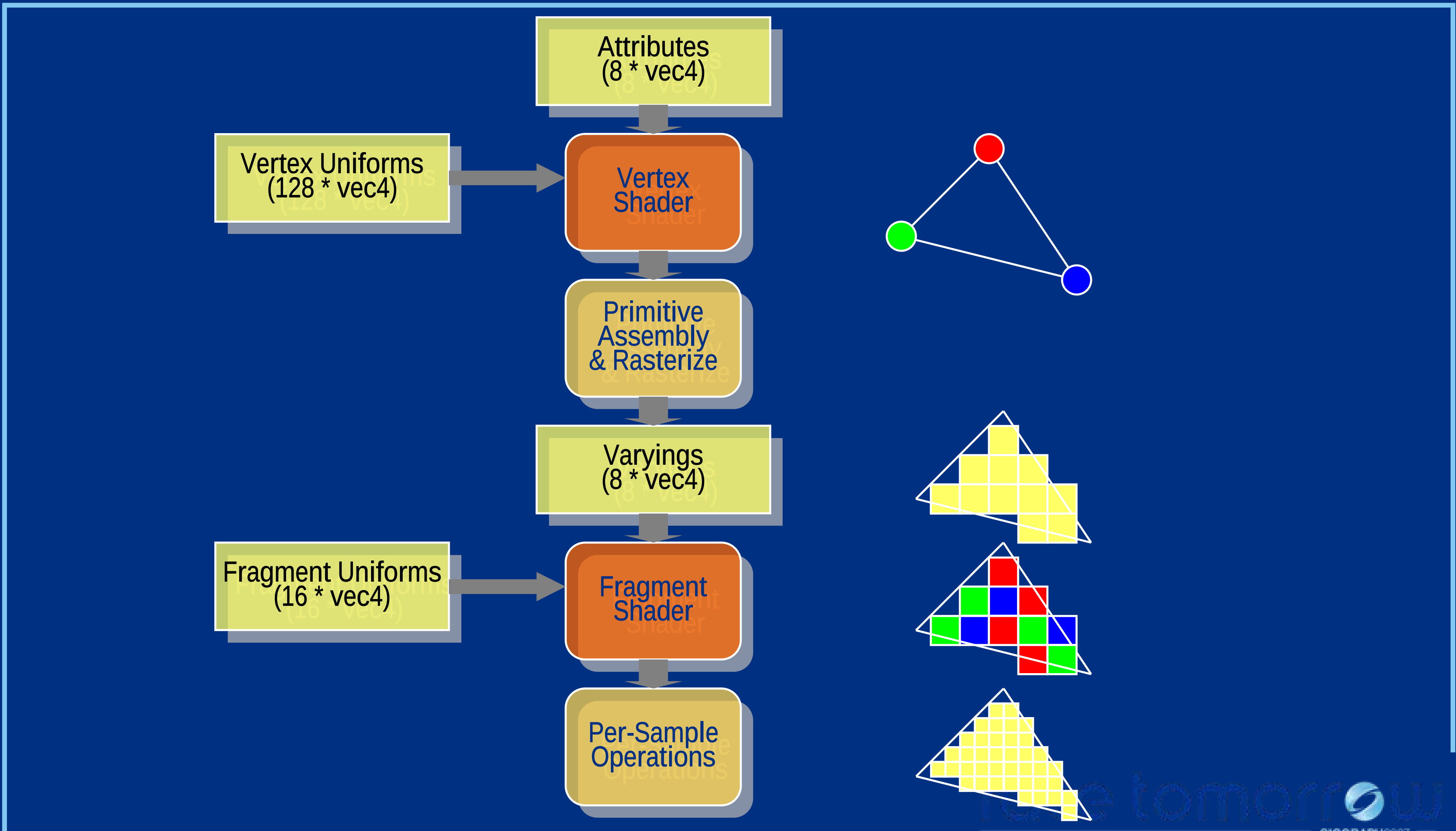
Open GL Fixed Function pipeline



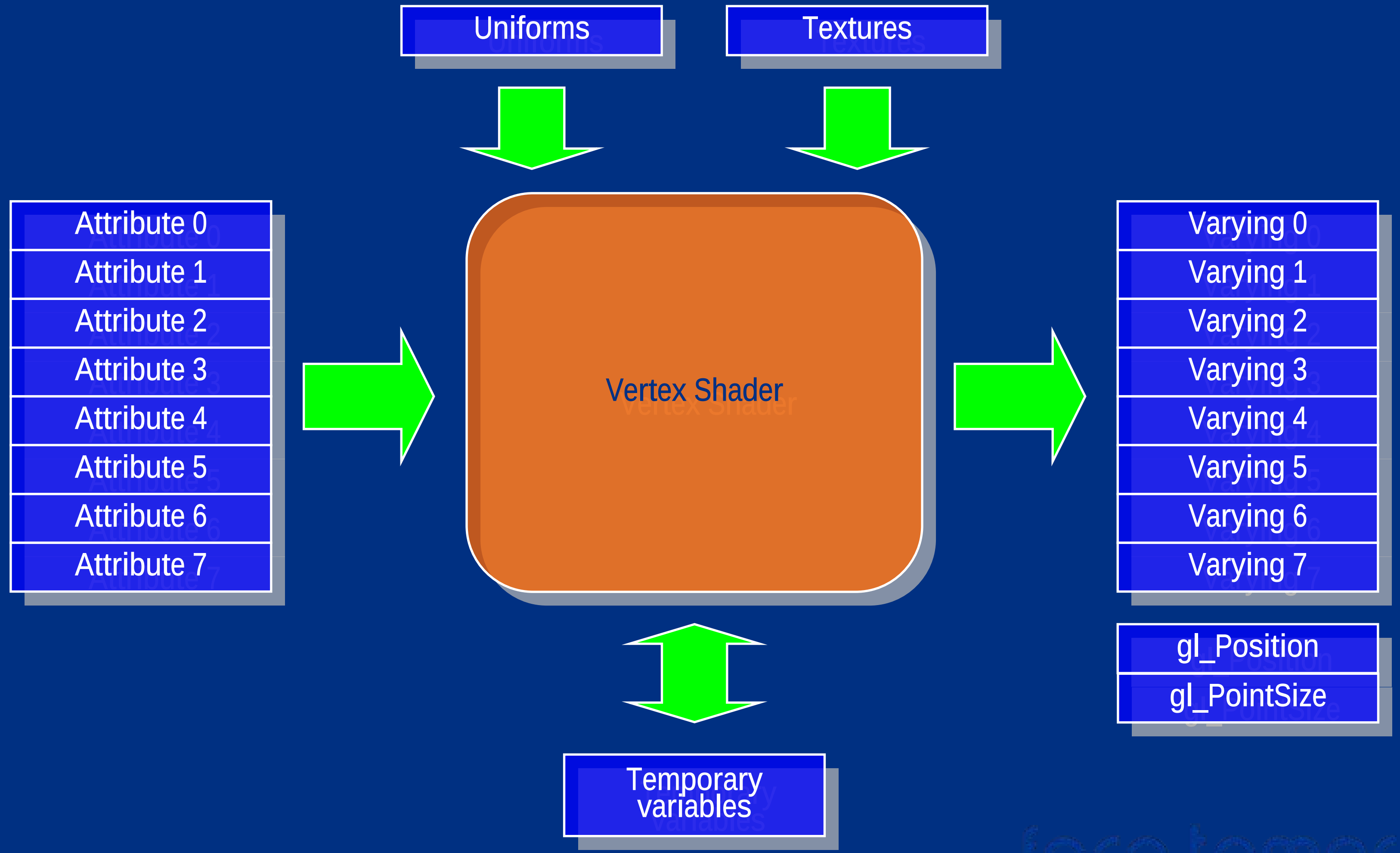
Open GL Programmable pipeline



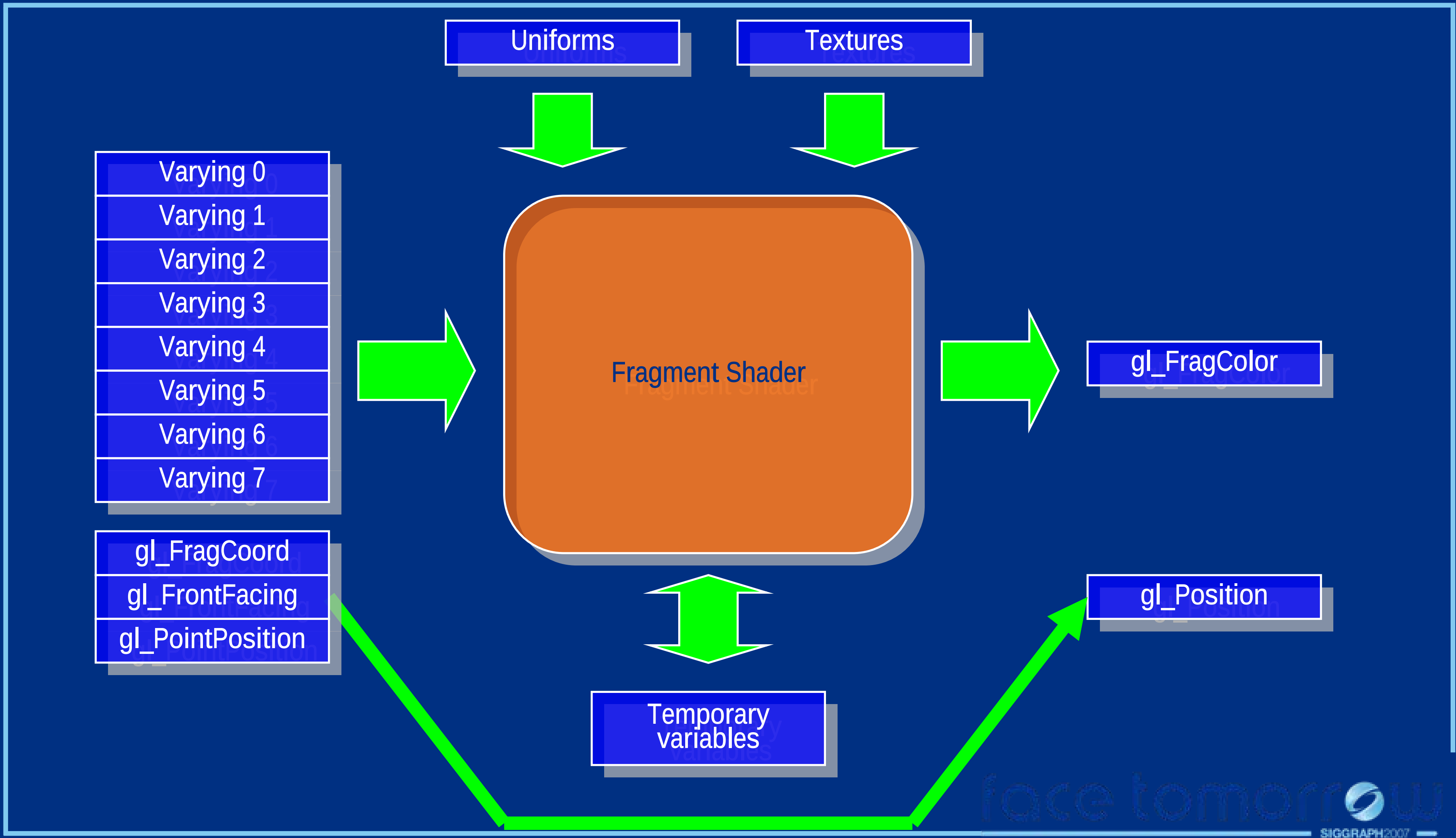
Programmer's model



Vertex Shader



Fragment Shader



The Vertex Shader

- The vertex shader can do:
  - Transformation of position using model-view and projection matrices
  - Transformation of normals, including renormalization
  - Texture coordinate generation and transformation
  - Per-vertex lighting
  - Calculation of values for lighting per pixel

The Vertex Shader

- The vertex shader cannot do:
  - Anything that requires information from more than one vertex
  - Anything that depends on connectivity.
  - Any triangle operations (e.g. clipping, culling)
  - Access colour buffer

The Fragment Shader

- The fragment shader can do:
  - Texture blending
  - Fog
  - Alpha testing
  - Dependent textures
  - Pixel discard
  - Bump and environment mapping

The Fragment Shader

- The fragment shader cannot do:
  - Blending with colour buffer
  - ROP operations
  - Depth or stencil tests
  - Write depth

GLSL ES Overview

- Based on GLSL as used in OpenGL 2.0
  - Open standard
- Pure programmable model
  - Most fixed functionality removed.
- Not 100% backward compatible with ES1.x
  - Embedded systems do not have the legacy requirements of the desktop
- No Software Fallback
  - Implementations (usually) hardware or nothing
  - Running graphics routines in software doesn't make sense on embedded platforms
- Optimized for use in Embedded devices
  - Aim is to reduce silicon cost
  - Reduced shader program sizes
  - Reduced register usage
  - Reduced numeric precision

GLSL ES Overview

- ‘C’ – like language
- Many simplifications
  - No pointers
  - Strongly typed. No implicit type conversion
  - Simplified preprocessor
- Some graphics-specific additions
  - Built-in vector and matrix types
  - Built-in functions
  - Support for mixed precisions
  - Invariance mechanism.
- Differences from Desktop OpenGL
  - Restrictions on shader complexity
  - Fewer sampler modes

GLSL ES Overview

- Comments
  `//`
  `/*   */`

- Control
  `#if`
  `#ifdef`
  `#ifndef`
  `#else`
  `#elif`
  `#endif`
  `#error`

- Operators
  `defined`

- Macros
  `#`
  `#define`
  `#undef`

- Extensions
  `#pragma`
  `#extension`

- Misc
  `#version`
  `#line`

GLSL ES Overview

- Scalar
  `void float int bool`
- Vector
  - boolean: `bvec2 bvec3 bvec4`
  - integer: `ivec2 ivec3 ivec4`
  - floating point: `vec2 vec3 vec4`
- Matrix
  - floating point `mat2 mat3 mat4`
- Sampler
  `sampler2D`
- Containers
  - Structures `struct`
  - Arrays `[]`

GLSL ES Storage Qualifiers

- **`const`**
  - Local constants within a shader.
- **`uniform`**
  - 'Constant shader parameters'
    (light position/direction, texture units, …)
  - Do not change per vertex.
- **`attribute`**
  - Per-vertex values (position, normal,…)
- **`varying`**
  - Generated by vertex shader
  - Interpolated by the rasterizer to generate per pixel values
  - Used as inputs to Fragment Shader
  - e.g. texture coordinates

Function parameter Qualifiers

- Used to pass values in or out or both e.g.

```
bool f(in vec2 in_v, out float ret_v)
{
        ...
}
```

- Qualifiers:

`in`	Input parameter. Variable can be modified
`const in`	Input parameter. Variable cannot be modified.
`out`	Output parameter.
`inout`	Input and output parameter.

- Functions can still return a value
  - But need to use a parameter if returning an array

Function Parameter Qualifiers

- Call by value ‘copy in, copy out’ semantics.
  - Not quite the same as c++ references:

```
bool f(inout float a, b)
{
        a++;
        b++;
}

void g()
{
        float x = 0.0;
        f(x,x);                 // x = 1.0 not 2.0
}
```

GLSL ES Overview

- Order of copy back is undefined

```
bool f(inout float a, b)
{
     a = 1.0;
     b = 2.0;
}

void g()
{
     float x ;
     f(x,x);   // x = 1.0 or 2.0
               // (undefined)
}
```

Precision Qualifiers

- `lowp float`
  - Effectively sign + 1.8 fixed point.
  - Range is -2.0 < x < 2.0
  - Resolution 1/256
  - Use for simple colour blending

- `mediump float`
  - Typically implemented by sign + 5.10 floating point
  - -16384 < x < 16384
  - Resolution 1 part in 1024
  - Use for HDR blending.

Precision Qualifiers

- **`highp float`**
  - Typically implemented by 24 bit float (16 bit mantissa)
  - range $\pm 2^{62}$
  - Resolution 1 part in 2^{16}
  - Use of texture coordinate calculation
    - e.g. environment mapping

- single precision (float32)
  - Not explicit in GLSL ES but usually available in the vertex shader (refer to device documentation)

Precision Qualifiers

- Precision depends on the operands:

```
lowp float x;
mediump float y;
highp float z = x * y;
```

(evaluated at medium precision)

- Literals do not have any defined precision

```
lowp float x;
highp float z = x * 2.0 + 1.2;
```

(evaluated at low precision)

Constructors

- Replaces type casting
- No implicit conversion: must use constructors
- All named types have constructors available
  - Includes built-in types, structures
  - Excludes arrays
- Integer to Float:

```
int n = 1;
float x,y;
x = float(n);
y = float(2);
```

Constructors

- Concatenation:

```
float x = 1.0,y = 2.0;
vec2 v = vec2(x,y);
```

- Structure initialization

```
struct S {int a; float b;};
S s = S(2, 3.5);
```

Swizzle operators

- Use to select a set of components from a vector
- Can be used in L-values

```
vec2 u,v;
v.x = 2.0;          // Assignment to single
                    // component
float a = v.x;      // Component selection
v.xy = u.yx;        // swap components
v = v.xx;           // replicate components
v.xx = u;           // Error
```

- Component sets: Use one of

  `xyzw` OR **`rgba`** OR **`stpq`**

Indexing operator

- Indexing operator

```
vec4 u,v;
float x = u[0]; // equivalent to u.x
```

- Must use indexing operator for matrices

```
mat4 m
vec4 v = m[0];
m.x; // error
```

GLSL ES Overview

- Operators

```
++  --  +  -  ! () []
*  /  +  -
<  <=  >  >=
==  !=
&&  ^^  ||
?:
=  *=  /=  +=  -=
```

- Flow control

```
x == y ? a : b
if else
for while do
return break continue
```

`discard` (fragment shader only)

Built-in Variables

- Aim of ES is to reduce the amount of fixed functionality
  - Ideal would be a totally pure programmable model
  - But still need some
- Vertex shader

```
vec4     gl_Position;      // Write-only
float    gl_PointSize;     // Write-only
```

- Fragment shader

```
vec4     gl_FragCoord;     // Read-only
bool     gl_FrontFacing;   // Read-only
vec2     gl_PointCoord;    // Read-only
float    gl_FragColor;     // Write only
```

Built-in Functions

- General
  `pow, exp2, log2, sqrt, inversesqrt`
  `abs, sign, floor, ceil, fract, mod,`
  `min, max, clamp`
- Trig functions
  `radians, degrees, sin, cos, tan,`
  `asin, acos, atan`
- Geometric
  `length, distance, cross, dot, normalize,`
  `faceForward, reflect, refract`

GLSL ES Overview

- Interpolations

```
mix(x,y,alpha)
    x*( 1.0-alpha) + y*alpha)
step(edge,x)
    x <= edge ? 0.0 : 1.0
smoothstep(edge0,edge1,x)
    t = (x-edge0)/(edge1-edge0);
    t = clamp( t, 0.0, 1.0);
    return t*t*(3.0-2.0*t);
```

- Texture

```
texture1D, texture2D, texture3D, textureCube
texture1DProj, texture2DProj, textureCubeProj
```

GLSL ES Overview

- Vector comparison (`vecn`, `ivecn`)
  ```
  bvecn lessThan(vecn, vecn)
  bvecn lessThanEqual(vecn, vecn)
  bvecn greaterThan(vecn, vecn)
  bvecn greaterThanEqual(vecn, vecn)
  ```
- Vector comparison (`vecn`, `ivecn`, `bvecn`)
  ```
  bvecn equal(vecn, vecn)
  bvecn notEqual(vecn, vecn)
  ```
- Vector (`bvecn`)
  ```
  bvecn any(bvecn)
  bvecn all(bvecn)
  bvecn not(bvecn)
  ```
- Matrix
  ```
  matrixCompMult (matn, matn)
  ```

Invariance: The Problem

- Mathematical operations are not precisely defined
- Same code may produce (slightly) different results
- Two cases to consider:
  - Invariance within a shader
  - Invariance between shaders

Invariance

- Consider a simple transform in the vertex shader:

$$\begin{pmatrix} x' \\ y' \\ z' \\ w' \end{pmatrix} = \begin{pmatrix} a & b & c & d \\ e & f & g & h \\ i & j & k & l \\ m & n & o & p \end{pmatrix} \begin{pmatrix} x \\ y \\ z \\ w \end{pmatrix}$$

x' = ax + by + cz + dw

But how is this calculated in practice?

- There may be several possible code sequences

Invariance

e.g.

```
MUL R1, a, x
MUL R2, b, y
MUL R3, c, z
MUL R4, d, w
ADD R1, R1, R2
ADD R3, R3, R4
ADD R1, R1, R3
```

or

```
MUL R1, a, x
MADD R1, b, y
MADD R1, c, z
MADD R1, d, w
```

Invariance

- Three reasons the result may differ:
  - Use of different instructions
  - Instructions executed in a different order
  - Different precisions used for intermediate results (only minimum precisions are defined)

- But it gets worse...

Invariance

- Modern compilers may rearrange your code
  - Values may lose precision when written to a register
  - Sometimes it is cheaper to recalculate a value rather than store it in a register.
    But will it be calculated the same way?

e.g.

```
uniform sampler2D tex1, tex2;
...
const vec2 pos = a + b * c;
vec4 col1 = texture2D(tex1, pos);
...
vec4 col2 = texture2D(tex2, pos); // is this
                                  // the same
                                  // value?
gl_FragColor = col1 - col2;
```

Invariance

- Solution is in two parts:
  - invariant keyword specifies that specific variables are invariant e.g.

    ```
    invariant varying vec3 LightPosition;
    ```

    Currently can only be used on certain variables

  - Global switch to make all variable invariant

    ```
    #pragma STDGL invariant(all)
    ```

Invariance

- Invariance flag controls:
  - Invariance within shaders

  and
  - Invariance between shaders.

- Usage
  - Turn on invariance to make programs ‘safe’ and easier to debug
  - Turn off invariance to get the maximum optimization from the compiler.

Writing an application - Overview

- Initialize EGL
- Setup shader, pipeline state
- Create vertex buffers, textures
- Bind buffers
- Draw

Writing an App – Initialization

- Set up EGL
- Compile and Link shaders
- Create and bind Textures
- Bind (or get) attributes
- Set up uniforms
- Create Vertex Buffers
- Map buffer data

Writing an App – EGL Initialization

```
EGLDisplay egl_display =
eglGetDisplay(EGL_DEFAULT_DISPLAY);

int ok = eglInitialize(egl_display,
                       &majorVersion,
                       &minorVersion)
```

EGL Initialization

Set up attributes for EGL context

```
EGLint attr[MAX_EGL_ATTRIBUTES];

attr[nAttrib++] = EGL_RED_SIZE;
attr[nAttrib++] = 5;
...
attr[nAttrib++] = EGL_DEPTH_SIZE;
attr[nAttrib++] = 16;
attr[nAttrib++] = EGL_STENCIL_SIZE;
attr[nAttrib++] = 0;
...
```

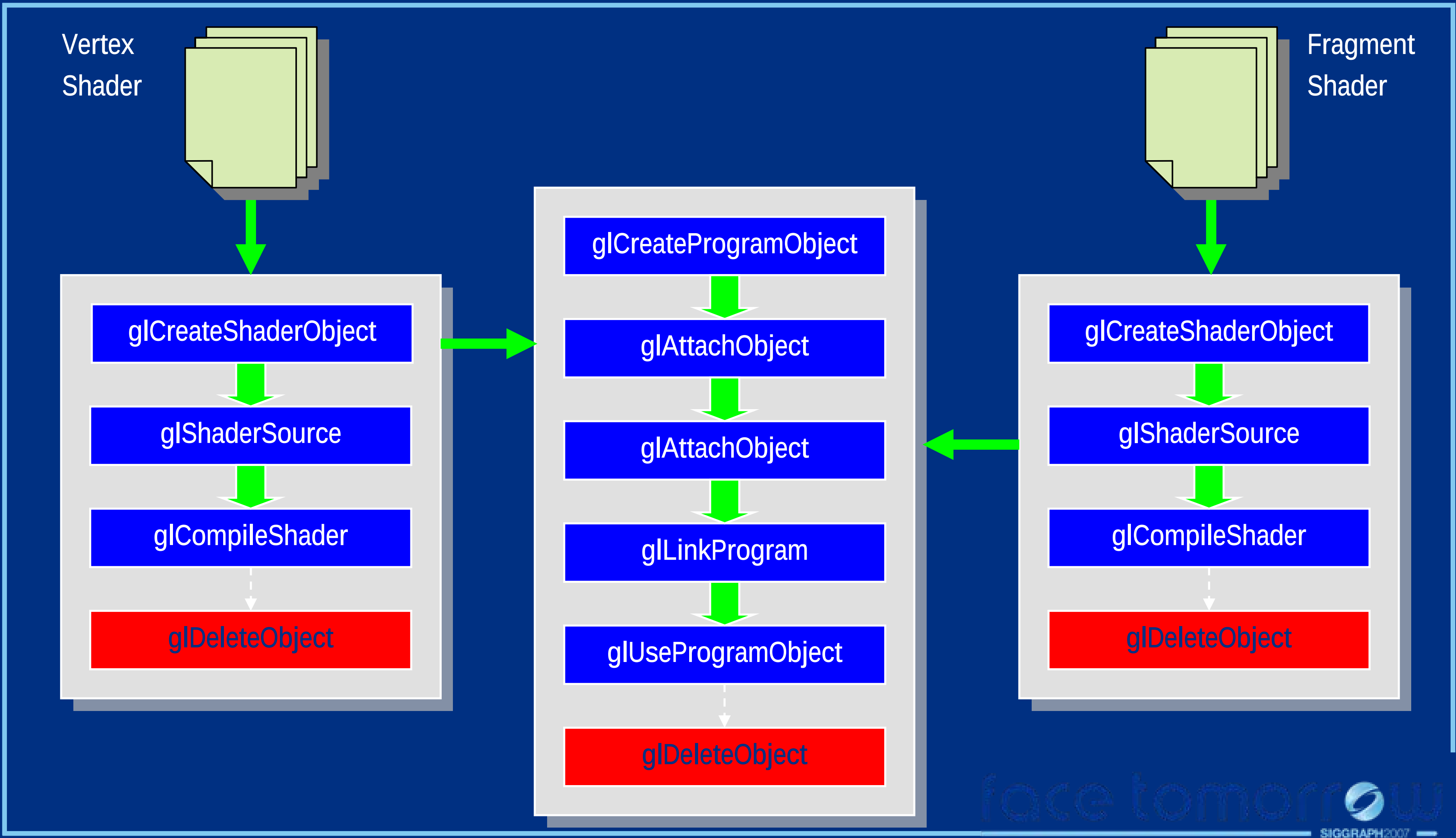
EGL Initialization (cont)

```
eglChooseConfig(egl_display,
                attrib_list,
                &egl_config,
                1,
                &num_configs);

eglCreateWindowSurface(egl_display,
                       egl_config,
                     NativeWindowType (hWnd),
                       NULL);
```

EGL Initialization: Creating a context

```
context = eglCreateContext(egl_display,
                           egl_config,
                           EGL_NO_CONTEXT,
                           NULL);

eglMakeCurrent(egl_display,
               egl_surface,
               egl_surface,
               egl_context);
```

Compiling and using shaders



Compiling and Linking Shaders

- Create objects

```
program_handle = glCreateProgram();
// Create one shader of object of each type.
GLuint vertex_shader_handle
      = glCreateShader (GL_VERTEX_SHADER);
GLuint fragment_shader_handle
      = glCreateShader (GL_FRAGMENT_SHADER);
```

Compiling Shaders

- Compile vertex shader (and fragment shader)

```
char* vert_source = ...
const char* vert_gls[1] = {vert_source};
glShaderSource(vertex_shader_handle,
               1,
               vert_gls,
               NULL );
glCompileShader(vertex_shader_handle);
GLint vertCompilationResult = 0;
glGetShaderiv(vertex_shader_handle,
              GL_COMPILE_STATUS,
              &vertCompilationResult);
```

Linking Shaders

- Attach shaders to program object and link

```
glAttachShader(program_handle,
               vertex_shader_handle);
glAttachShader(program_handle,
               fragment_shader_handle);
glLinkProgram (program_handle);
```

- Note that many compilers will only report errors at link time.

Setting up Attributes

- Can bind attributes before linking e.g.

```
glBindAttribLocation (prog_handle, 0, “pos");
```

- Or get attribute location after linking:

```
GLint p;
p = glGetAttribLocation (prog_handle, “pos");
```

- Can do a combination.

Setting up Textures

- Texture samplers are ***Uniforms*** in GLSL ES
- First Generate ID and specify type (cube map)

```
uint32 Id;
glGenTextures(1, &Id);
glActiveTexture(GL_TEXTURE0);
glBindTexture(GL_TEXTURE_CUBE_MAP, Id);
```

Setting up Textures (cont)

```
glTexImage2D(GL_TEXTURE_CUBE_MAP_POSITIVE_X,
             0,
             GL_RGBA,
             width,
             height,
             0,
             GL_RGBA,
             GL_UNSIGNED_BYTE,
             image [0].pixels);

glTexImage2D(GL_TEXTURE_CUBE_MAP_NEGATIVE_X, ...
glTexImage2D(GL_TEXTURE_CUBE_MAP_POSITIVE_Y, ...
glTexImage2D(GL_TEXTURE_CUBE_MAP_NEGATIVE_Y, ...
glTexImage2D(GL_TEXTURE_CUBE_MAP_POSITIVE_Z, ...
glTexImage2D(GL_TEXTURE_CUBE_MAP_NEGATIVE_Z, ...
```

Setting up Uniforms

- Must do this after glUseProgram:

```
glUseProgram(prog_handle);
```

- Use glGetUniformLocation e.g.

```
GLint loc_sky_box =
  glGetUniformLocation (prog_handle,"skyBox“);
```

- Can then set value e.g.

```
GLint texture_unit = 0;
glUniform1i (loc_sky_box,texture_unit);
```

Setting up Attribute Buffers

- Create buffer names

```
GLuint bufs[1];
glGenBuffers (1, bufs);
```

- Create and initialize buffer

```
glBindBuffer (GL_ARRAY_BUFFER,
  bufs[0]);
glBufferData (GL_ARRAY_BUFFER,
  size_bytes, p_data, GL_STATIC_DRAW);
```

Setting up Attribute Buffers (cont)

- Specify format:

```
glBindBuffer(GL_ARRAY_BUFFER, bufs[0]);
glVertexAttribPointer(0,         // index
                      4,         // size
                      GL_FLOAT,// type
                      GL_FALSE,// norm
                      0,
                      NULL );
```

Drawing the frame

- Clear frame buffer
- Set render state
- Enable array
- DrawArray

Drawing

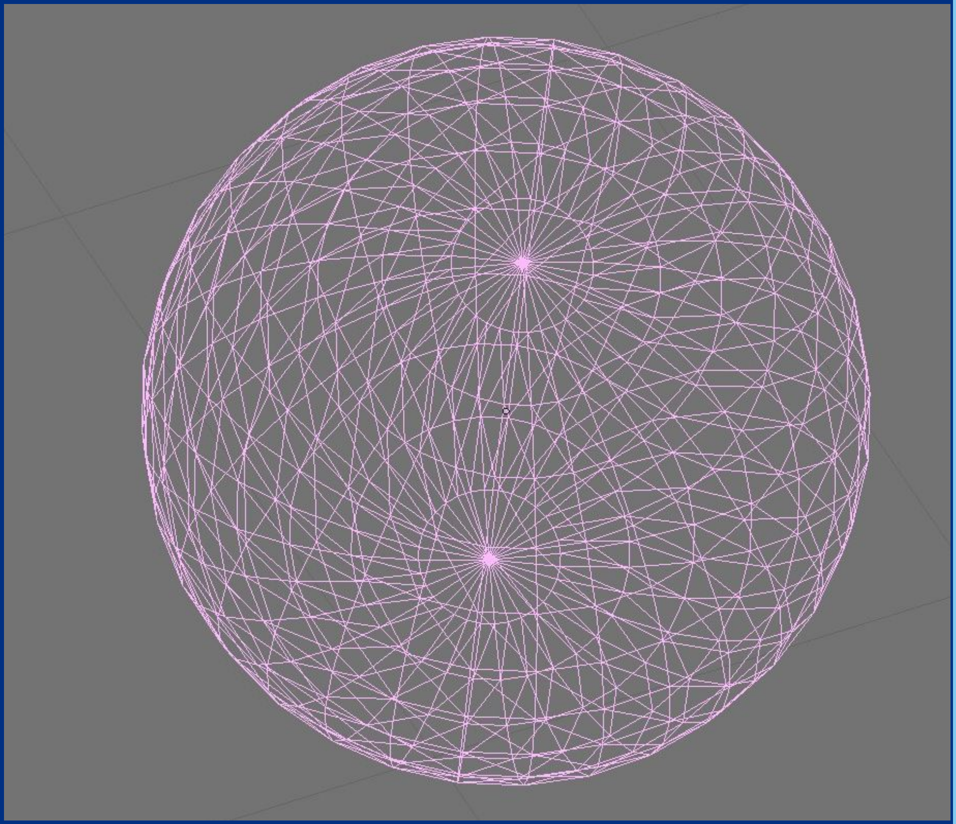
- Enable array and Draw

```
glEnableVertexAttribArray( 0 );
glBindBuffer (GL_ARRAY_BUFFER,0);


glDrawArrays (GL_TRIANGLE_STRIP,0,
              n_vertices);
```

Example: Water demo

Skybox

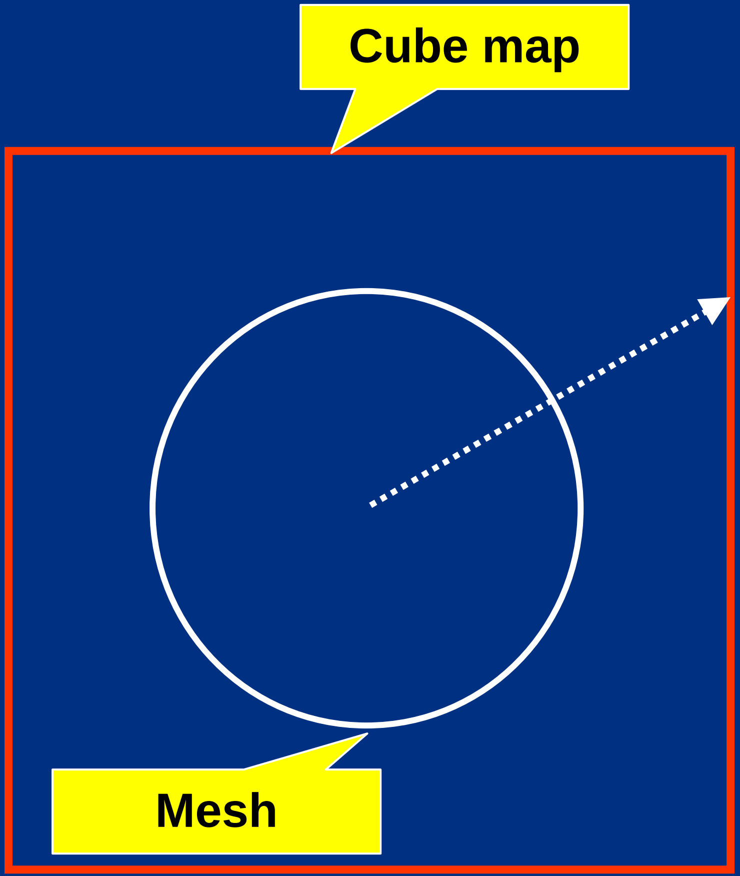
- Geometry is a sphere
- Use position to access a cube map



Cube Map

Skybox

- Can use position to access cube map
- Don't need to normalize.
- No need for separate normals



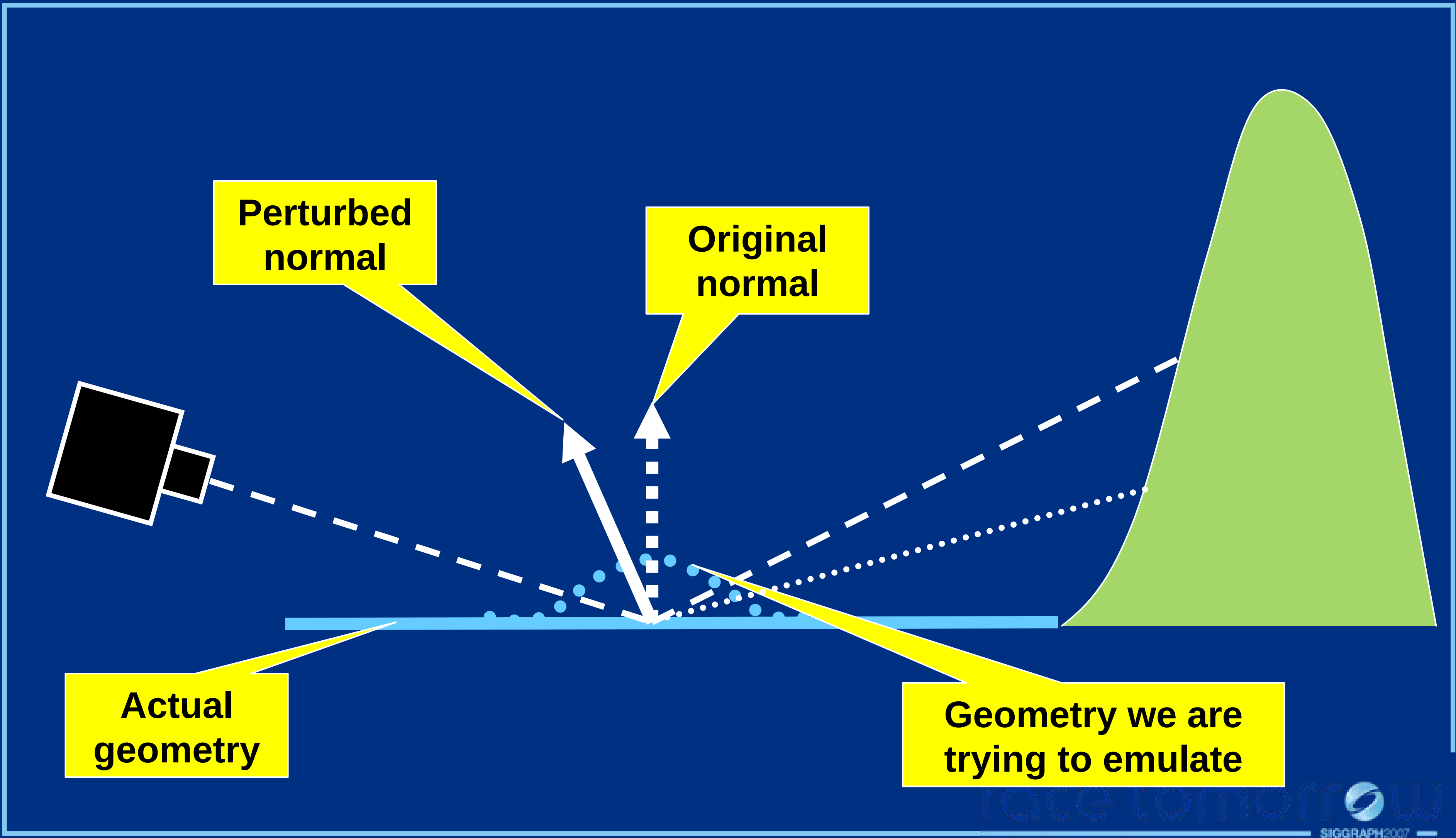
Sky box: Vertex shader

```
uniform mat4 view_proj_matrix;
uniform vec4 view_position;
attribute vec4 rm_Vertex;
varying vec3 vTexCoord;
void main(void)
{
   vec4 newPos = vec4(1.0);
   newPos.xyz  = rm_Vertex.xyz + view_position.xyz;
   gl_Position = view_proj_matrix * vec4(newPos.xyz, 1.0);
   vTexCoord = rm_Vertex.xyz;
}
```

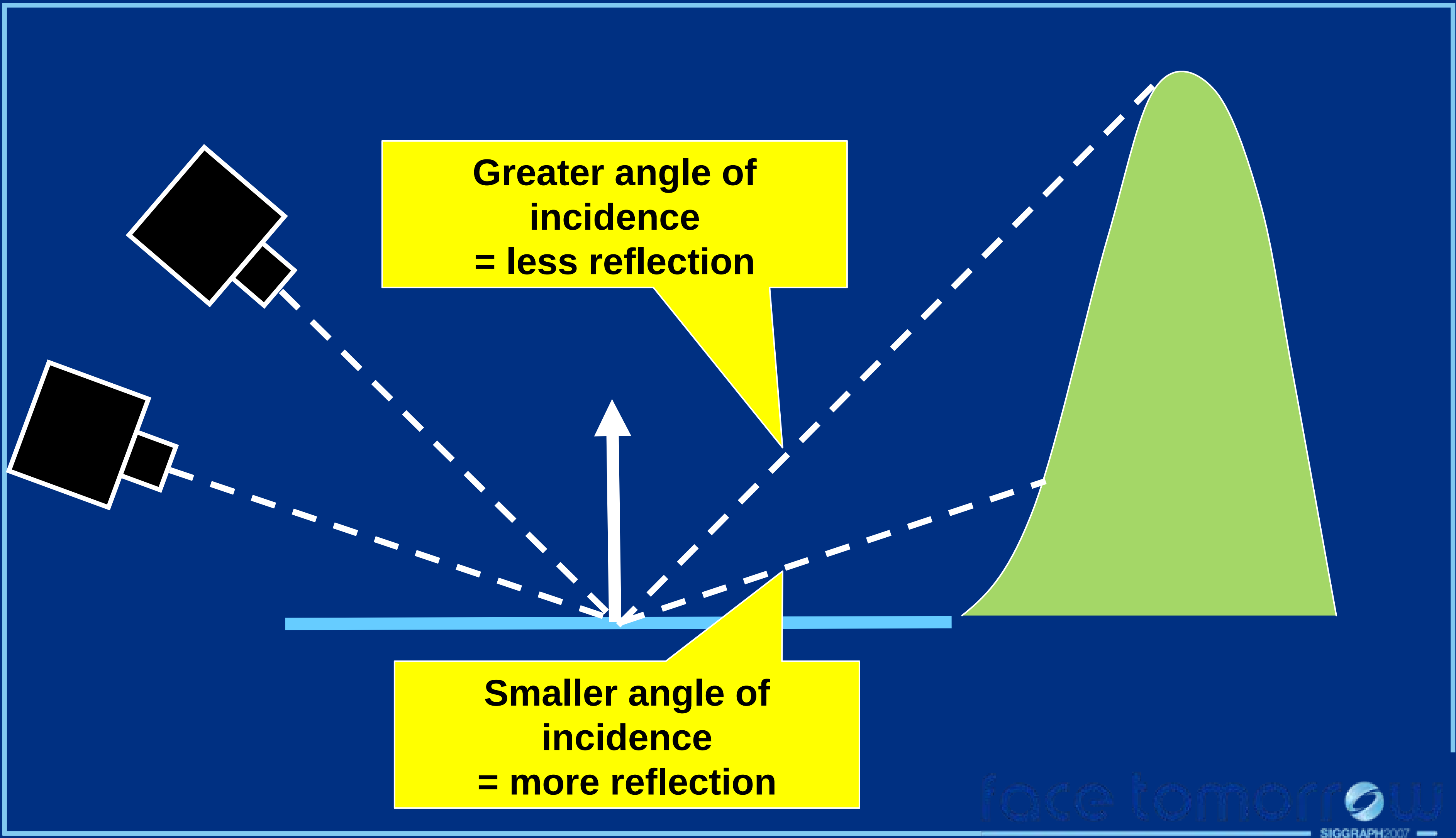
Sky box: Fragment Shader

```
precision highp float;
uniform samplerCube skyBox;
varying vec3 vTexCoord;
void main(void)
{
  gl_FragColor =
          textureCube(skyBox,vTexCoord);
}
```

Water: Reflection Mapping

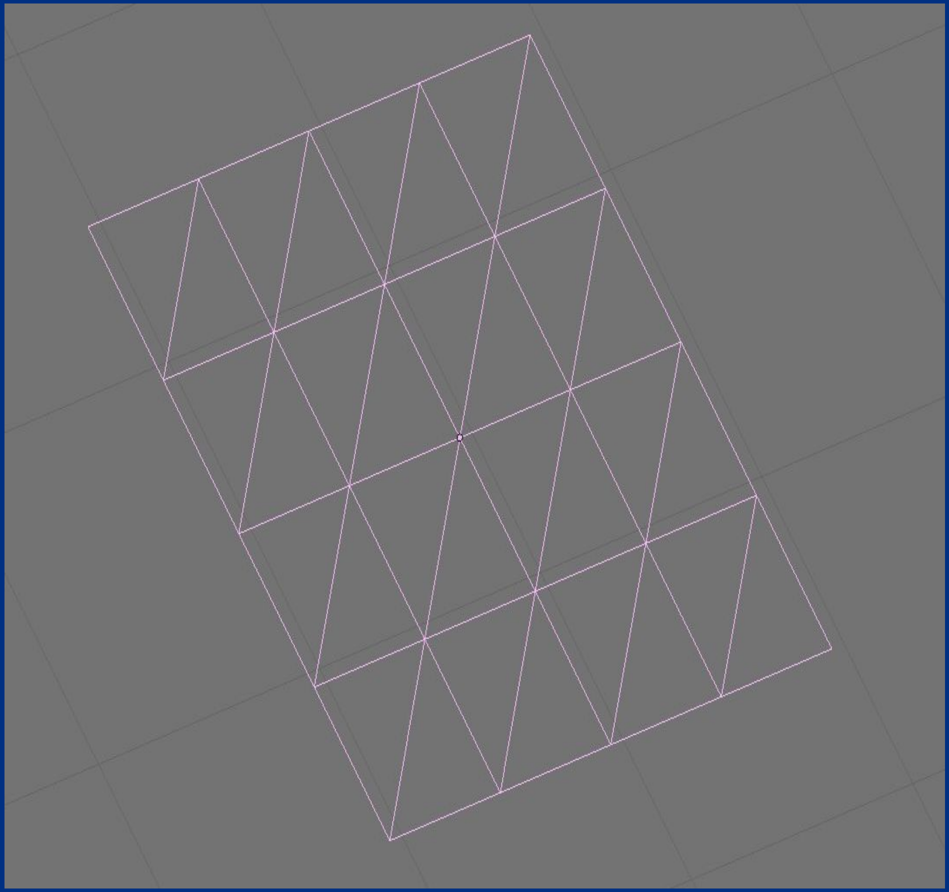


Approximating Fresnel Reflection



Water

- Geometry is a simple grid
- Uses the same cubemap as the skybox



Water Ripples

- Use noise texture for bump map.
- Exact texture not important
  - Try experimenting

Water: Vertex Shader

```
uniform vec4 view_position;
uniform vec4 scale;
uniform mat4 view_proj_matrix;
attribute vec4 rm_Vertex;
attribute vec3 rm_Normal;
varying vec2 vTexCoord;
varying vec3 vNormal;
varying vec3 view_vec;
```

Water: Vertex Shader (cont)

```
void main(void)
{
   vec4 Position = rm_Vertex.xyzw;
   Position.xz *= 1000.0;
   vTexCoord    = Position.xz * scale.xz;
   view_vec     = Position.xyz -
                   view_position.xyz;
   vNormal      = rm_Normal;
   gl_Position = view_proj_matrix * Position;
}
```

Water: Fragment Shader

```
uniform sampler2D noise;
uniform samplerCube skyBox;
uniform float time_0_X;
uniform vec4  waterColor;
uniform float fadeExp;
uniform float fadeBias;
uniform vec4  scale;
uniform float waveSpeed;
varying vec2 vTexCoord;
varying vec3 vNormal;
varying vec3 vViewVec;
```

Water Fragment Shader (cont)

```
void main(void)
{
   vec2 tcoord = vTexCoord;
   tcoord.x += waveSpeed  * time_0_X;
   vec4 noisy = texture2D(noise, tcoord.xy);
   // Signed noise
   vec3 bump = 2.0 * noisy.xyz - 1.0;
   bump.xy *= 0.15;

   // Make sure the normal always points upwards
   bump.z = 0.8 * abs(bump.z) + 0.2;
```

Water Fragment Shader (cont)

```
// Offset the surface normal with the bump
bump = normalize(vNormal + bump);

// Find the reflection vector
vec3 reflVec = reflect(vViewVec, bump);
vec4 refl = textureCube(skyBox, reflVec.yzx);
```

Water Fragment Shader (cont)

```
  float lrp =
   1.0 - dot(-normalize(vViewVec), bump);

  // Interpolate between the water color and
  // reflection
  float blend = fadeBias + pow(lrp, fadeExp);
  blend = clamp(blend ,0.0, 1.0);
  gl_FragColor = mix(waterColor, refl, blend);
}
```

Programming Tips

- Check for errors regularly
  - Use e.g.

    ```
    assert(!glError ());
    ```

  - But remember glError () gets the last error:

    ```
    ... // error here
    Glint error = glError ();
    ...
    assert(!glError ()); // No error
    ```

The coordinate system

- Coordinate system is:
  - Right handed before projection
    - Increasing z is towards the viewer.
  - Left handed after projection
    - Increasing z is away from the viewer.

Matrix Convention

- Matrices are column-major
  - column index varies more slowly
- Vectors are columns
- But this is purely convention
- Only the position in memory is important
  - Translation specified in elements 12,13,14

The projection matrix

- You need to provide a projection matrix e.g.

$$\begin{bmatrix} \frac{2.0*near}{right-left} & 0.0 & \frac{right+left}{right-left} & 0.0 \\ 0.0 & \frac{2.0*near}{top-bottom} & \frac{top+bottom}{top-bottom} & 0.0 \\ 0.0 & 0.0 & \frac{-(far+near)}{far-near} & \frac{-2.0*far*near}{far-near} \\ 0.0 & 0.0 & -1.0 & 0.0 \end{bmatrix}$$

- near and far are both *positive*

Performance Tips

- Keep fragment shaders simple
  - Fragment shader hardware is expensive.
  - Early implementations will not have good performance with complex shaders.
- Try to avoid using textures for function lookups.
  - Calculation is quite cheap, accessing textures is expensive.
  - This is more important with embedded devices.

Performance Tips (cont)

- Minimize register usage
  - Embedded devices do not support the same number of registers compared with desktop devices. Spilling registers to memory is expensive.
- Minimize the number of shader changes
  - Shaders contain a lot of state
  - May require the pipeline to be flushed
  - Use uniforms to change behaviour in preference to loading a new shader.

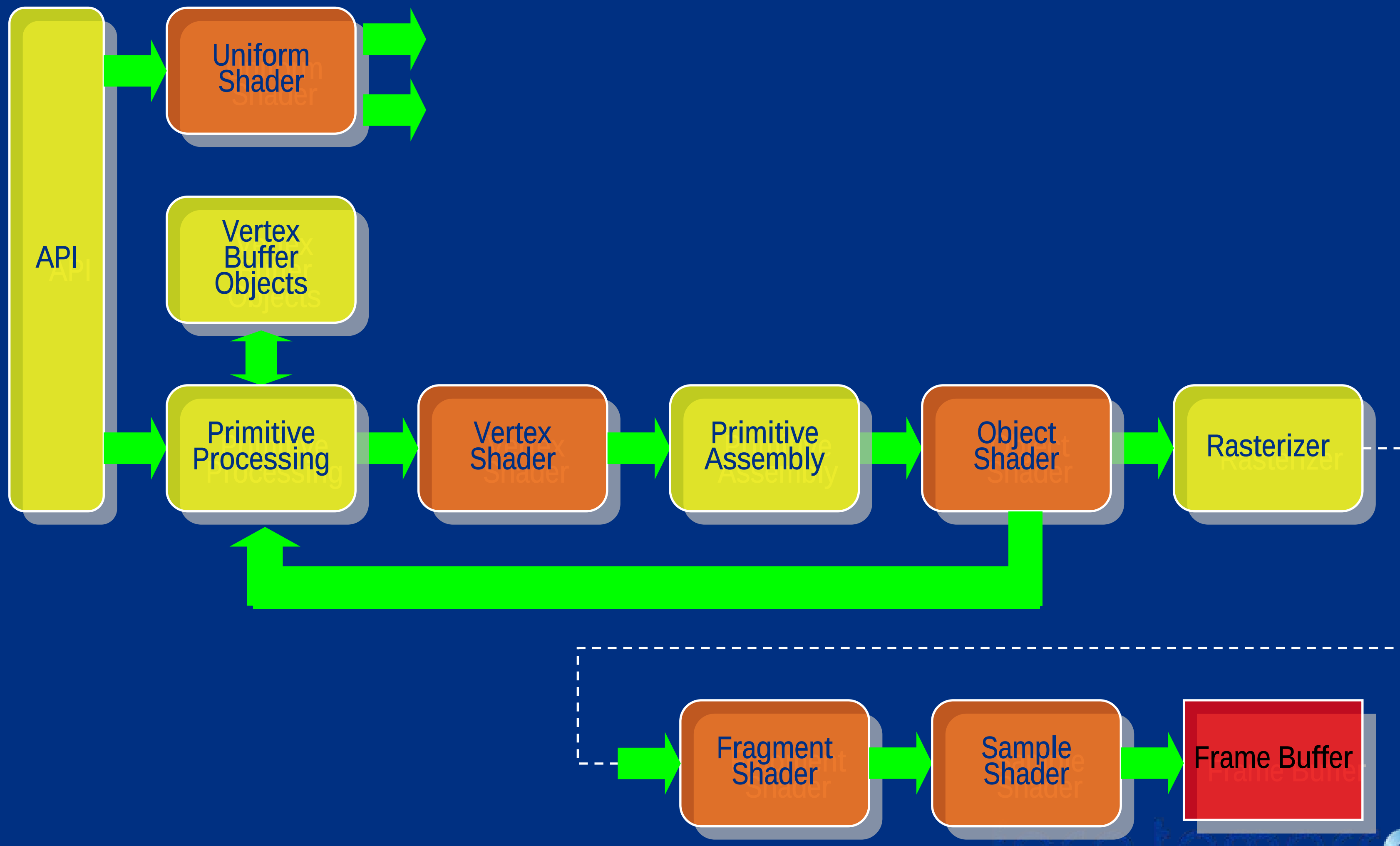
Future Directions

- Sample Shaders
  - Enables alpha testing at per-sample resolution
  - Enables more of the fixed function pipeline to be removed.
  - Allows more programmability when using multi-sampling.
  - e.g. Read and write depth and stencil

Future Directions

- Object (Geometry) Shaders
  - Programmable tessellation
  - Higher order surfaces
  - Procedural geometry
  - Possibility of accelerating many more algorithms e.g. shadows, occlusion culling.

Future ES Pipeline?



SIGGRAPH2007

M3G Intro

SIGGRAPH2007

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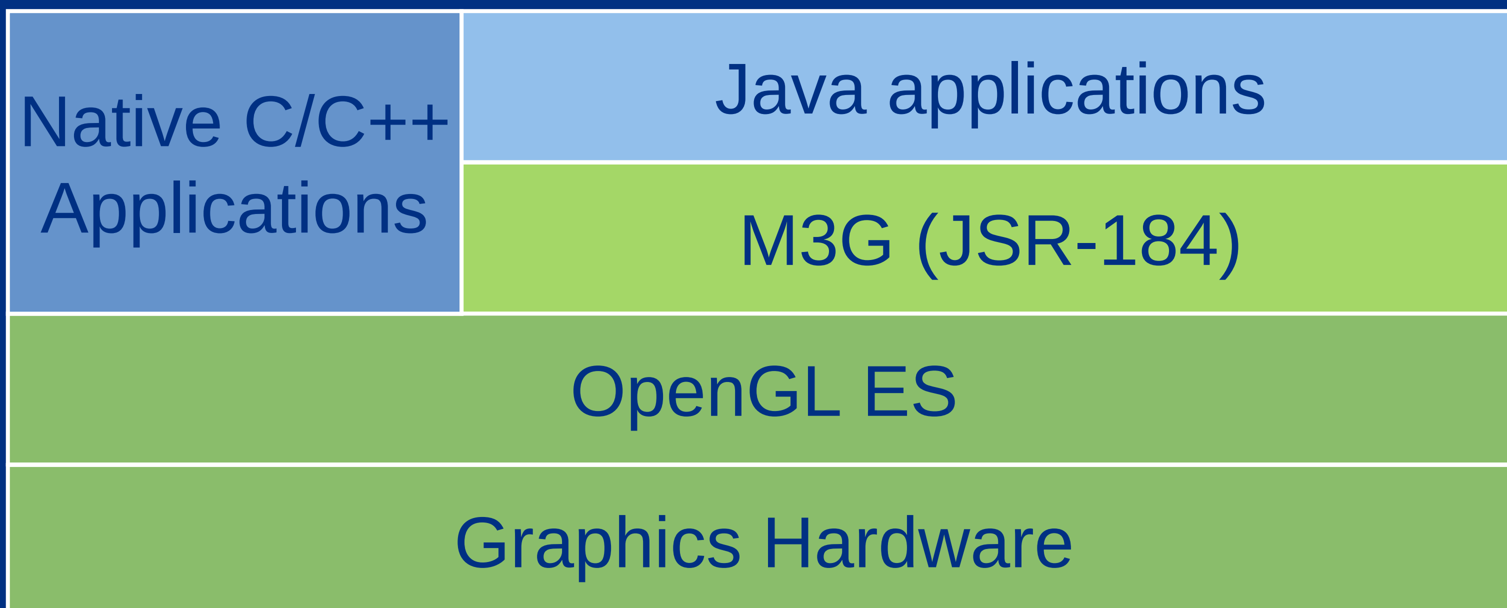
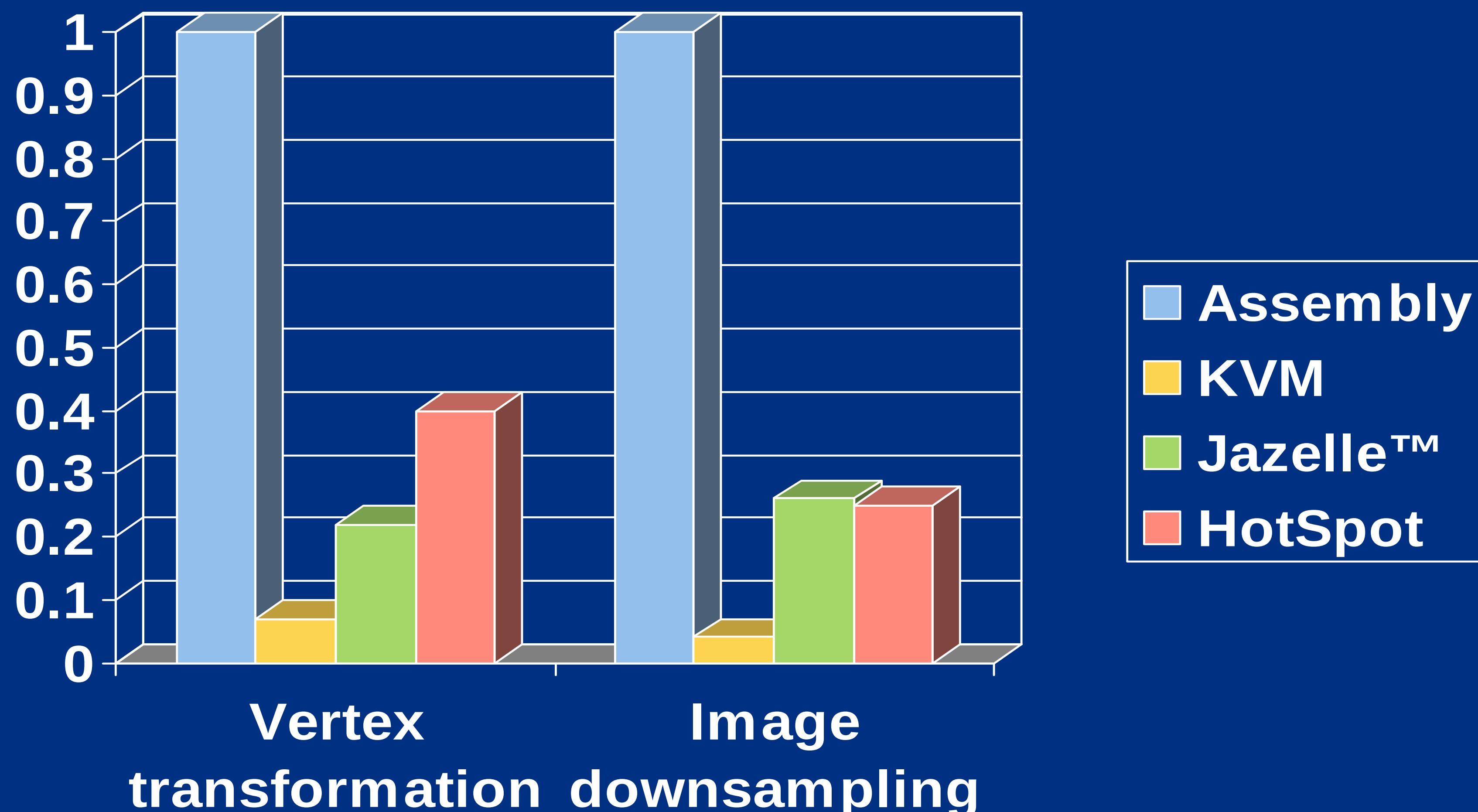
Mobile 3D Graphics APIs



Why Should You Use Java?

- Largest and fastest growing installed base
  - 1200M phones running Java by June 2006
  - The majority of phones sold today support Java
- Better productivity compared to C/C++
  - Much fewer opportunities to introduce bugs
  - Comprehensive, standardized class libraries

Java Will Remain Slower



Benchmarked on an ARM926EJ-S processor with hand-optimized Java and assembly code

M3G Design Principles

#1 — **No Java code along critical paths**

- Move all graphics processing to native code
  - Not only rasterization and transformations
  - Also morphing, skinning, and keyframe animation
  - All data on native side to avoid Java-native traffic

M3G Design Principles

#2 **Cater for both software and hardware**

- Do not mandate hardware-only features
  - Such as per-pixel mipmapping or per-pixel fog
- Do not try to expand the OpenGL pipeline
  - Such as with hardcoded transparency shaders

M3G Design Principles

#3 **Maximize developer productivity**

- Address content creation and tool chain issues
  - Export art assets into a compressed file (.m3g)
  - Load and manipulate the content at run time
  - Need scene graph and animation support for that
- Minimize the amount of “boilerplate code”

M3G Design Principles

#4	Minimize engine complexity
#5	Minimize fragmentation
#6	Plan for future expansion

Why a New Standard?

- OpenGL ES is too low-level
  - Lots of Java code and function calls needed
  - No support for animation and scene management
- Java 3D is too bloated
  - A hundred times larger (!) than M3G
  - Still lacks a file format, skinning, etc.

SIGGRAPH2007

M3G API Overview

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Objectives

- Get an idea of the API structure and features
- Learn practical tricks not found in the spec

Prerequisites

- Fundamentals of 3D graphics
- Some knowledge of OpenGL ES
- Some knowledge of scene graphs

M3G API Overview

Getting started

Rendering

Scene graph

Performance tips

Deformable meshes

Keyframe animation

Demos

Programming Model

- Not an “extensible scene graph”
  - Rather a black box – much like OpenGL
  - No interfaces, events, or render callbacks
  - No threads; all methods return only when done

Programming Model

- Scene update is decoupled from rendering
  - **`render`** → Draw the scene, no side-effects
  - **`animate`** → Update the scene to the given time
  - **`align`** → Re-orient target cameras, billboards

Key Classes

Graphics3D

3D graphics context
Performs all rendering

Loader

Loads individual objects and entire scene graphs

Mesh

Encapsulates triangles, vertices and appearance

World

Scene graph root node

Graphics3D: How to Use

- Bind a target to it, render, release the target

```
void paint(Graphics g) {
    myGraphics3D.bindTarget(g);
    myGraphics3D.render(world);
    myGraphics3D.releaseTarget();
}
```

Rendering State

- Graphics3D contains global state
  - Frame buffer, depth buffer
  - Viewport, depth range
- Most rendering state is in the scene graph
  - Vertex buffers, textures, matrices, materials, …
  - Packaged into Java objects, referenced by meshes
  - Minimizes Java-native data traffic, enables caching

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Renderable Objects

Sprite3D

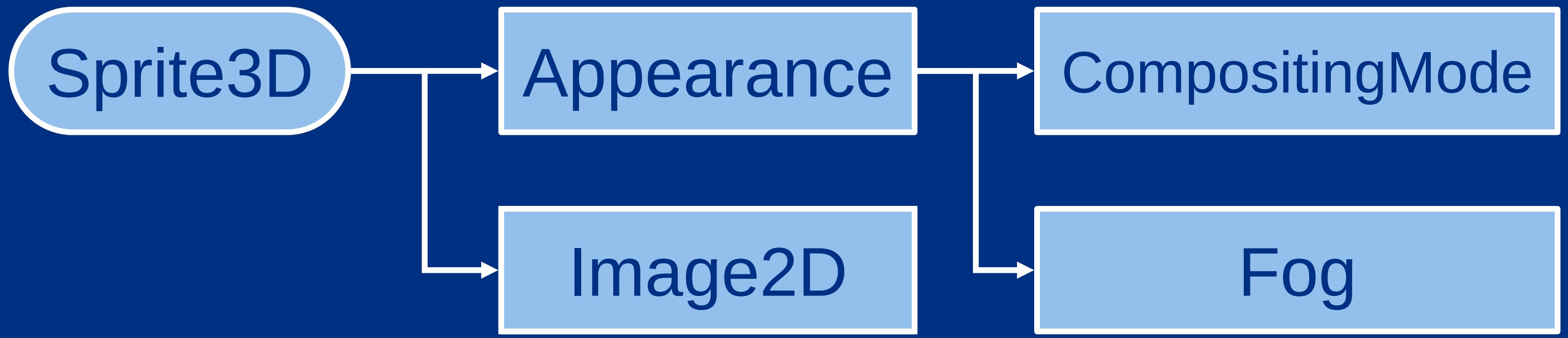
- *2D image placed in 3D space*
- *Always facing the camera*

Mesh

- *Made of triangles*
- *Base class for meshes*

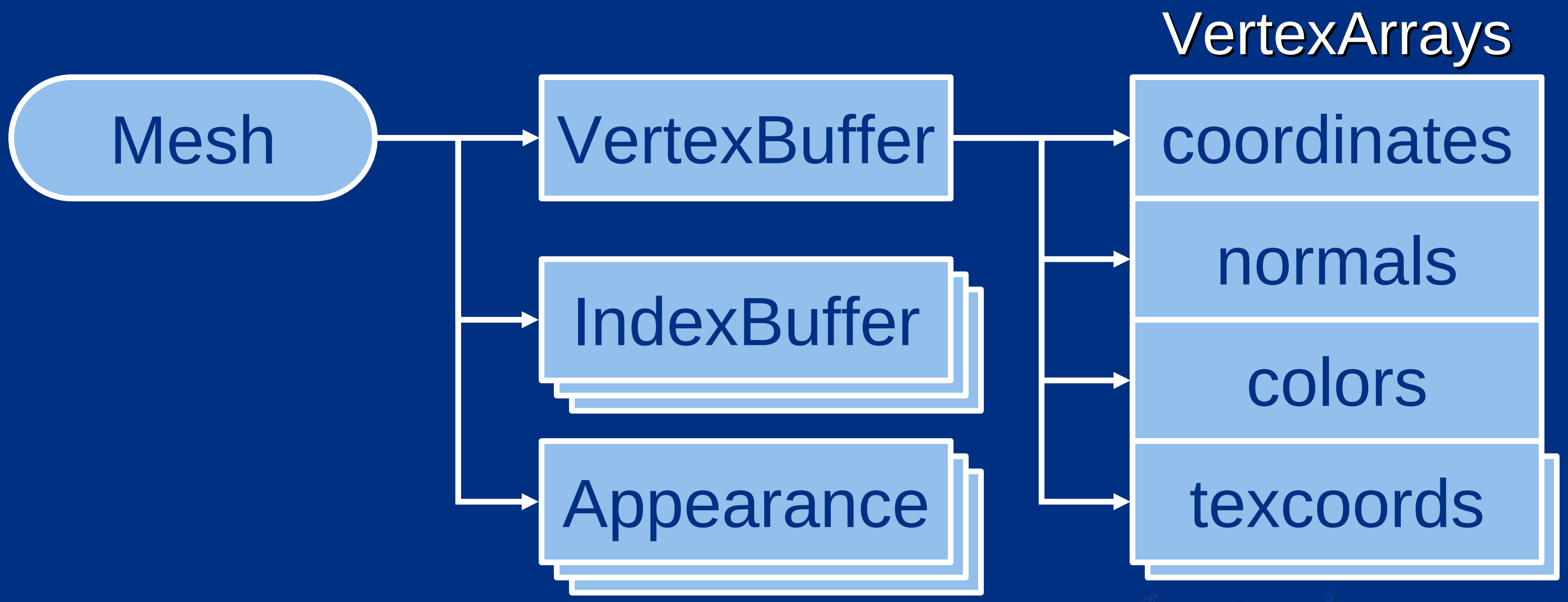
Sprite3D

- 2D image with a position in 3D space
  - Scaled mode for billboards, trees, etc.
  - Unscaled mode for text labels, icons, etc.
  - Too much overhead for particle effects



Mesh

- One VertexBuffer, containing VertexArrays
- 1..*N* submeshes (IndexBuffer + Appearance)



IndexBuffer Types

	Byte	Short	Implicit	Strip	Fan	List
Triangles	✓	✓	✓	✓	✗	✗
Lines	✗	✗	✗	✗	✗	✗
Points	✗	✗	✗			✗
Point sprites	✗	✗	✗			✗

Relative to OpenGL ES 1.1

VertexBuffer Types

	Byte	Short	Fixed	Float	2D	3D	4D
Vertices	✓	✓	✗	✗	✗	✓	✗
TexCoords	✓	✓	✗	✗	✓	✓	✗
Normals	✓	✓	✗	✗		✓	
Colors	✓		✗	✗		✓*	✓
PointSizes			✗	✗			

* OpenGL ES only supports RGBA colors

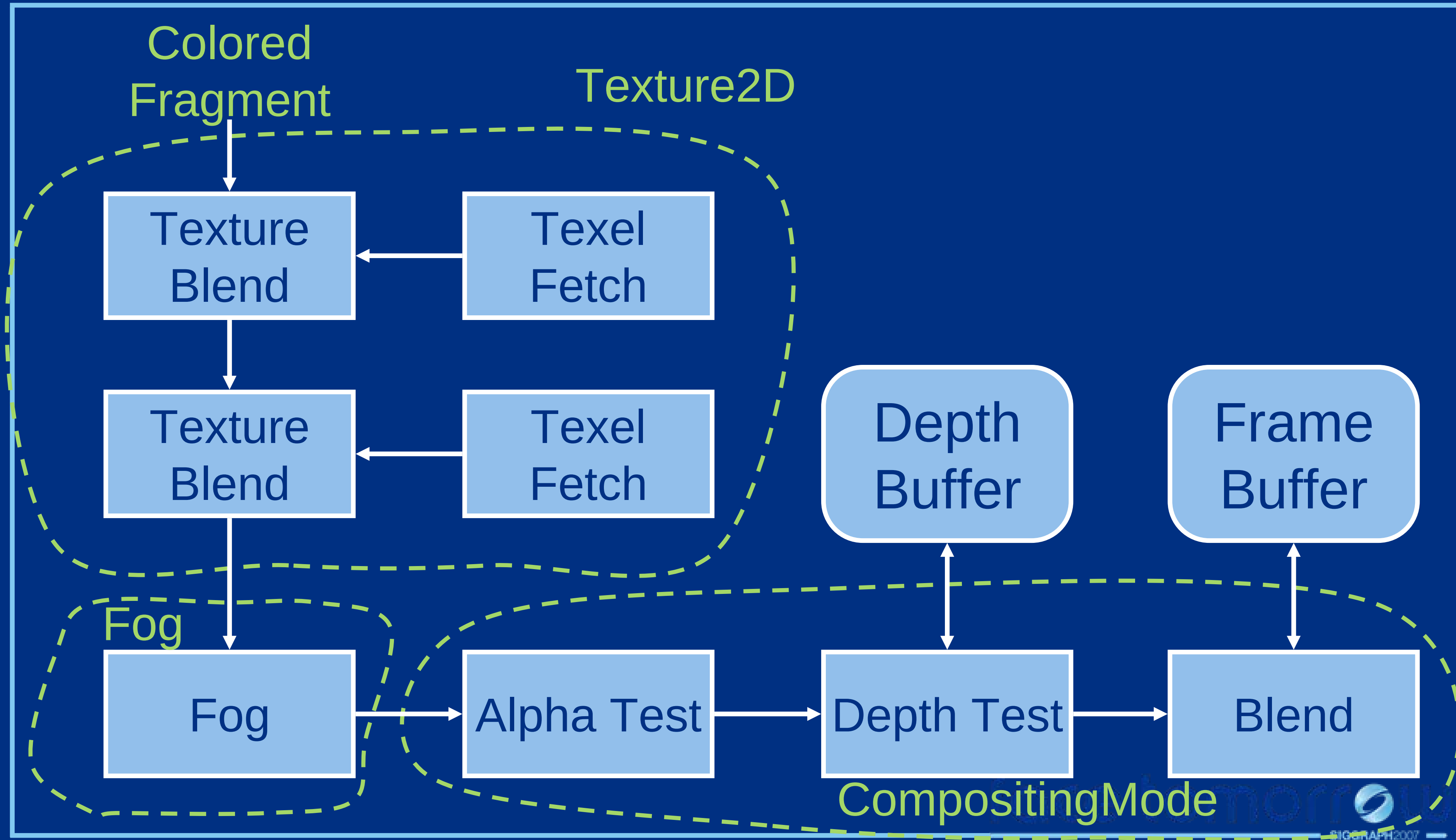
Vertex and Index Buffer Objects

- Vertices and indices are stored on server side
  - Similar to OpenGL Buffer Objects
  - Reduces data traffic from Java to native
  - Allows caching, bounding box computation, etc.

Appearance Components

Material	*Material colors for lighting* *Can track per-vertex colors*
CompositingMode	*Blending, depth buffering* *Alpha testing, color masking*
PolygonMode	*Winding, culling, shading* *Perspective correction hint*
Fog	*Fades colors based on distance* *Linear and exponential mode*
Texture2D	*Texture matrix, blending, filtering* *One Texture2D for each unit*

Fragment Pipeline



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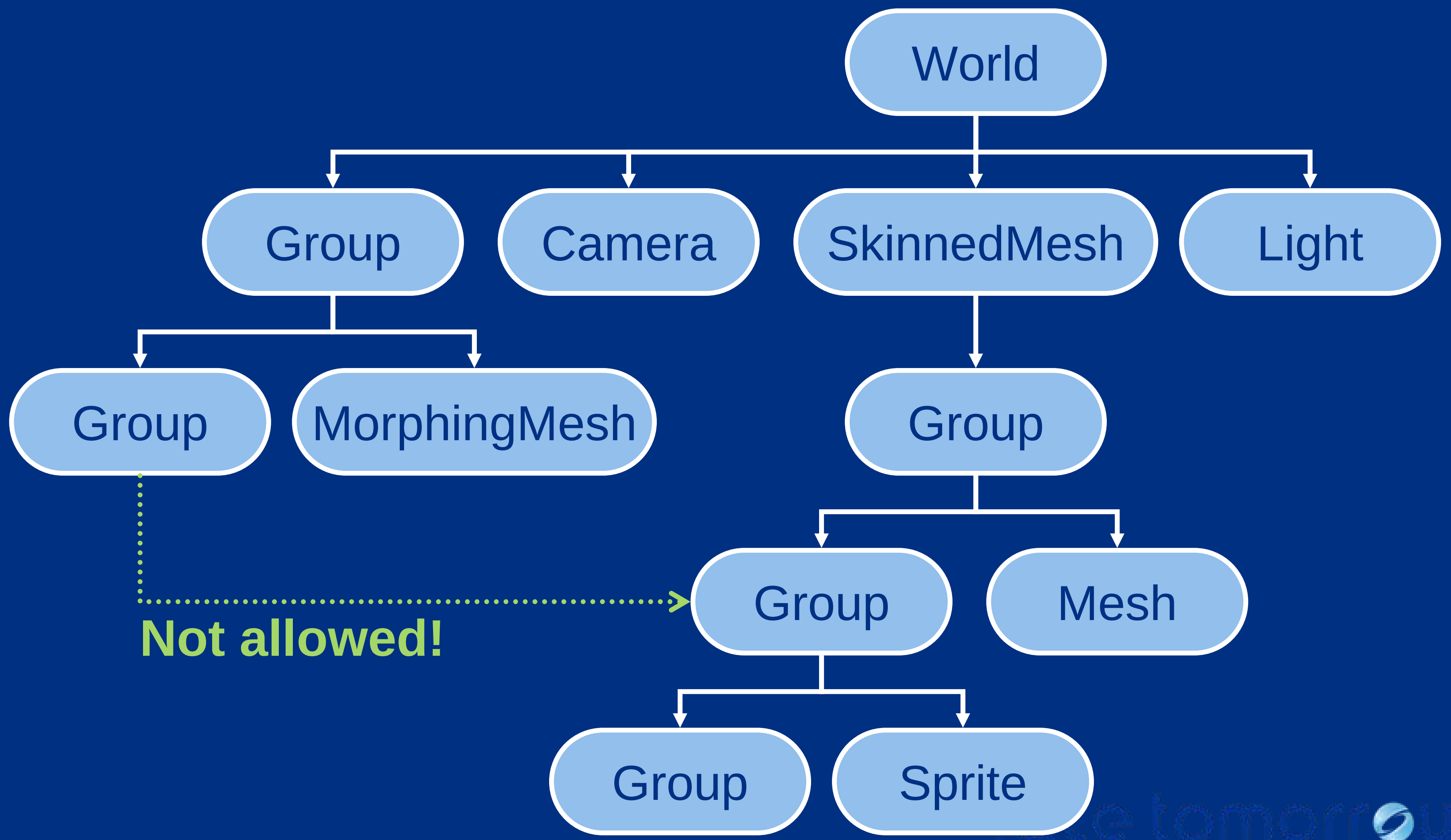
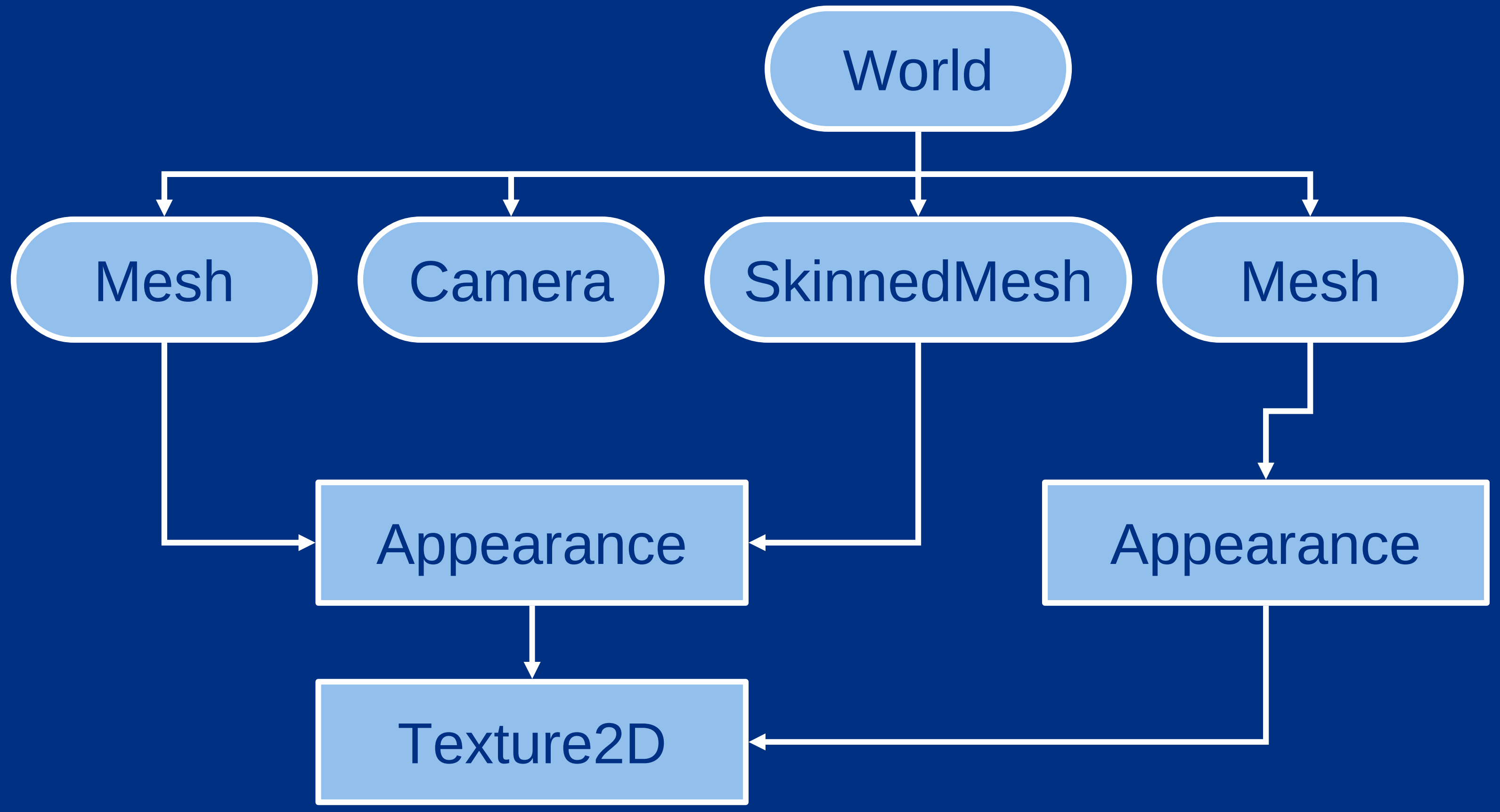


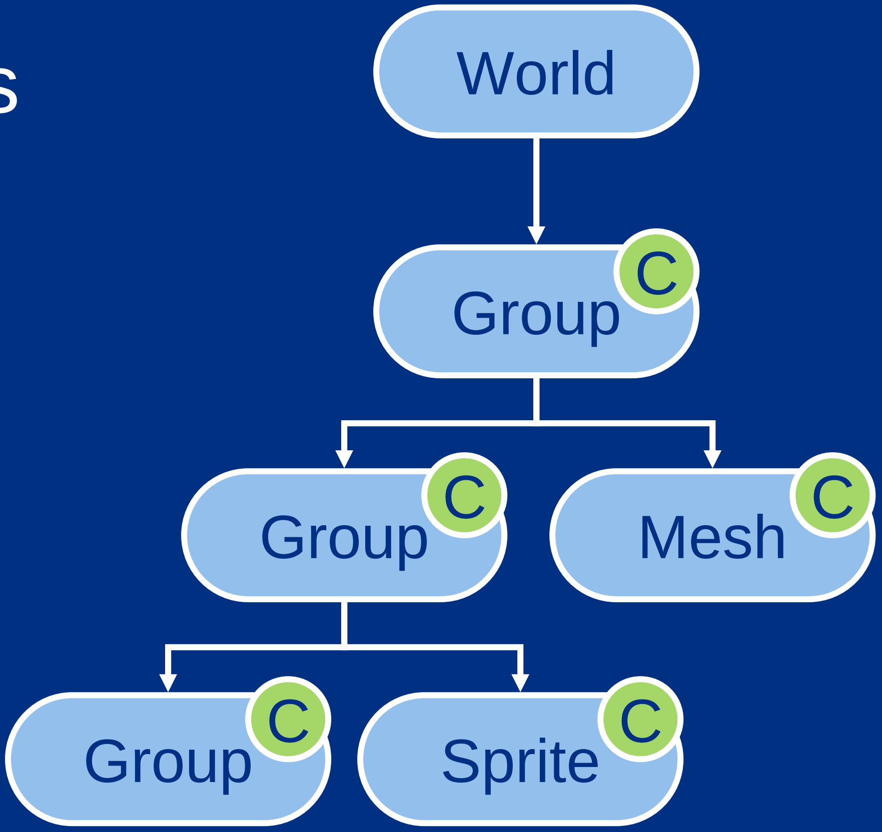
World
Group
Camera
SkinnedMesh
Light
Group
MorphingMesh
Group
Group
Mesh
Not allowed!
Group
Sprite

Shared Node Components



Node Transformations

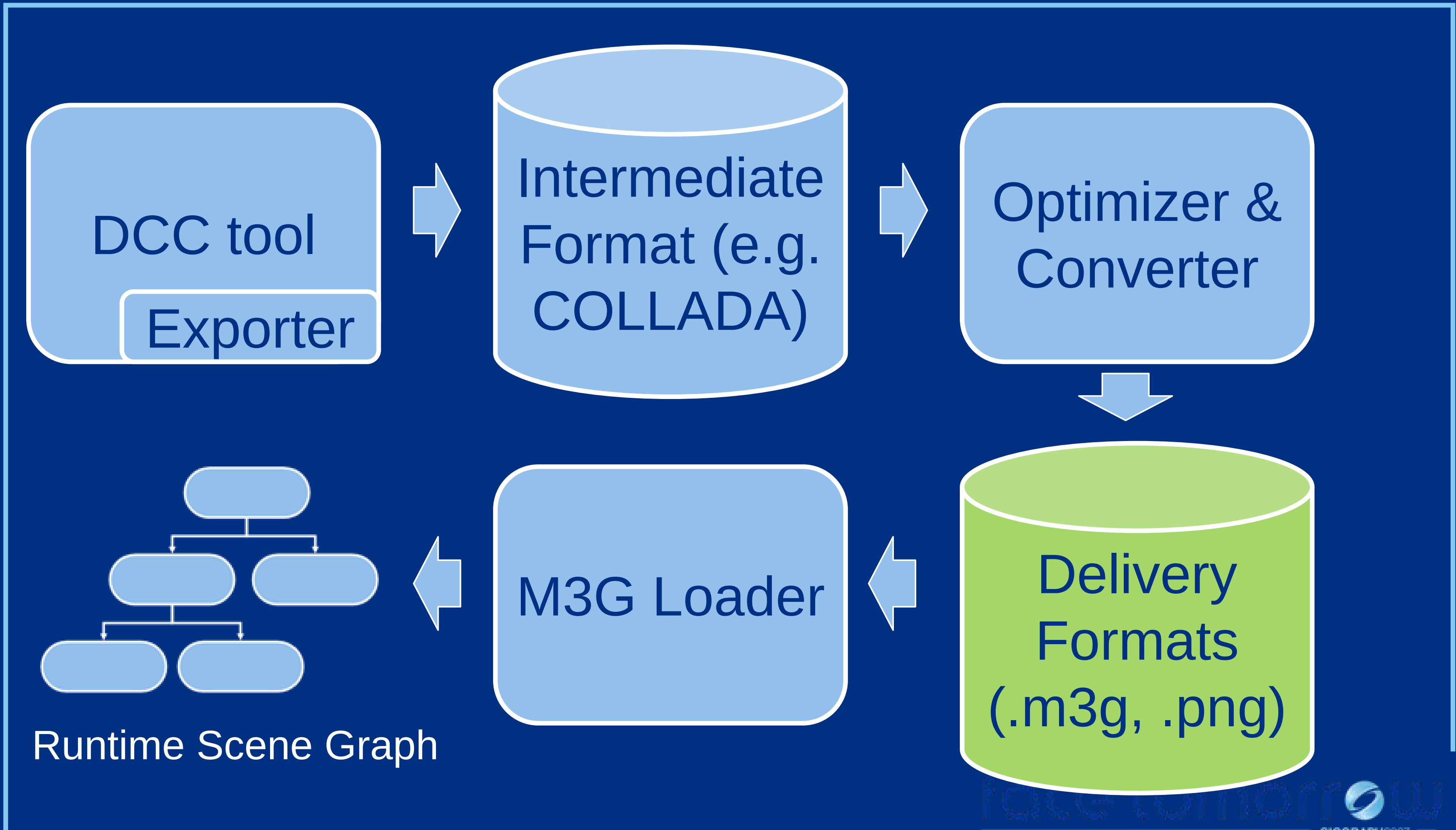
- From this node to the parent node
- Composed of four parts
  - Translation T
  - Orientation R
  - Non-uniform scale S
  - Generic 3x4 matrix M
- **C = T R S M**



Other Node Features

- Automatic alignment
  - Aligns the node's Z and/or Y axes towards a target
  - Recomputes the orientation component (R)
- Inherited properties
  - Alpha factor (for fading in/out)
  - Rendering enable (on/off)
  - Picking enable (on/off)
- Scope mask

Content Production



M3G File Format

- Small size, easy to decode
- Matches 1:1 with API features
- Stores individual objects, entire scenes
- ZLIB compression of selected sections
- Can reference external files – e.g. textures
- Highly portable – no extensions

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Use the Retained Mode

- Render a World instead of separate objects
  - Minimizes Java code and method calls
  - Allows view frustum culling, etc.
- Put co-located objects into Groups
  - Speeds up hierarchic view frustum culling

Simplify Node Properties

- Transformations
  - Favor the **T R S** components over **M**
  - Avoid non-uniform scales in **S**
  - Use auto-alignment sparingly

- Keep the alpha factor at 1.0

Optimize Rendering Order

- `Appearance.setLayer(int layer)`
  - Defines a <u>global</u> ordering for submeshes
  - Within each layer, opaque objects come first

- Use layers for…
  - Making sure that overlays are drawn <u>first</u>
  - Making sure that distant objects are drawn <u>last</u>
  - Multipass effects (e.g. for lighting)

Optimize Texturing

- Multitexturing is faster than multipass
  - Transformation and setup costs cut by half
- Use mipmaps to save memory bandwidth
  - Tradeoff: 33% extra memory consumption
- Combine small textures into a texture atlas

Use Perspective Correction

- Much faster than increasing triangle count
  - Nokia: 2% fixed overhead, 20% in the worst case
- Pitfall: Quality varies by implementation
  - Refer to quality scores at www.jbenchmark.com

Reduce Object Count

- Per-Mesh processing overhead is high
- Per-submesh overhead is also fairly high

- Merge
  - Meshes that are close to each other
  - submeshes that have a common Appearance

Avoid Dynamic Geometry

- `VertexArray.set(…)` can be slow
  - Java array contents must be copied in
  - May also trigger bounding box updates, etc.
  - Replace with morphing or skinning where possible
- IndexBuffers have no `set(…)` method at all
  - `new IndexBuffer(…)` per frame is <u>not</u> a good idea
  - Switch between predefined IndexBuffers instead

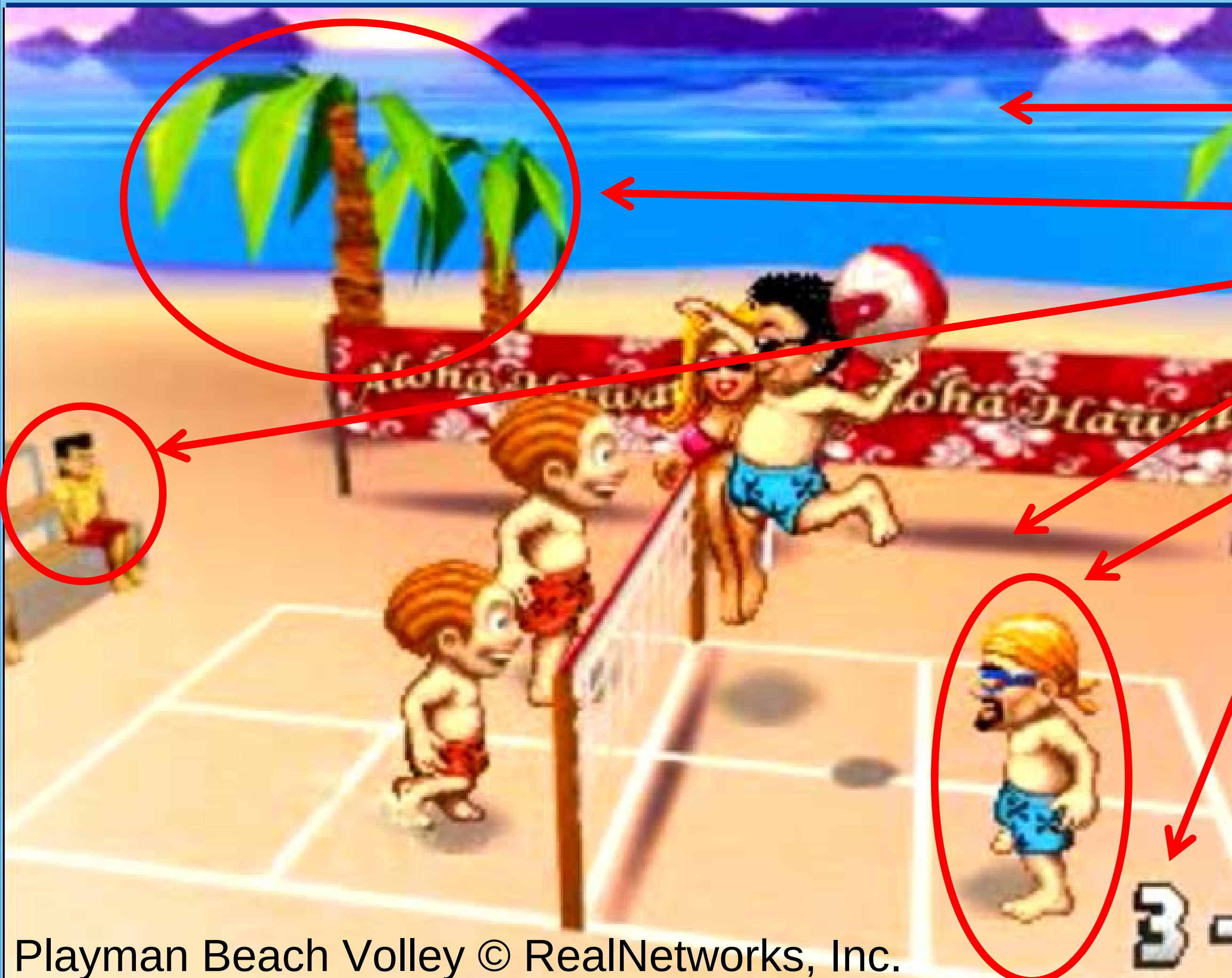
Beware of Exporters

- Exported content is not always optimal
  - Lighting enabled, but overwritten by texture
  - Lighting disabled, normal vectors still included
  - Alpha blending enabled, but alpha always 1.0
  - 16-bit vertices when 8 bits would be enough
  - Perspective correction always enabled
  - …
- Always review the exported scene tree!

Hardware vs. Software

- Shading state
  - SW: Minimize per-pixel operations
  - HW: Minimize shading state changes
- Mixing 2D and 3D rendering
  - SW: No performance penalty
  - HW: Substantial penalty (up to 3x)

Layering 2D and 3D



Playman Beach Volley © RealNetworks, Inc.

- 2D backdrop
- 3D background
- 2D spectators
- 3D field
- 2D players
- 2D overlays

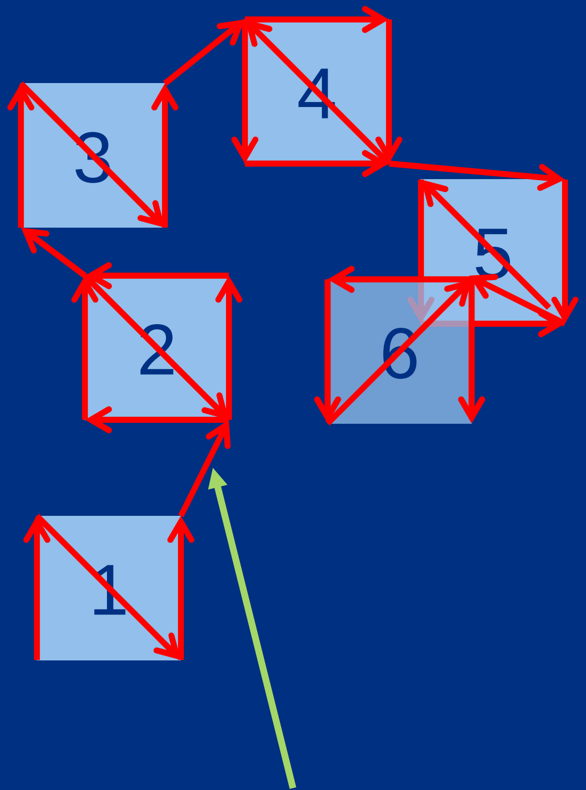
~7 layers of 2D and 3D!

Use Picking with Caution

- `myWorld.pick(...)` can be <u>very</u> slow
- Restrict the pick ray to
  - meshes in a specific Group
  - meshes with a specific scope mask
- Use simplified geometry for picking
  - `setPickingEnable(true)`
  - `setRenderingEnable(false)`

Particle Effects

- Point sprites – not available
- Sprite3D – much too slow
- Put all particles in one Mesh
  - One particle == two triangles
  - Animate by `VertexArray.set(…)`



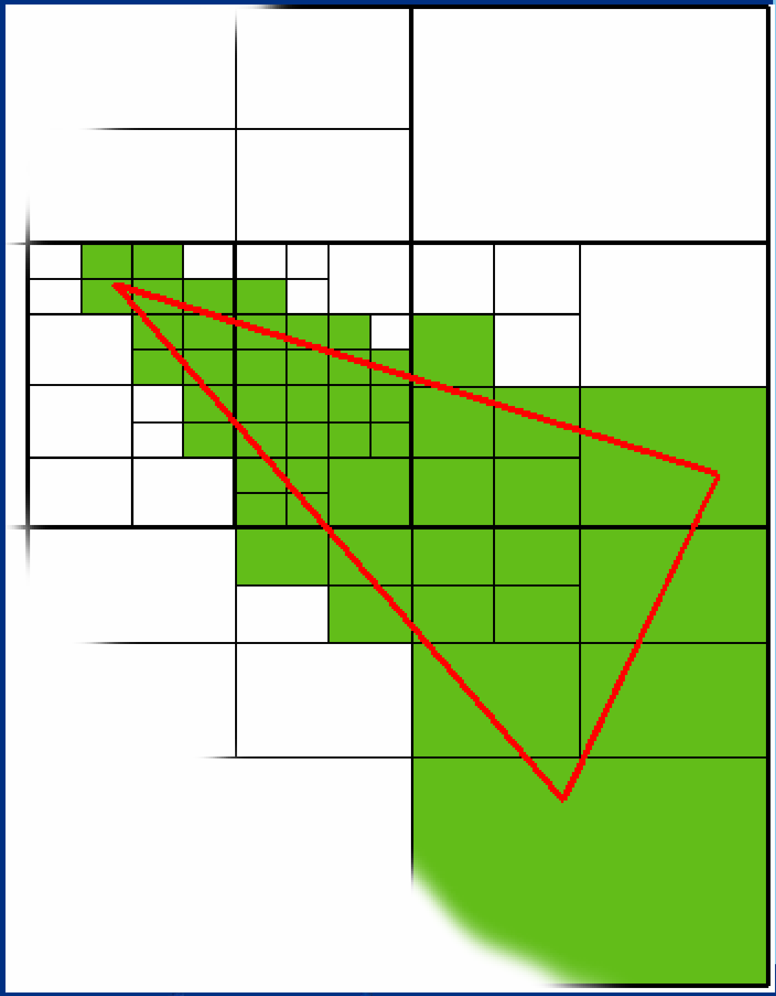
Particles glued into a tri-strip

Easy Terrain Rendering

- Split the terrain into tiles (Meshes)
- Put the meshes into a scene graph
- The engine will do view frustum culling

Terrain Rendering with LOD

- Preprocess into a quadtree
  - leaf node == Mesh
  - inner node == Group
- Use `setRenderingEnable` based on the view frustum



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Deforming Meshes

MorphingMesh — *Vertex morphing mesh*

SkinnedMesh — *Skeletally animated mesh*

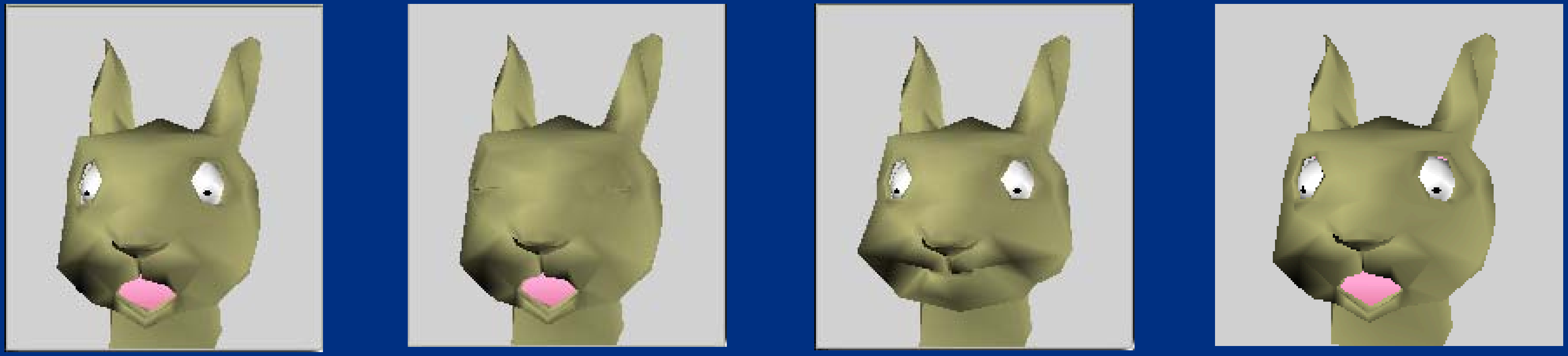
MorphingMesh

- Traditional vertex morphing animation
  - Can morph any vertex attribute(s)
  - A base mesh **B** and any number of morph targets $\mathbf{T_i}$
  - Result = weighted sum of morph deltas

$$\mathbf{R} = \mathbf{B} + \sum_i w_i \left(\mathbf{T}_i - \mathbf{B} \right)$$

- Change the weights $\boldsymbol{w_i}$ to animate

MorphingMesh



Base

Target 1
eyes closed

Target 2
mouth closed

Animate eyes
and mouth
independently

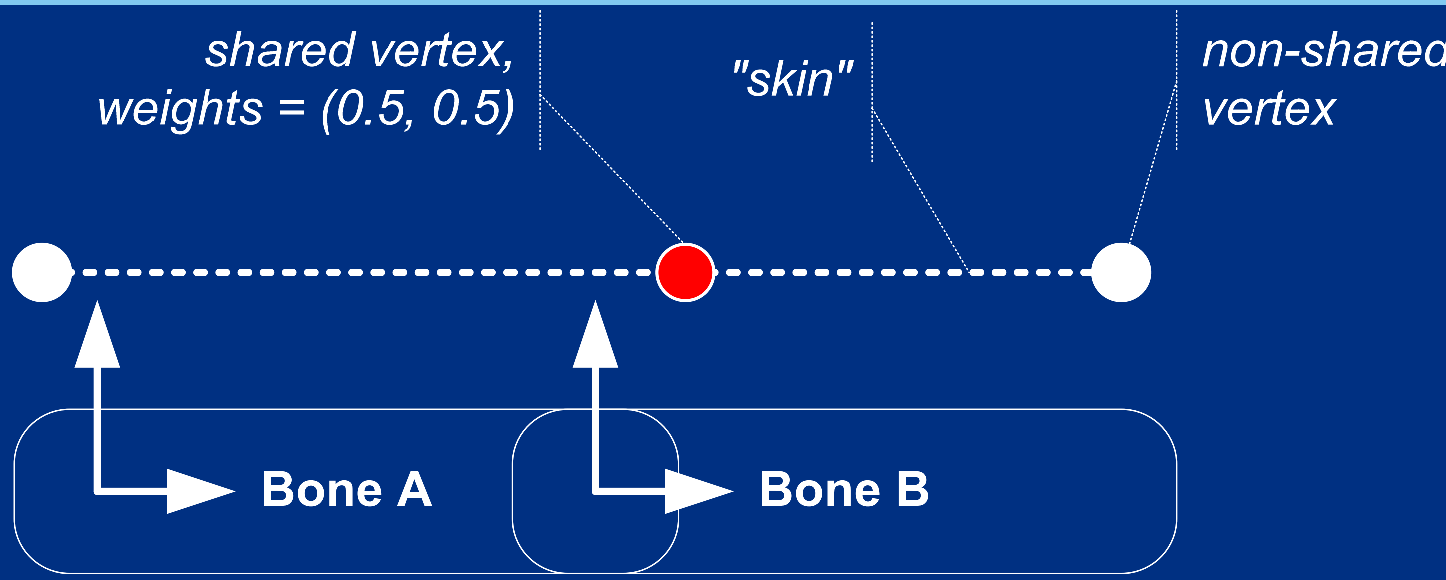
SkinnedMesh

- Articulated characters without cracks at joints
- Stretch a mesh over a hierarchic “skeleton”
  - The skeleton consists of scene graph nodes
  - Each node (“bone”) defines a transformation
  - Each vertex is linked to one or more bones

$$v' = \sum_i w_i \mathbf{M}_i \mathbf{B}_i v$$

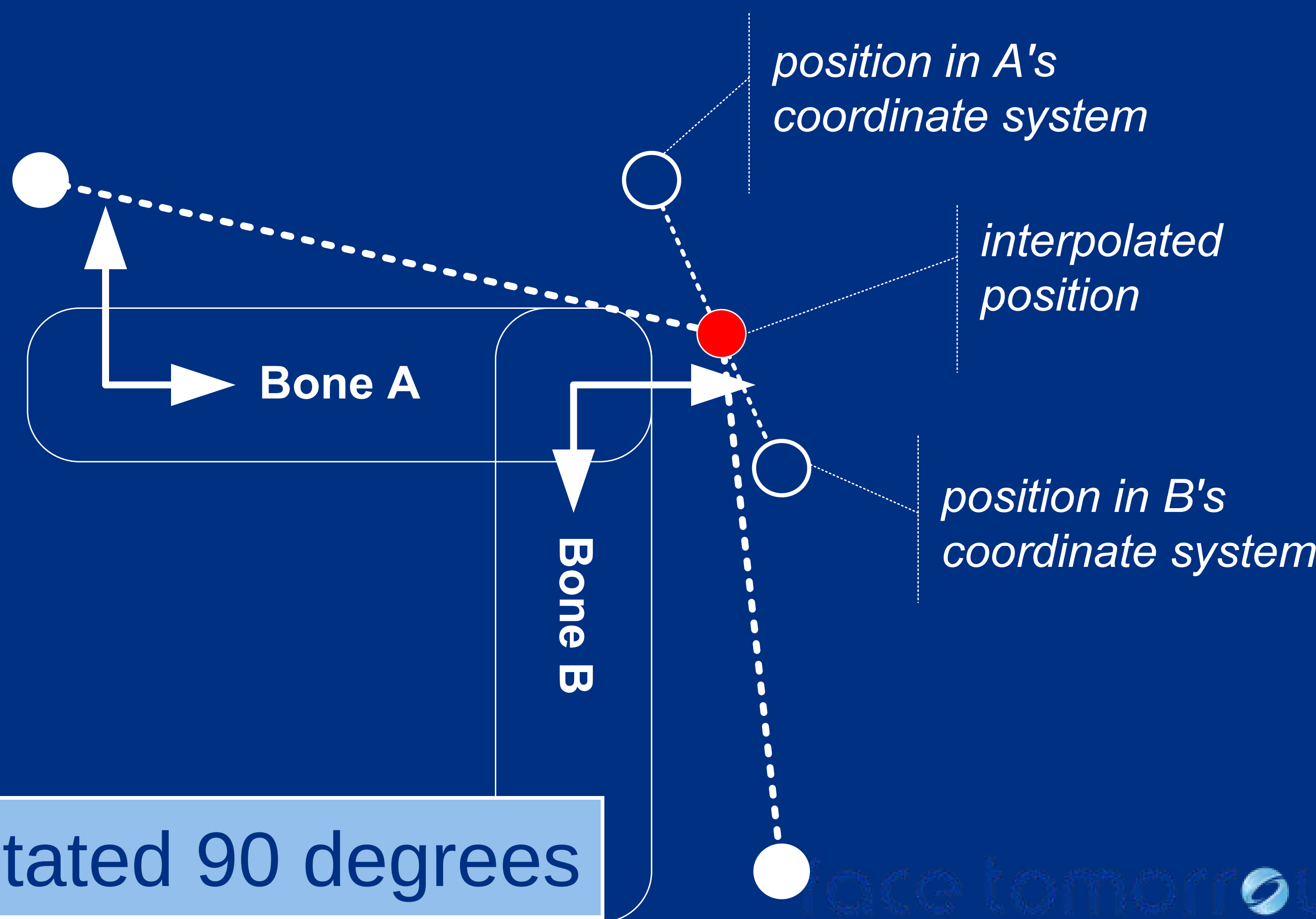
  - $\mathbf{M}_i$ are the node transforms – $\boldsymbol{v}$, $\boldsymbol{w}$, $\mathbf{B}$ are constant

SkinnedMesh



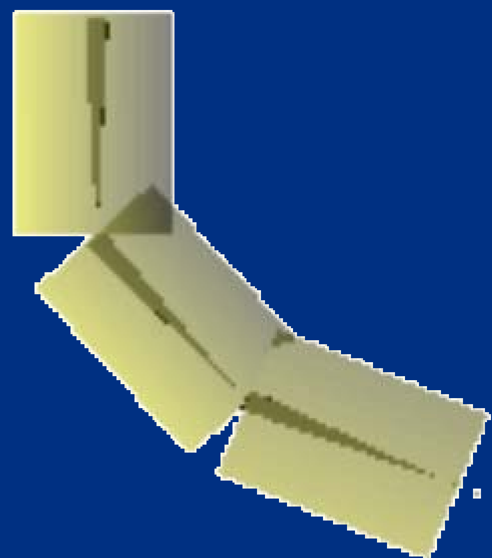
Neutral pose, bones at rest

SkinnedMesh

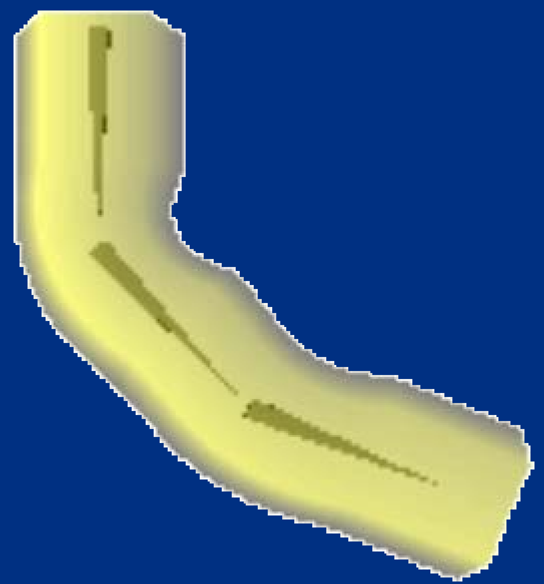


Bone B rotated 90 degrees

SkinnedMesh



Mesh



SkinnedMesh

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Animation Classes

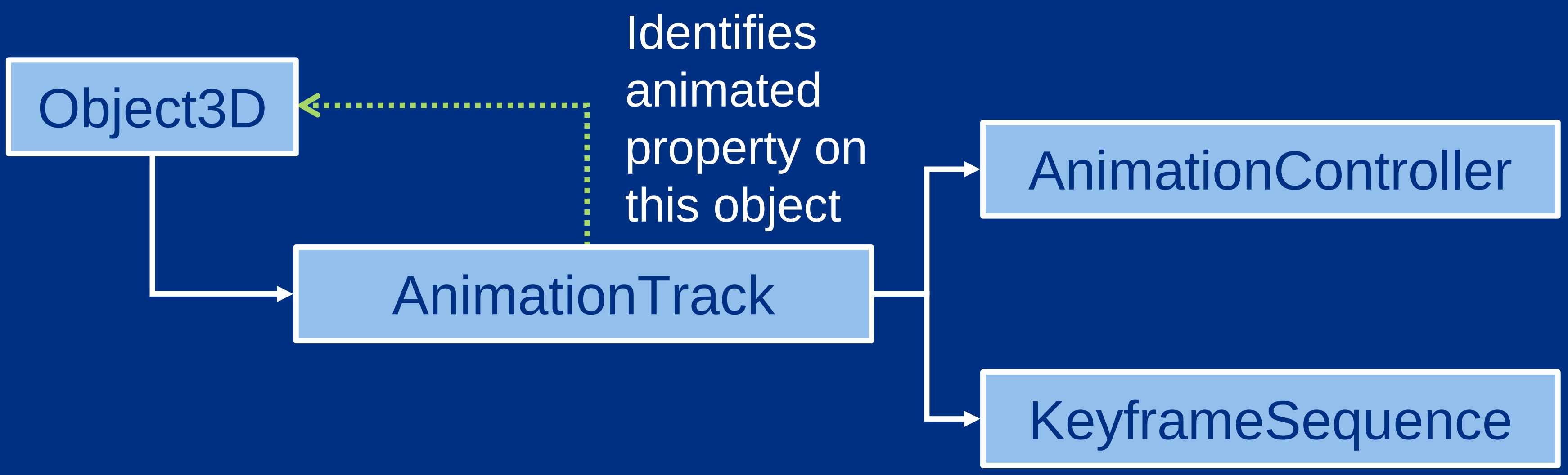
KeyframeSequence
Storage for keyframes
Defines interpolation, looping

AnimationController
Controls the playback of one or more sequences

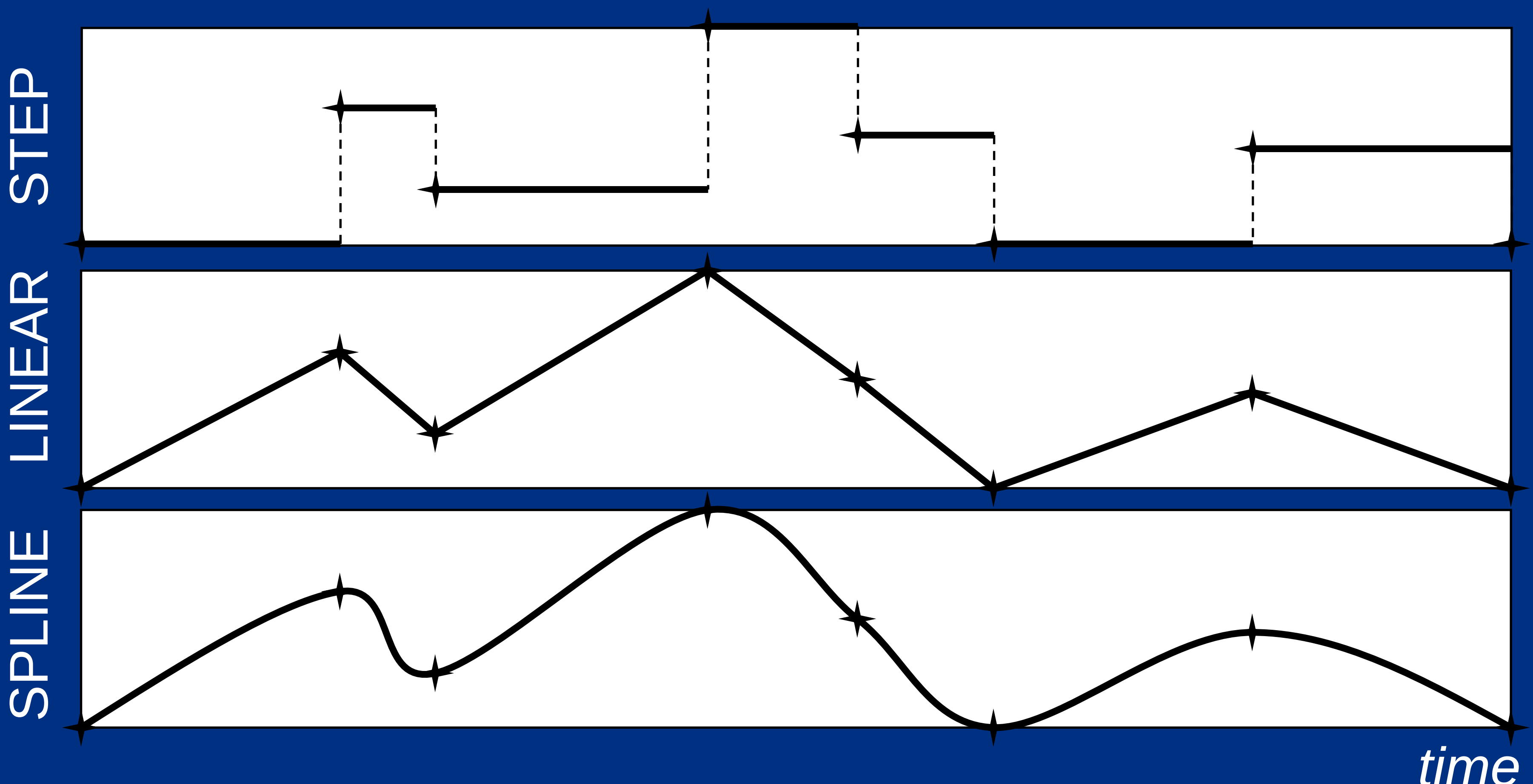
AnimationTrack
A link between sequence, controller and target

Object3D
Base class for all objects that can be animated

Animation Classes



KeyframeSequence: Interpolation Modes



…plus SLERP and SQUAD for quaternions

AnimationController: Timing and Speed

- Maps world time into sequence time
- Can control any number of sequences

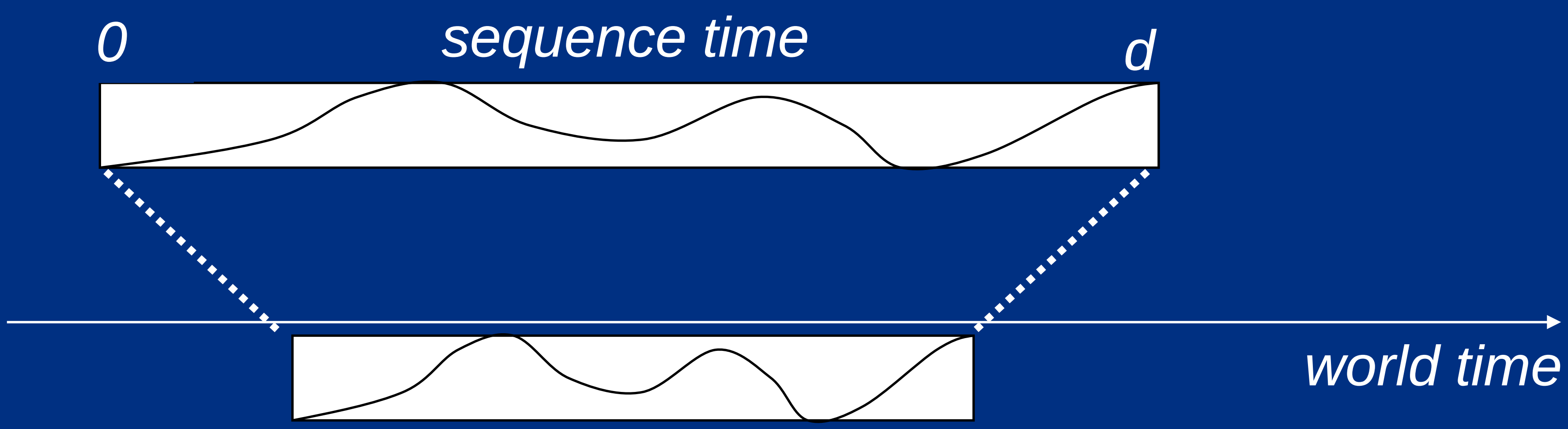


Diagram courtesy of Sean Ellis, ARM

Animation

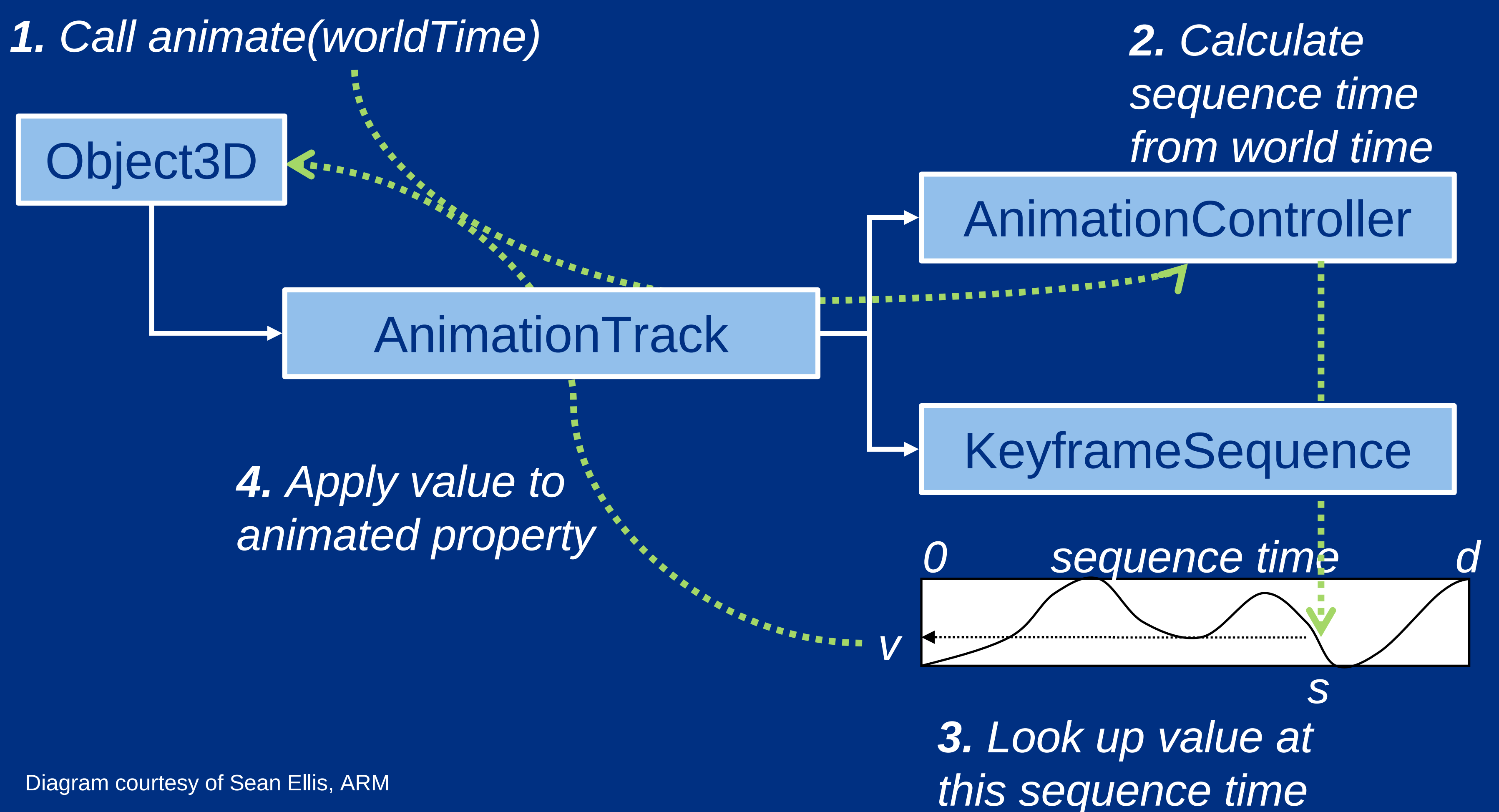


Diagram courtesy of Sean Ellis, ARM

Animation

Tip: Interpolate quaternions as ordinary 4-vectors

- Supported in HI Corp's M3G Exporter
- SLERP and SQUAD are slower, but need less keyframes
- Quaternions are automatically normalized before use

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Summary

- M3G enables real-time 3D on mobile Java
  - Minimizes Java code along critical paths
  - Designed for both software and hardware
- OpenGL ES features at the foundation
- Animation & scene graph layered on top

30’000 devices sold during this presentation

Demos

Playman Winter Games – RealNetworks

Side view only

2D

Perspective and depth

3D

Playman World Soccer – RealNetworks

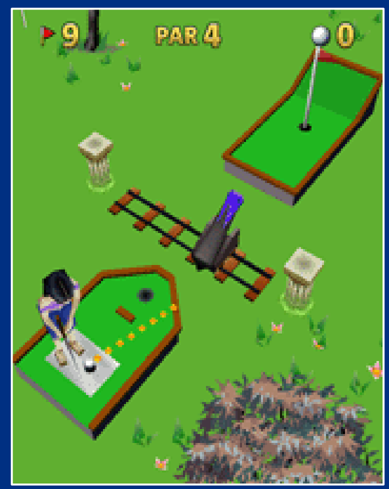
- 2D/3D hybrid
- Cartoon-like 2D figures in a 3D scene
- 2D particle effects etc.

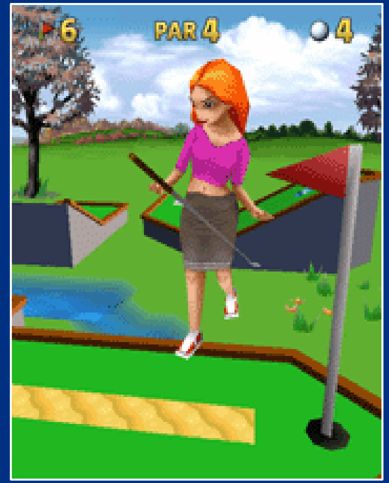
Tower Bloxx – Digital Chocolate

- Puzzle/arcade mixture
- Tower building mode is in 3D, with 2D overlays and backgrounds
- City building mode is in pure 2D

Mini Golf Castles – Digital Chocolate

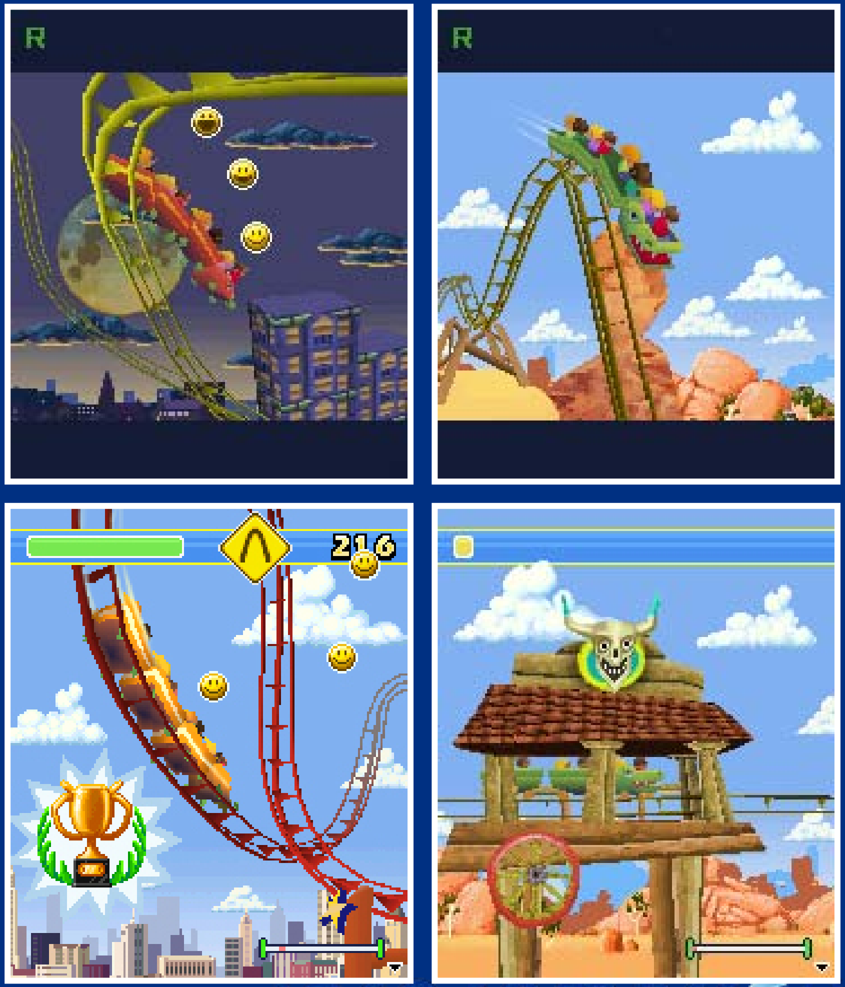
- 3D with 2D background and overlays
- Skinned characters
- Realistic ball physics





Rollercoaster Rush – Digital Chocolate

- 2D backgrounds
- 3D main scene
- 2D overlays



Q&A

Thanks:

Sean Ellis (ARM)

Kimmo Roimela (Nokia)

Markus Pasula (RealNetworks)

Sami Arola (Digital Chocolate)

SIGGRAPH2007

M3G in the Real World

Mark Callow

Chief Architect

HI CORPORATION

SIGGRAPH2007

An M3G Game

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DIGITAL CHOCOLATE

Rollercoaster Rush 3D™

Agenda

- J2ME game development
- Tools
- COFFEE BREAK
- The structure of a MIDlet
- A walkthrough a sample game
- Why mobile game development is hard
- Publishing your content

Agenda

- J2ME game development
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Game Development Process

- Traditional Java Game

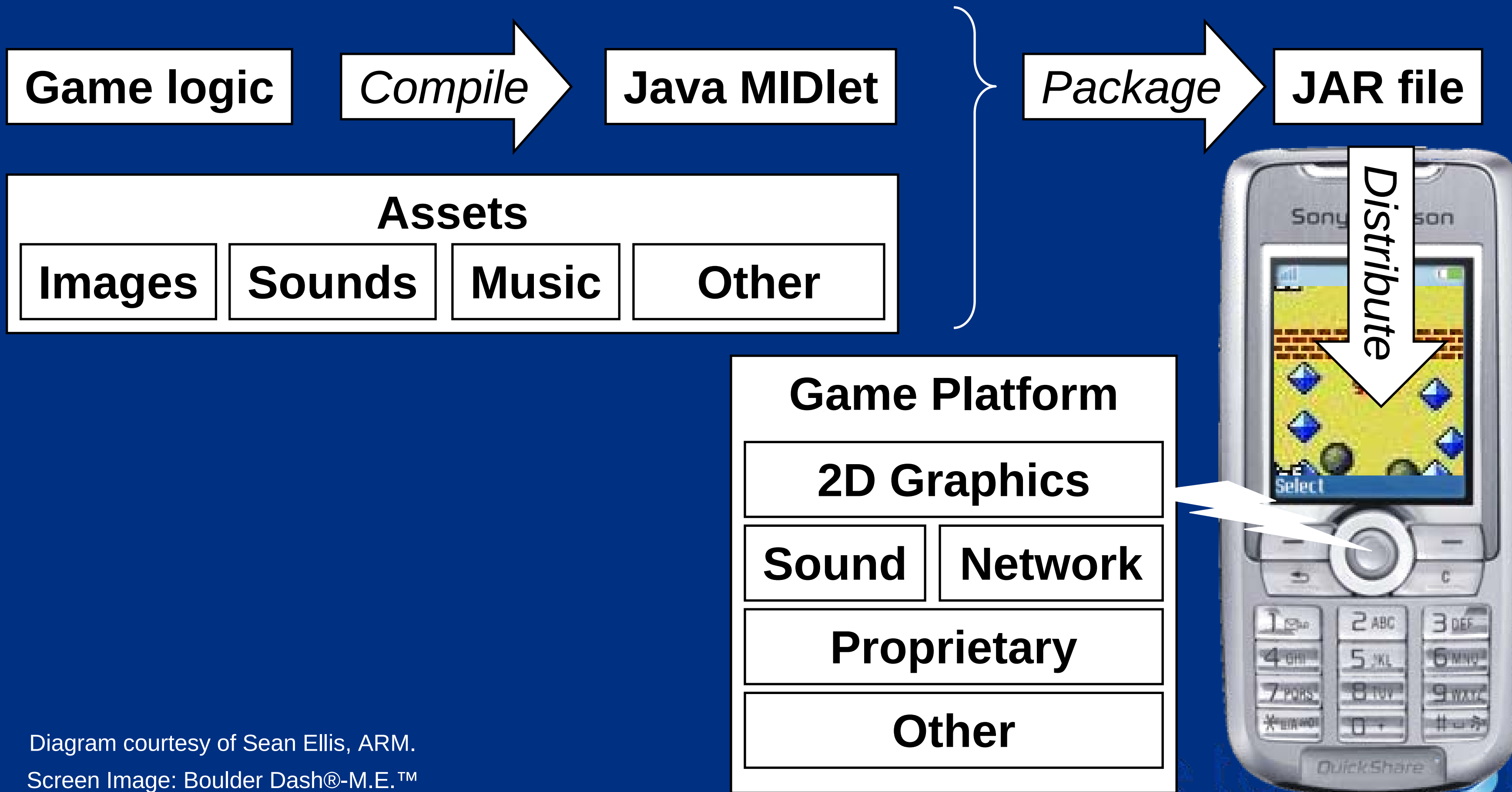


Diagram courtesy of Sean Ellis, ARM.
Screen Image: Boulder Dash®-M.E.™

M3G Game Development Process

- How M3G Fits

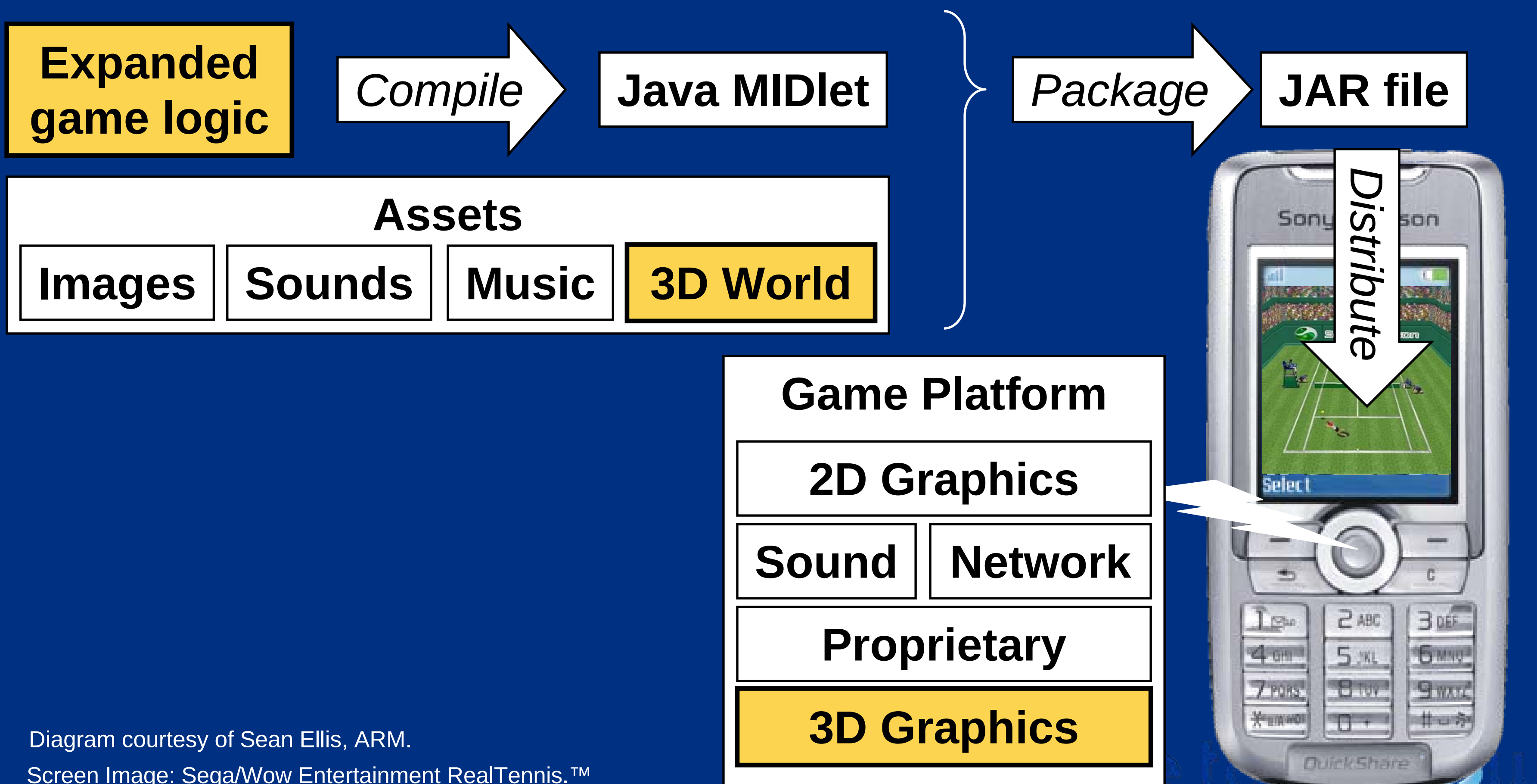
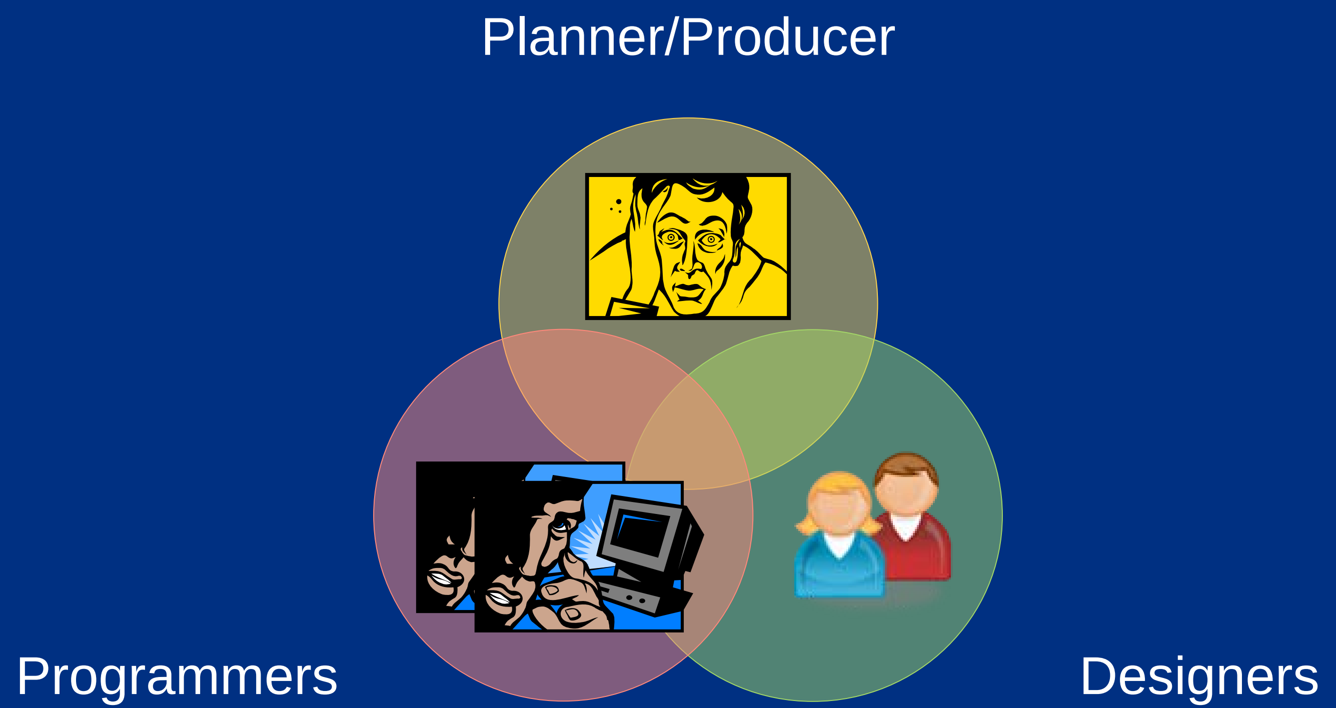


Diagram courtesy of Sean Ellis, ARM.

Screen Image: Sega/Wow Entertainment RealTennis.™

Development Team Structure



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- Tools
- COFFEE BREAK
- The structure of a MIDlet
- A walkthrough a sample game
- Why mobile game development is hard
- Publishing your content

Tools Agenda

- Tools
  - Creating your assets
  - Programming tools & development platforms

Creating Your Assets: Images

- Textures & Backgrounds

Expanded game logic

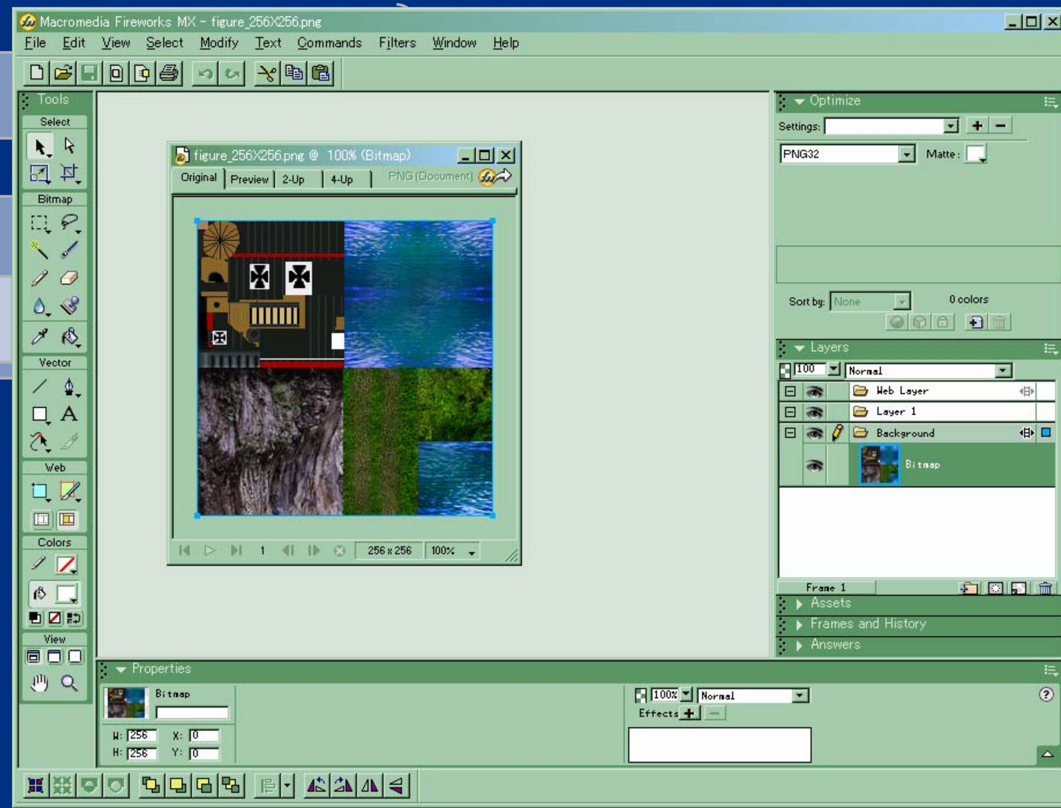
Compile

Assets

Images

Sounds

Music



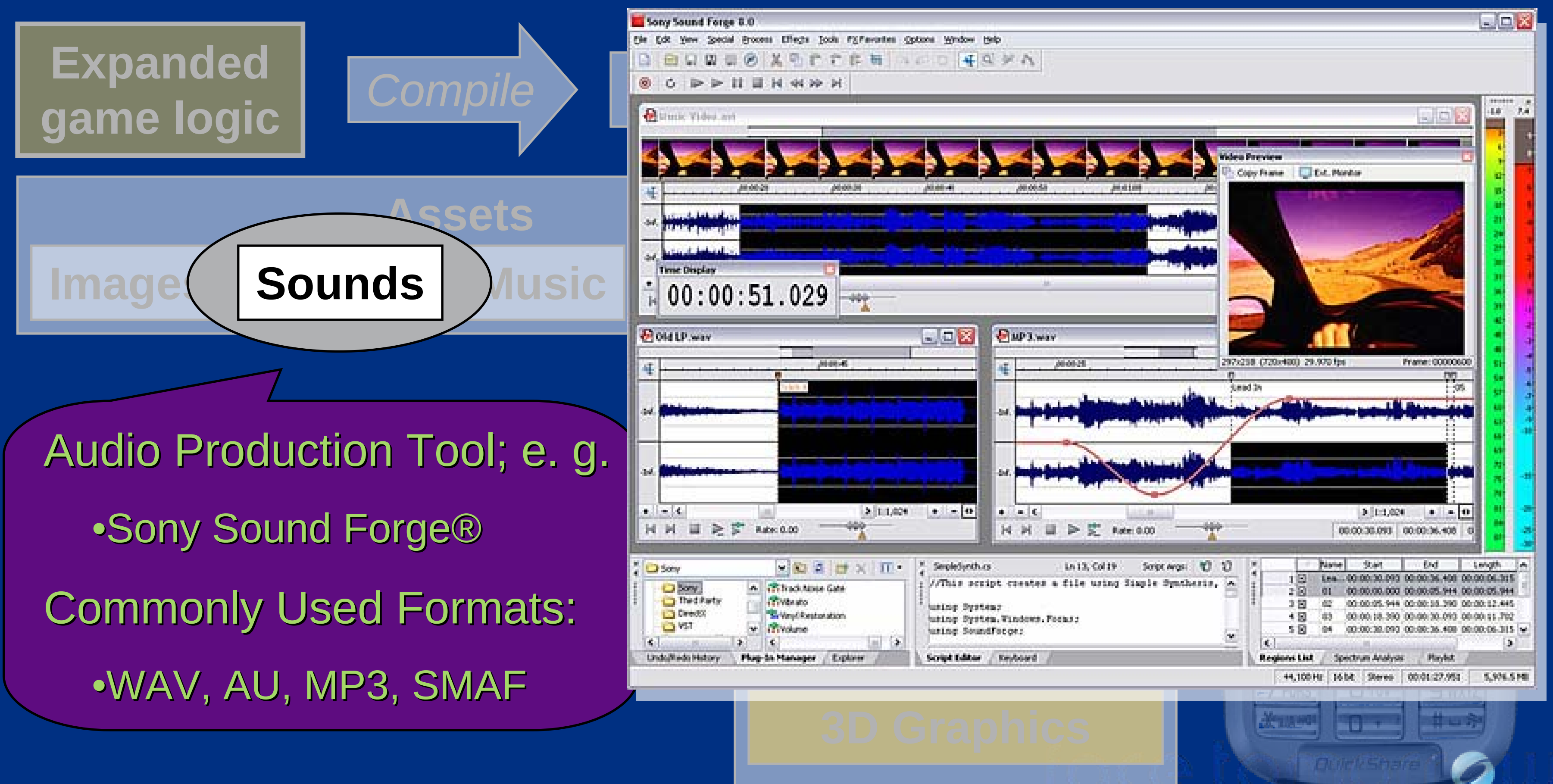
3D Graphics

Image Editor with PNG output. E. g:

- Adobe Fireworks
- Adobe Photoshop

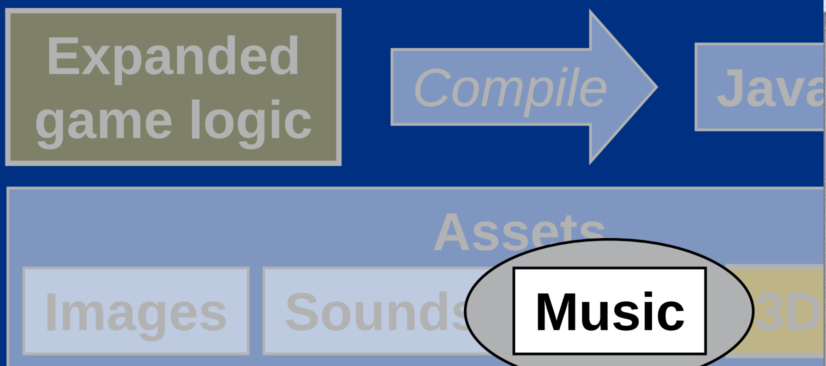
Creating Your Assets: Sounds

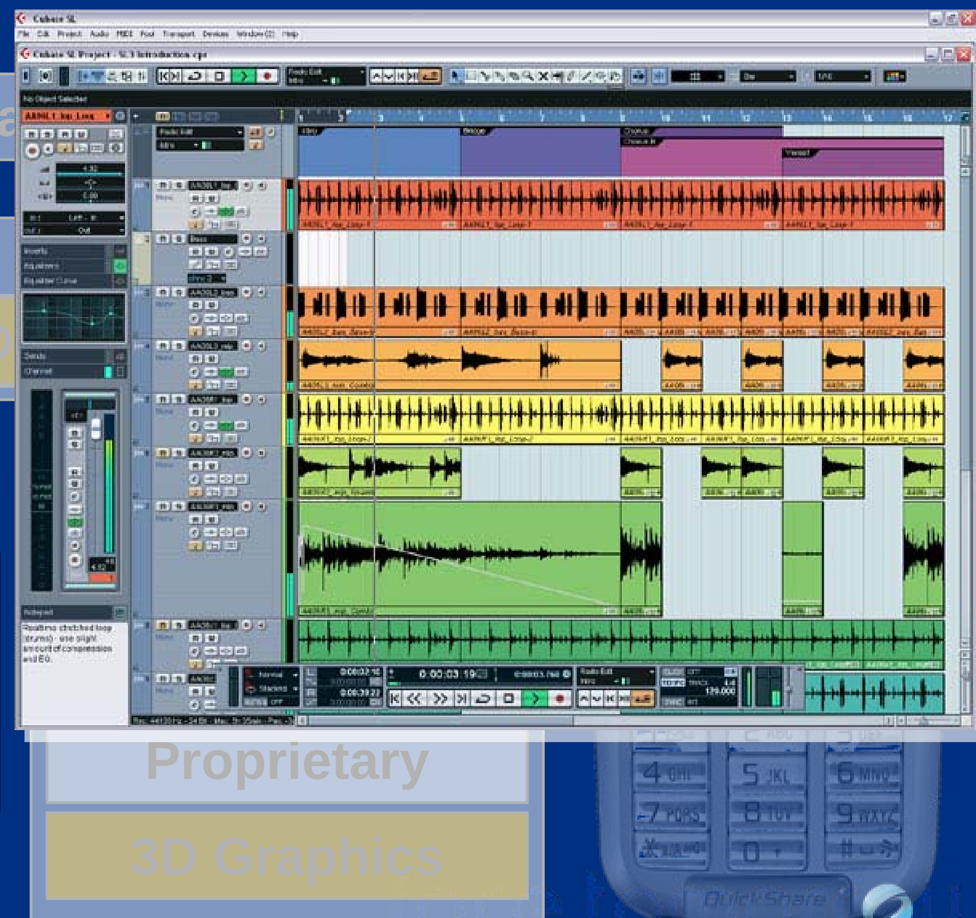
- Audio Tools



Creating Your Assets: Music

- Music Tools





MIDI Sequencer; e. g.

- Steinberg Cubase

Formats:

- SMAF, MIDI, cMIDI, MFi

Creating Your Assets: 3d Models

- Modeling Tools

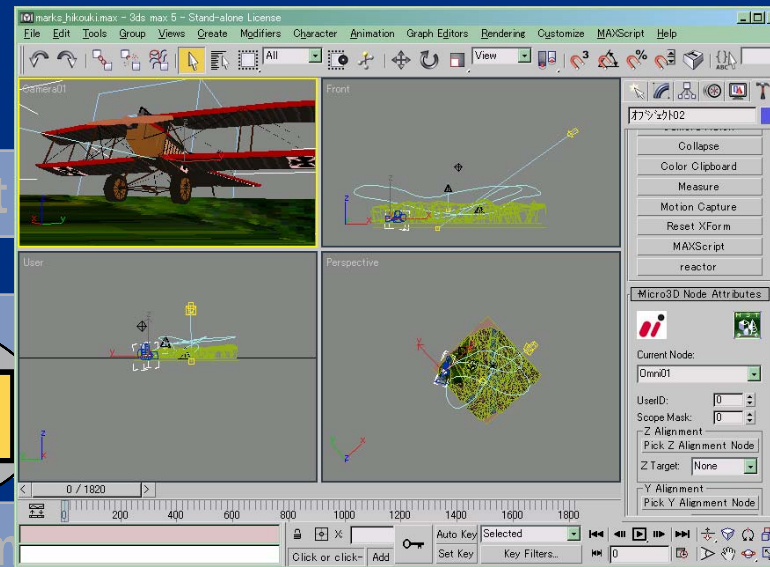
Expanded game logic

Compile

Java MIDlet

Assets

Images | Sounds | Music | 3D World



Gam...

2D Graphics

...und | Network

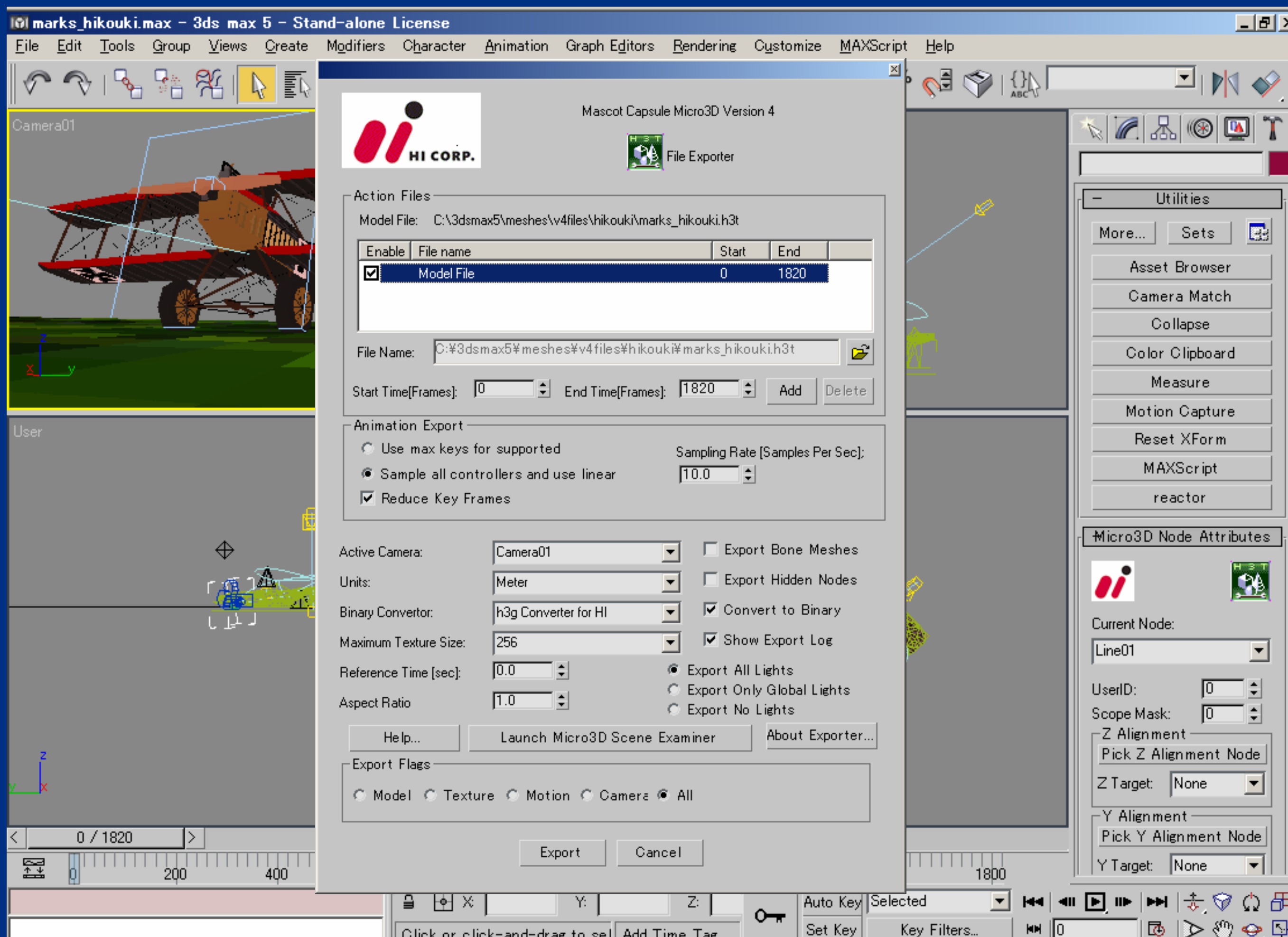
Proprietary

3D Graphics

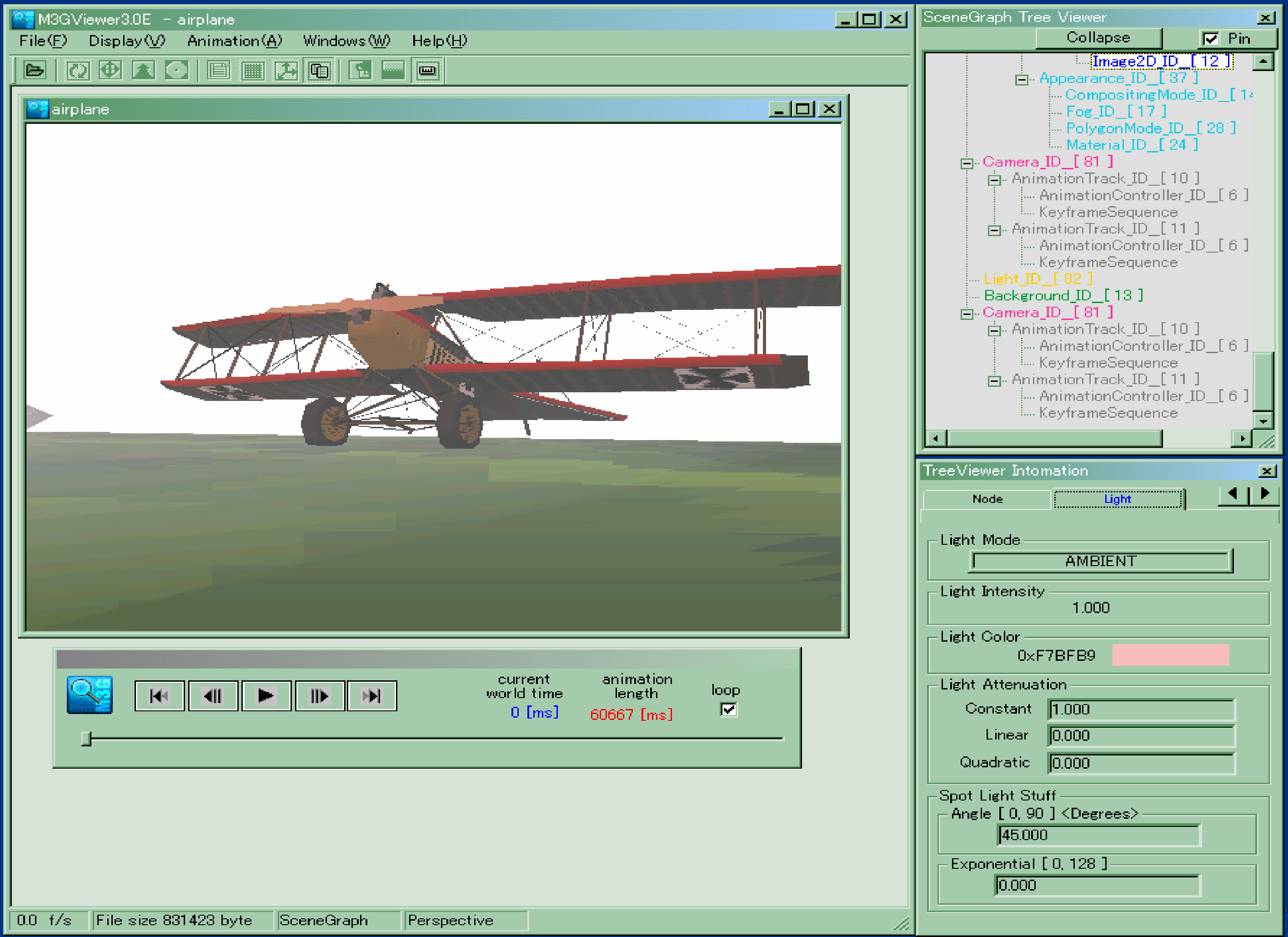
3d Modeler with M3G plug-in; e.g.

- •Lightwave
- •Maya
- •3d studio max
- •Softimage|XSI

Export 3d Model to M3G



M3G File Viewer



Demo: On a Real Phone

Tips for Designers 1

- *TIP: Don't use GIF files*
  - *The specification does not require their support*
- *TIP: Create the best possible quality audio & music*
  - It's much easier to reduce the quality later than increase it
- *TIP: Polygon reduction tools & polygon counters are your friends*
  - Use the minimum number of polygons that conveys your vision satisfactorily

Tips for Designers 2

- *TIP: Use light maps for lighting effects*
  - Usually faster than per-vertex lighting
  - Use luminance textures, not RGB
  - Multitexturing is your friend
- *TIP: Try LINEAR interpolation for Quaternions*
  - *Faster than SLERP*
  - *But less smooth*

Tips for Designers 3

- *TIP: Favor textured quads over Background & Sprite3D*
  - Background and Sprite3D will be deprecated in M3G 2.0
  - Were intended to speed up software renderers
  - but implementation is complex, so not much speed up and no speed up at all with hardware renderers
  - Nevertheless Sprite3Ds are convenient to use for 2D overlays and Backgrounds are convenient when background scrolling is required.
- *LIMITATION: Sprites not useful for particle systems*

Tools Agenda

- Tools
  - Creating your assets
  - Programming tools & development platforms

Program Development

- Edit, Compile, Package

Traditional

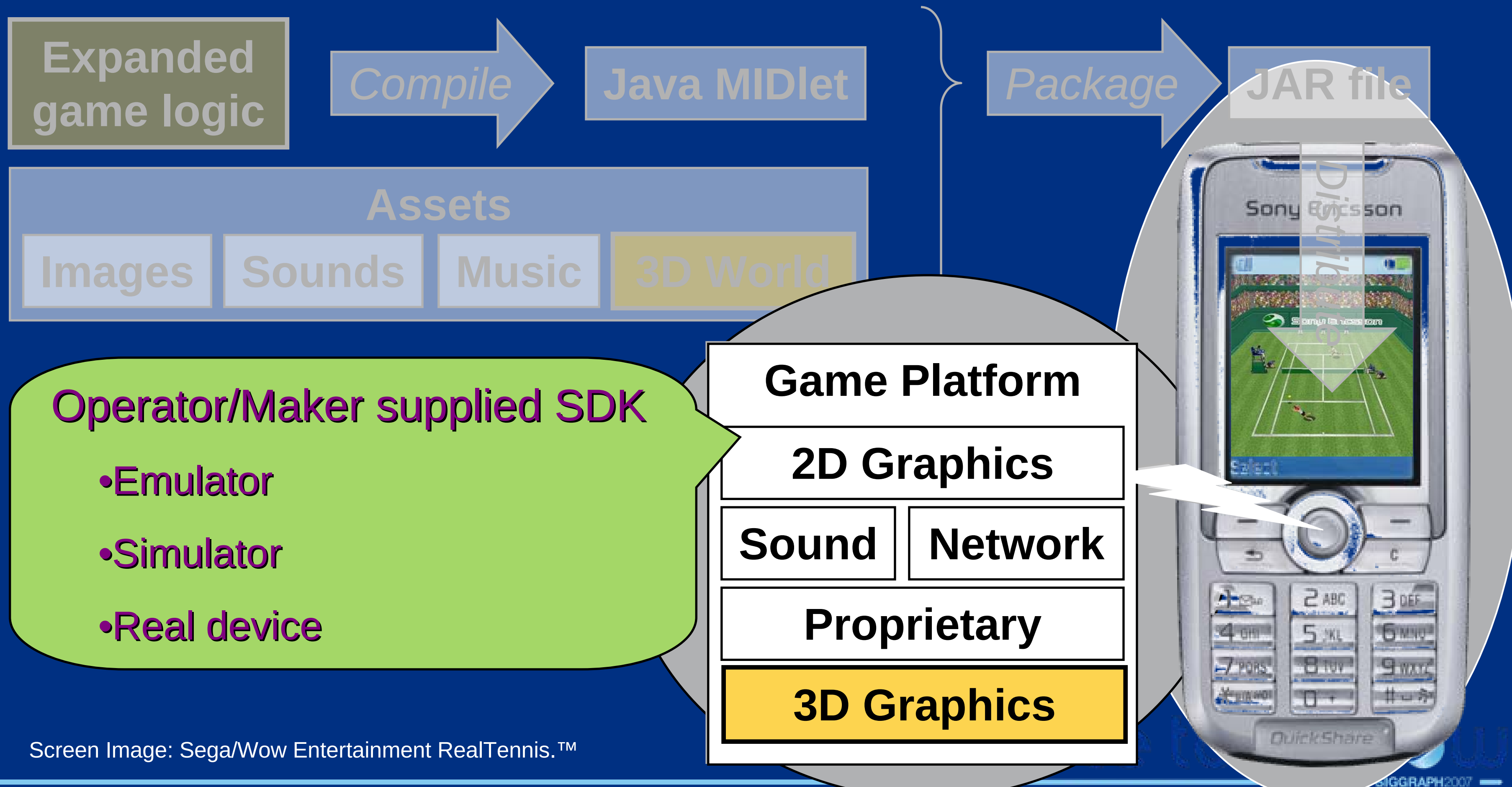
- WTK, shell, editor, make, javac, preverifier

Integrated Development Environment

- *Eclipse + EclipseME*
- *Borland JBuilder + J2ME Wireless Toolkit*
- *NetBeans IDE + Mobility Pack*

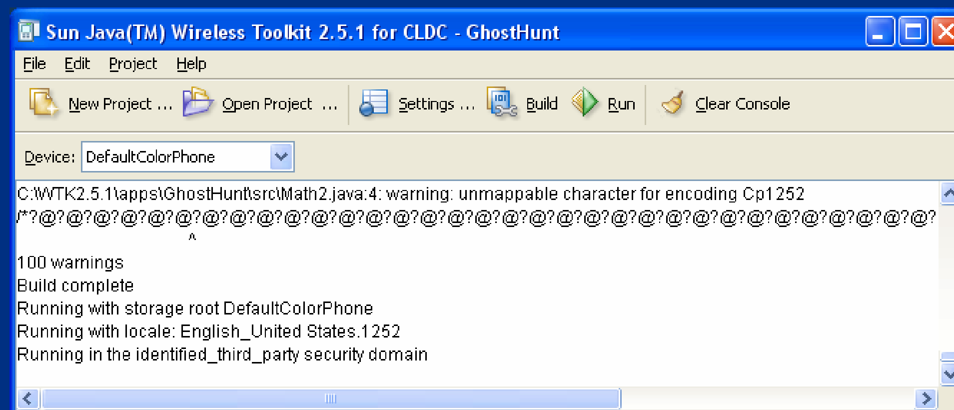
Program Development

- Test & Debug



Screen Image: Sega/Wow Entertainment RealTennis.™

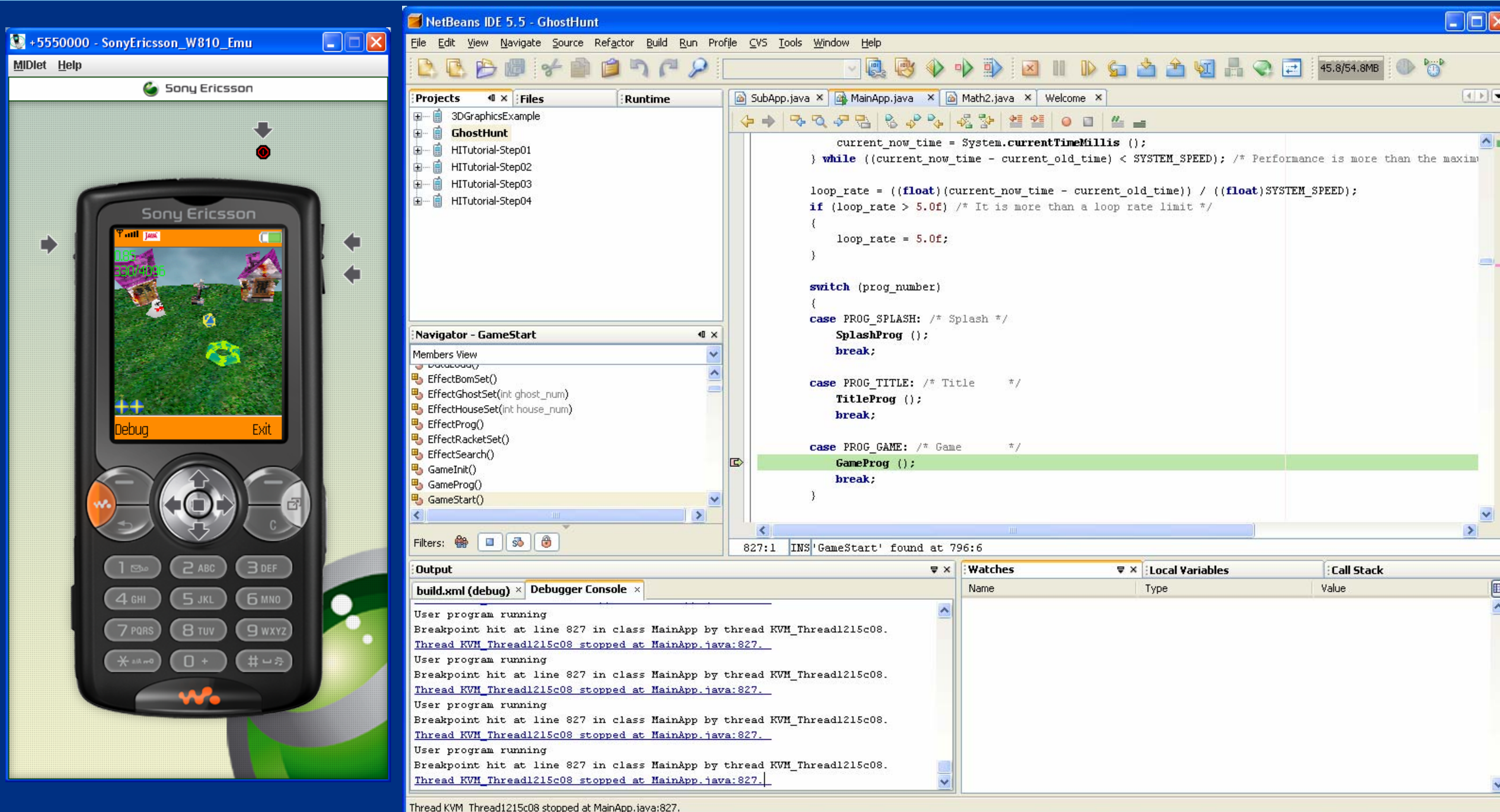
Java Wireless Toolkit 2.5.1 for CLDC



KToolBar

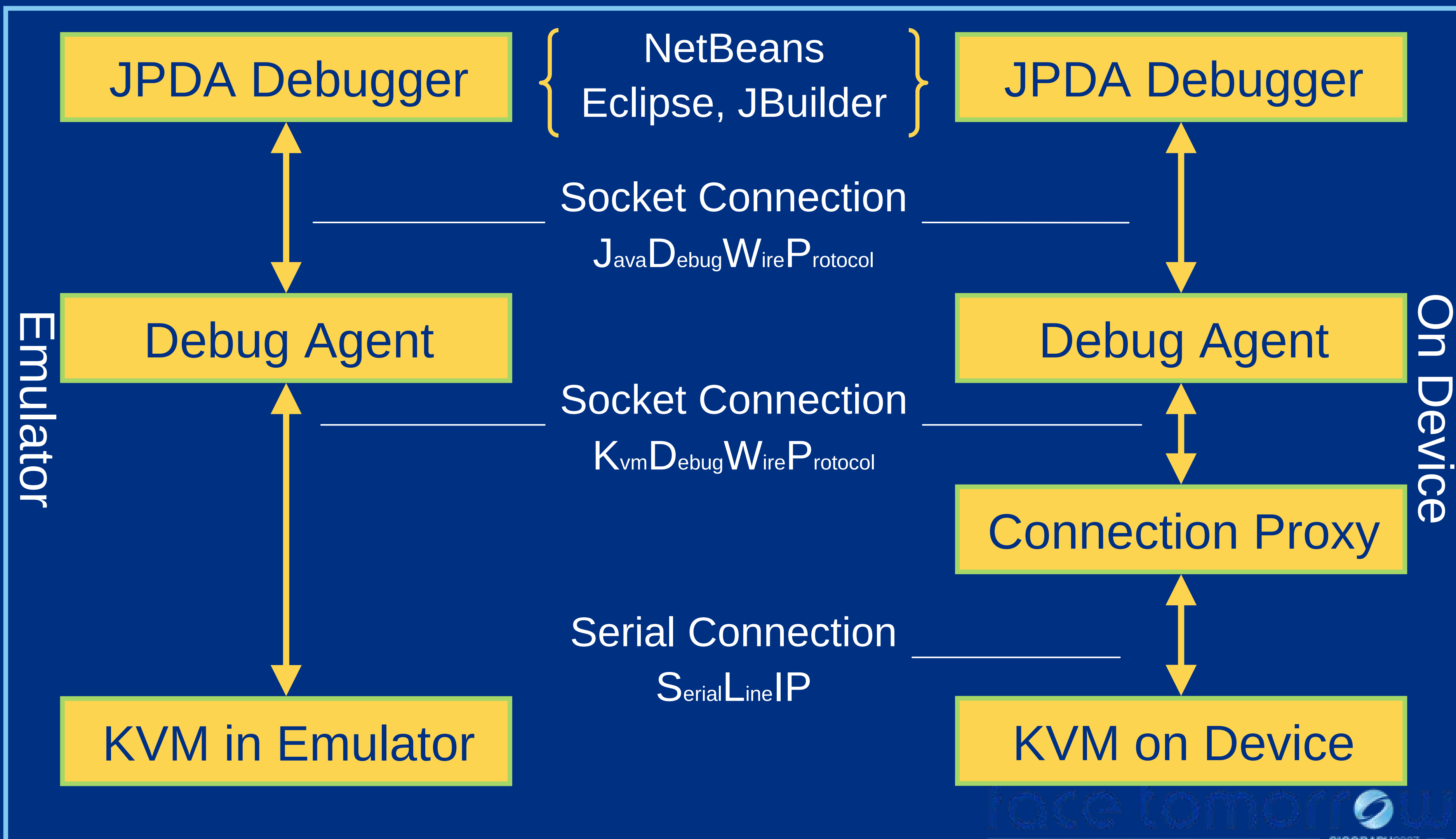
Handset Emulator

NetBeans + Mobility Pack + SE SDK



face tomorrow SIGGRAPH2007

Java ME Debugging



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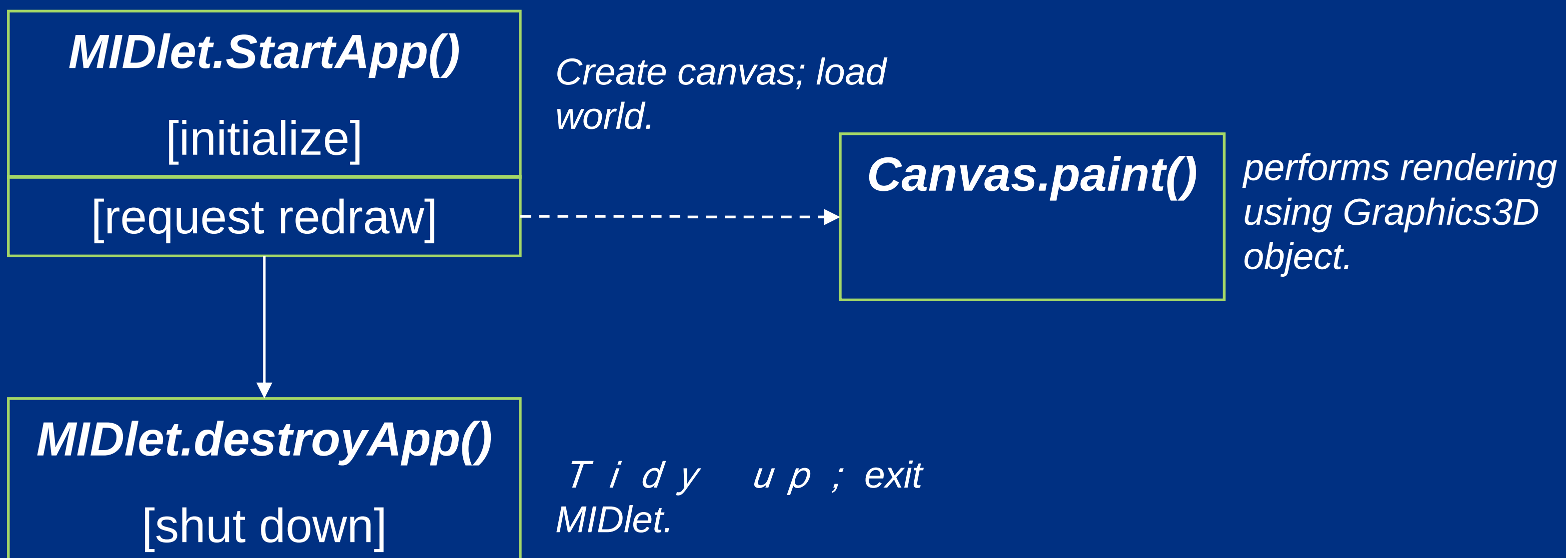
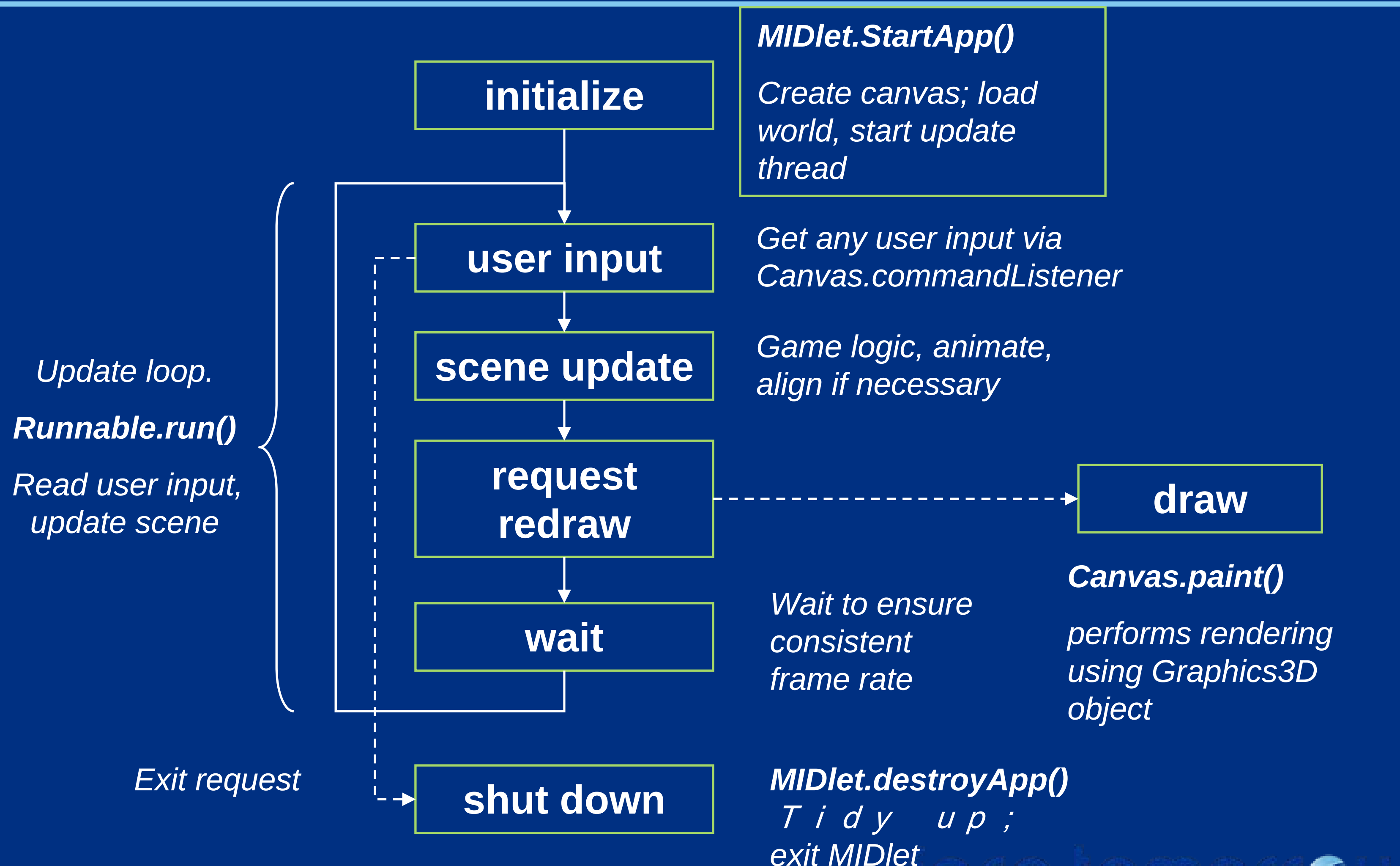
The Simplest MIDlet

- Derived from MIDlet,
- Overrides three methods



- And that’s it.

A More Interesting MIDlet



Flow-chart courtesy of Sean Ellis, ARM

MIDlet Phases

- Initialize
- Update
- Draw
- Shutdown

Initialize

- Load assets: world, other 3D objects, sounds, etc.
- Find any objects that are frequently used
- Perform game logic initialization
- Initialize display
- Initialize timers to drive main update loop

Update

- Usually a thread driven by timer events
- Get user input
- Get current time
- Run game logic based on user input
- Game logic updates world objects if necessary
- Animate
- Request redraw

Update Tips

- *TIP: Don't create or release objects if possible*
- *TIP: Call* system.gc() *regularly to avoid long pauses*
- *TIP: cache any value that does not change every frame; compute only what is absolutely necessary*

Draw

- Usually on overridden paint method
- Bind Graphics3D to screen
- Render 3D world or objects
- Release Graphics3D
  - …whatever happens!
- Perform any other drawing (UI, score, etc)
- Request next timed update

Draw Tips

- *TIP: Don’t do 2D drawing while Graphics3D is bound*

Shutdown

- Tidy up all unused objects
- Ensure once again that Graphics3D is released
- Exit cleanly
- Graphics3D should also be released during pauseApp

MIDlet Review

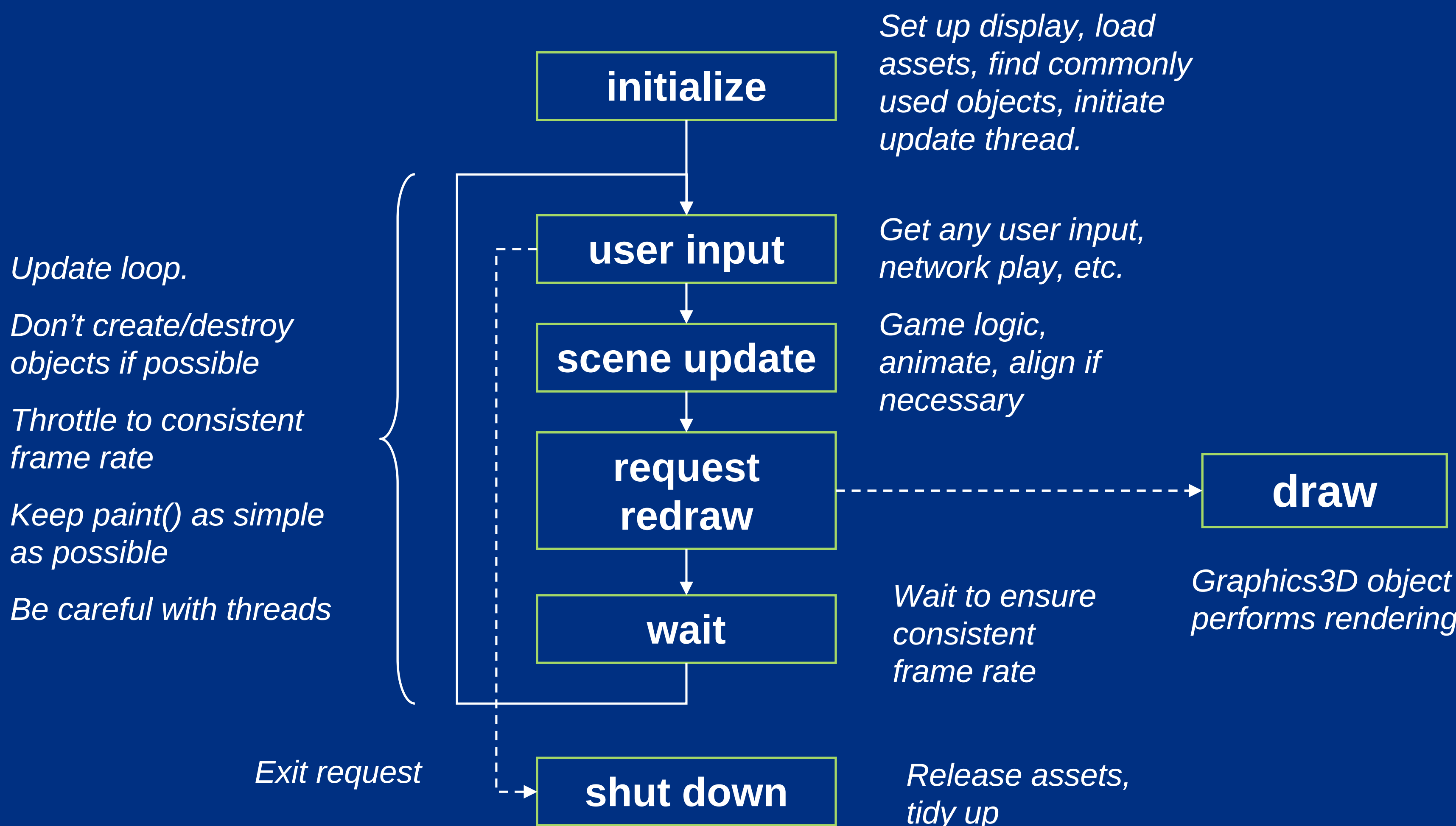


Diagram courtesy of Sean Ellis, ARM

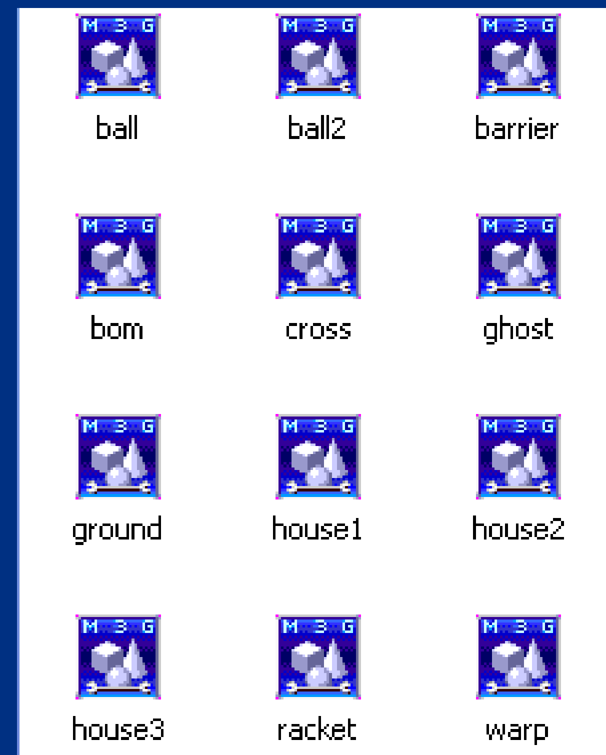
Agenda

- J2ME game development
- Tools
- COFFEE BREAK
- The structure of a MIDlet
- A walkthrough a sample game
- Why mobile game development is hard
- Publishing your content

Demo: *GhostHunt*

GhostHunt Models

GhostHunt Assets



GhostHunt

- Loads data from .m3g and .png files
- Arrow keys move a “plasma” racquet side to side to hit a “plasma” ball
- Ball hits deform ghost houses and make the ghosts disappear
- Uses Immediate mode
- Uses 2D for sky and scores

GhostHunt Framework

- MainApp.java – MIDlet specialization; handles initialization & data loading; contains run thread
- SubApp.java – canvas specialization
- Math2.java – math library

GhostHunt: initialization

```
import javax.microedition.midlet.*;
import javax.microedition.lcdui.*;
import javax.microedition.m3g.*;

class MainApp extends MIDlet implements CommandListener {
  MainApp() {
    exit_command   = new Command("Exit" , Command.EXIT  , 0);
    select_command = new Command("Debug", Command.SCREEN, 0);

     /* Create canvas */
     subapp = new SubApp ();
     subapp.addCommand (exit_command);
     subapp.addCommand (select_command);
     subapp.setCommandListener (this);

     SystemInit ();
     prog_number = PROG_SPLASH;
     WorkInit ();
     GameInit ();
     DataLoad ();
  }
```

GhostHunt: loading data

```
DataLoad() {
  try {
    image [TITLE_SP] = Image.createImage ("/title.png");
    …
  } catch (Exception e) {
    System.out.println ("-------------- SP Load");
    ApplicationEnd ();
  }

  try {
    load_data [RACKET_DATA] = Loader.load("/racket.m3g");
  } catch (Exception e) {
    …
  }
  mesh [RACKET_DATA] = (Mesh)load_data [RACKET_DATA][0];
  vbuf [RACKET_DATA] = mesh [RACKET_DATA].getVertexBuffer();
  ibuf [RACKET_DATA] = mesh [RACKET_DATA].getIndexBuffer(0);
  app  [RACKET_DATA] = mesh [RACKET_DATA].getAppearance(0);
  …
}
```

GhostHunt: MIDlet functions

```
public void startApp () {
  thread = new Thread () {
    public void run () {
      GameStart ();
    }
  };
  // Call the new thread's run method.
  thread.start ();
}

public void pauseApp ()
{
    thread = null;
}

public void destroyApp (boolean unconditional)
{
    ApplicationEnd();
}
```

GhostHunt: GameStart thread

```
void GameStart () {
  Thread thisThread = Thread.currentThread();
  Display.getDisplay (this).setCurrent (subapp);
  while (thread == thisThread) {
    prev_time = now_time;
    do {
      now_time = System.currentTimeMillis ();
    } while ((now_time - prev_time) < SYSTEM_SPEED);
    loop_rate = (now_time - prev_time) / SYSTEM_SPEED;
    if (loop_rate > 5.0f) { /* More than loop rate limit */
      loop_rate = 5.0f;
    }
        /* do game stuff here … */
    try {
      Thread.sleep (1);
    } catch (InterruptedException e) {
      ApplicationEnd ();
    }
  }
}
```

GhostHunt: "do game stuff here ..."

```
void GameStart () {
  …
  switch (prog_number) {
    case PROG_SPLASH: /* Splash */
      SplashProg ();
      break;
   case PROG_TITLE: /* Title     */
      TitleProg ();
      break;
   case PROG_GAME: /* Game       */
      GameProg ();
      break;
  }
  …
}
```

GhostHunt: TitleProg

```
void TitleProg ()
{
  key_dat = subapp.sys_key; /* Get keypresses */

  if ((key_dat & KEY_FIRE) != 0) /* it is fire key */
  {
    racket_tx = 0.0f;
    racket_tz = 0.0f; /* for initializing camera */
    WorkInit ();
    GameInit ();
   …
    prog_number = PROG_GAME;
  }

/*------ Updating------*/
  start_loop++;

/*------ Drawing ------*/
  subapp.repaint ();
}
```

SubApp: *GhostHunt's* Canvas

```
public class SubApp extends Canvas {
  int cnt;
  static int keydata [] = { UP, LEFT, RIGHT, DOWN, FIRE };
  int length = keydata.length;

  static int sys_key = 0;

  synchronized public void paint (Graphics graphics) { }

  …

  protected void keyPressed (int key) { }

  protected void keyRepeated (int key) { }

  protected void keyReleased (int key) { }
}
```

GhostHunt: key handling

```
static int keydata [] = { UP, LEFT, RIGHT, DOWN, FIRE };

protected void keyPressed (int key) {
  for (cnt = 0; cnt < length; cnt++) { /* Search key data. */
    if (getGameAction (key) == keydata [cnt]) {
      sys_key |= (1 << cnt);
    }
  }
}

protected void keyReleased (int key) {
  for (cnt = 0; cnt < length; cnt++) { /* Search key data. */
    if (getGameAction (key) == keydata [cnt]) {
      sys_key &= (~(1 << cnt));
    }
  }
}
```

SubApp *paint* Method

```
synchronized public void paint (Graphics graphics) {
/*------ select drawing process ------*/
   switch (MainApp.prog_number)
   {
   case MainApp.PROG_SPLASH:
        SplashDraw (graphics);  /* Splash */
        break;

   case MainApp.PROG_TITLE:
        TitleDraw (graphics);   /* Title  */
        break;

   case MainApp.PROG_GAME:
        GameDraw (graphics);    /* Game */
        break;
   }

   Math2.Rand ();
}
```

GameDraw

```
void GameDraw (Graphics graphics)
{
    …
   graphics.drawImage (MainApp.image[MainApp.BG_SP], 0, 0,
    Graphics.TOP | Graphics.LEFT); /* 2D background sprite */

   MainApp.g3d.bindTarget (graphics);
   MainApp.g3d.clear (MainApp.background);

   /*------ camera setup ------*/
   …
   /*------ draw 3D objects ------*/
   …

   MainApp.g3d.releaseTarget ();

   /*------ draw score, items etc. in 2D ------*/
   …
}
```

GameDraw: camera set-up

```
MainApp.ctrans.setIdentity();
MainApp.ctrans.postTranslate( MainApp.camera_tx,
                              MainApp.camera_ty,
                              MainApp.camera_tz );
MainApp.ctrans.postRotate( MainApp.camera_ry,
                           0.0f, 1.0f, 0.0f );
MainApp.ctrans.postRotate( MainApp.camera_rx,
                           1.0f, 0.0f, 0.0f );
MainApp.ctrans.postRotate( MainApp.camera_rz,
                           0.0f, 0.0f, 1.0f );

MainApp.g3d.setCamera( MainApp.camera, MainApp.ctrans );
```

GameDraw: draw 3d objects

```
for (count = 0; count != MainApp.GHOST_MAX; count++)
{
  if (MainApp.ghost_draw_flag [count] != 0) {
    data  = count * 2;
    x     = MainApp.ghost_xz [data + 0];
    z     = MainApp.ghost_xz [data + 1];
    r     = MainApp.ghost_r  [count   ];
    trans = MainApp.trans[MainApp.GHOST_M + count];

    trans.setIdentity   ();
    trans.postTranslate (x, 0.0f, z);
    trans.postRotate    (r, 0.0f, 1.0f, 0.0f);
    trans.postScale     (MainApp.ghost_scale [count],
                         MainApp.ghost_scale [count],
                         MainApp.ghost_scale [count]);

    MainApp.g3d.render (MainApp.vbuf [MainApp.GHOST_DATA],
                        MainApp.ibuf [MainApp.GHOST_DATA],
                        MainApp.app  [MainApp.GHOST_DATA],
                        trans);
  }
}
```

GameProg

```
void GameProg() {
  key_dat_old = key_dat; /*---- Get key data ----*/
  key_dat     = subapp.sys_key;

  CameraWorldSet ();
  if (Math2.DistanceCalc2D (0.0f, 0.0f, ball_tx,
   ball_tz) > 1.5f) {
    CameraSet (15.0f * (1.0f / loop_rate));
  }

  if (freeze_time == 0) /* The Game is not frozen */ {
    /*------- do game calculations ------*/
    …
  }
  EffectProg ();
  subapp.repaint ();
  …
}
```

GameProg: do game calculations

```
  RacketProg (key_dat, key_dat_old); /*-- Plasma Racket --*/

  if (racket_break_flag != 1) /*- Racket not destroyed -*/
    BallProg ();

  GhostProg ();

  if (racket_break_flag != 1) /*- Racket not destroyed -*/ {
    BallHit          ();      /*--- Collision Decision ---*/
    RacketBreakCheck ();
  }

  house = HouseCheck (); /*------ Final Check ------*/
  if (house == 0)  /* All ghost houses are destroyed. */ {
    /*------ make all remaining ghosts disappear ------*/
    …
    freeze_time = (int)(MOJI_CLEAR_WAIT * (1.0f/loop_rate));
    moji_number = MOJI_CLEAR;
  }
}
```

BallProg: compute new ball position

```
void BallProg () {
  …
  ball_speed_rate = ball_speed * loop_rate;

  dis = Math2.DistanceCalc2D(ball_tx, ball_tz, 0.0f, 0.0f);
  pd = Math2.DistanceCalc2D(ball_tx2, ball_tz2, 0.0f, 0.0f);
  if ((dis > 2.0f) && pd > dis)) /* Homing is necessary */ {
    angle = Math2.AngleCalc (ball_tx, ball_tz, 0.0f, 0.0f);
    if (Math2.DiffAngleCalc (angle, ball_vec) > 0.0f) {
      ball_vec -= (0.6f * loop_rate);
     } else {
      ball_vec += (0.6f * loop_rate);
     }
   }
   Math2.RotatePointCalc (ball_speed_rate, ball_vec);
   ball_tx2 = ball_tx; /* Save the previous coordinates */
   ball_tz2 = ball_tz;
   ball_tx += Math2.calc_x;
   ball_tz += Math2.calc_y;
}
```

BallHit

```
void BallHit () {
  …
  /*------ racket collision detection ------*/
  …
  /*------ ghost house collision detection ------*/
  …
  /*------ ghost collision detection ------*/
  …
  /*------ obstacle (cross) collision detection ------*/
  …
  /*------ warp hole collision detection ------*/
  …
  /*------ check for outside the field ------*/
  …
}
```

BallHit: racket collision detection

```
void BallHit () {
  …   /* final static int Math2.ANGLE = 360 */
  dist = Math2.DistanceCalc2D (racket_tx, racket_tz
                               ball_tx, ball_tz);
  if (dist <= BALL_RACKET_DISTANCE) {
    angle = Math2.AngleCalc (ball_tx, ball_tz, racket_tx,
                             racket_tz);
    diff  = Math2.DiffAngleCalc(angle, ball_vec
                                       + (Math2.ANGLE/2.0f));
    if (Math2.Absf (diff) > (Math2.ANGLE / 4.0f)) {
      /* Feasible angle for collision */
       ball_vec = angle + (diff * -1.0f);

       Math2.RotatePointCalc (ball_speed_rate, ball_vec);
       ball_tx  = ball_tx2 + Math2.calc_x;
       ball_tz  = ball_tz2 + Math2.calc_y;
     }
  }
  …
}
```

Room for improvement?

Improvement 1: simpler drawing

```
for (count = 0; count != MainApp.GHOST_MAX; count++)
{
  if (MainApp.ghost_draw_flag [count] != 0) {
    …
    MainApp.g3d.render (MainApp.vbuf [MainApp.GHOST_DATA],
                        MainApp.ibuf [MainApp.GHOST_DATA],
                        MainApp.app  [MainApp.GHOST_DATA],
                        trans);
    MainApp.g3d.render (MainApp.mesh[MainApp.GHOST_DATA],
                        trans)
  }
}
```

Improvement 2: no busy waiting

```
while (thread == thisThread) {
  prev_time = now_time;
  do {
    now_time = System.currentTimeMillis ();
  } while ((now_time - prev_time) < SYSTEM_SPEED);
  loop_rate = (now_time - prev_time) / SYSTEM_SPEED;
  if (loop_rate > 5.0f) { /* More than loop rate limit */
    loop_rate = 5.0f;
  }
/* do game stuff here … */
  try {
    Thread.sleep (1);
  } catch (InterruptedException e) {
    ApplicationEnd ();
  }
}
```

Improvement 2: no busy waiting

```
while (thread == thisThread) {
  prev_time = now_time;
  do {
    now_time = System.currentTimeMillis ();
  } while ((now_time - prev_time) < SYSTEM_SPEED);
  now_time = System.currentTimeMillis();
  long sleep_time = SYSTEM_SPEED + prev_time - now_time;
  if (sleep_time < 0)
    sleep_time = 1; /* yield anyway so other things can run */
  try {
    Thread.sleep(sleep_time);
  } catch (InterruptedException e) {
    ApplicationEnd ();
  }
  if (thread != thisThread) return;
  now_time = System.currentTimeMillis ();
  loop_rate = (now_time - prev_time) / SYSTEM_SPEED;
  if (loop_rate > 5.0f) { /* More than loop rate limit */
    loop_rate = 5.0f;
  }
/* do game stuff here … */
}
```

Programming Tricks

- Use per-object fog to highlight objects
- Use black fog for night time
- Draw large background objects last
- Draw large foreground objects first
- Divorce logic from representation

Agenda

- J2ME game development
- Tools
- COFFEE BREAK
- The structure of a MIDlet
- A walkthrough a sample game
- Why mobile game development is hard
- Publishing your content

Why Mobile Game Development is Hard

- Device Fragmentation
- Device Fragmentation
- Device Fragmentation
  - Porting platforms and tools are available:
    - www.tirawireless.com, www.javaground.com
  - Porting and testing services are available:
    - www.tirawireless.com
  - **For some self-help using NetBeans see**
    - **J2ME MIDP Device Fragmentation Tutorial with Marv The Miner**

Why Mobile Game Development is Hard

- Severe limits on application size
  - Download size limits
  - Small Heap memory
- Small screens
- Poor input devices
- Poor quality sound
- Slow system bus and memory system

Why Mobile Game Development is Hard

- No floating point hardware
- No integer divide hardware
- Many tasks other than application itself
  - Incoming calls or mail
  - Other applications
- Short development period
- Tight $100k – 250k budget

Memory

- Problems
  ① Small application/download size
  ② Small heap memory size
- Solutions
  – Compress data ①
  – Use single large file ①
  – Use separately downloadable levels ①
  – Limit contents ②
  – Optimize your Java: combine classes, coalesce var's, eliminate temporary & local variables, … ②

Performance

- Problems
  ① Slow system bus & memory
  ② No integer divide hardware
- Solutions
  - Use smaller textures ①
  - Use mipmapping ①
  - Use byte or short coordinates and key values ①
  - Use shifts ②
  - Let the compiler do it ②

User-Friendly Operation

- Problems
  - Button layouts differ
  - Diagonal input may be impossible
  - Multiple simultaneous button presses not recognized
- Solutions
  - Plan carefully
  - Different difficulty levels
  - Same features on multiple buttons
  - Key customize feature

Many Other Tasks

- Problem
  - Incoming calls or mail
  - Other applications
- Solution
  - Create library for each handset terminal

Agenda

- J2ME game development
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Publishing Your Content Agenda

- Publishing your content
  - Preparing contents for distribution
  - Getting published and distributed

Preparing for Distribution: Testing

- Testing on actual handsets essential
  - May need contract with operator to obtain tools needed to download test MIDlets to target handset.
  - May need contractor within operator's region to test over-the-air aspects as handset may not work in your area
- Testing services are available
  - e.g. www.tirawireless.com

Preparing for Distribution: Signing

- Java has 4 security domains:
  - Manufacturer   Operator
  - 3rd Party   Untrusted
- Most phones will not install untrusted MIDlets
  - If unsigned MIDlets are allowed, there will be limits on access to certain APIs
- Operators will not allow untrusted MIDlets in their distribution channels

Preparing for Distribution: Signing

- Your MIDlet must be certified and signed using a 3rd party domain root certificate
- Method varies by operator and country
  - Many makers and operators participate in the Java Verified Program to certify and sign MIDlets for them
- To get certification, MIDlet must meet all criteria defined by JVP and must pass testing

Publishing Your Content Agenda

- Publishing your content
  - Preparing contents for distribution
  - Getting published and distributed

Publishing Your Content: Distribution Channels

- Game deck
  - e.g. “More Games button”
- Off deck, in portal
  - e.g. Cingular’s *Beyond MEdia Net*
- Off deck, off portal
  - Independent of operator
  - Premium SMS or web distribution

Distribution Channels: Game Deck

- Customers find you easily
  - but many carriers only allow a few words of text to describe and differentiate the on-deck games
- Operator does billing
  - No credit worries
- Operator may help with marketing
  - or they may not
- Shelf space limited

Distribution Channels: off Deck, in Portal

- Hard to find you. Need viral marketing
  - Customers must enter search terms in operator’s search box
  - or find URL in some other way
- Operator does billing, may help with marketing
- May be able to get here without a publisher

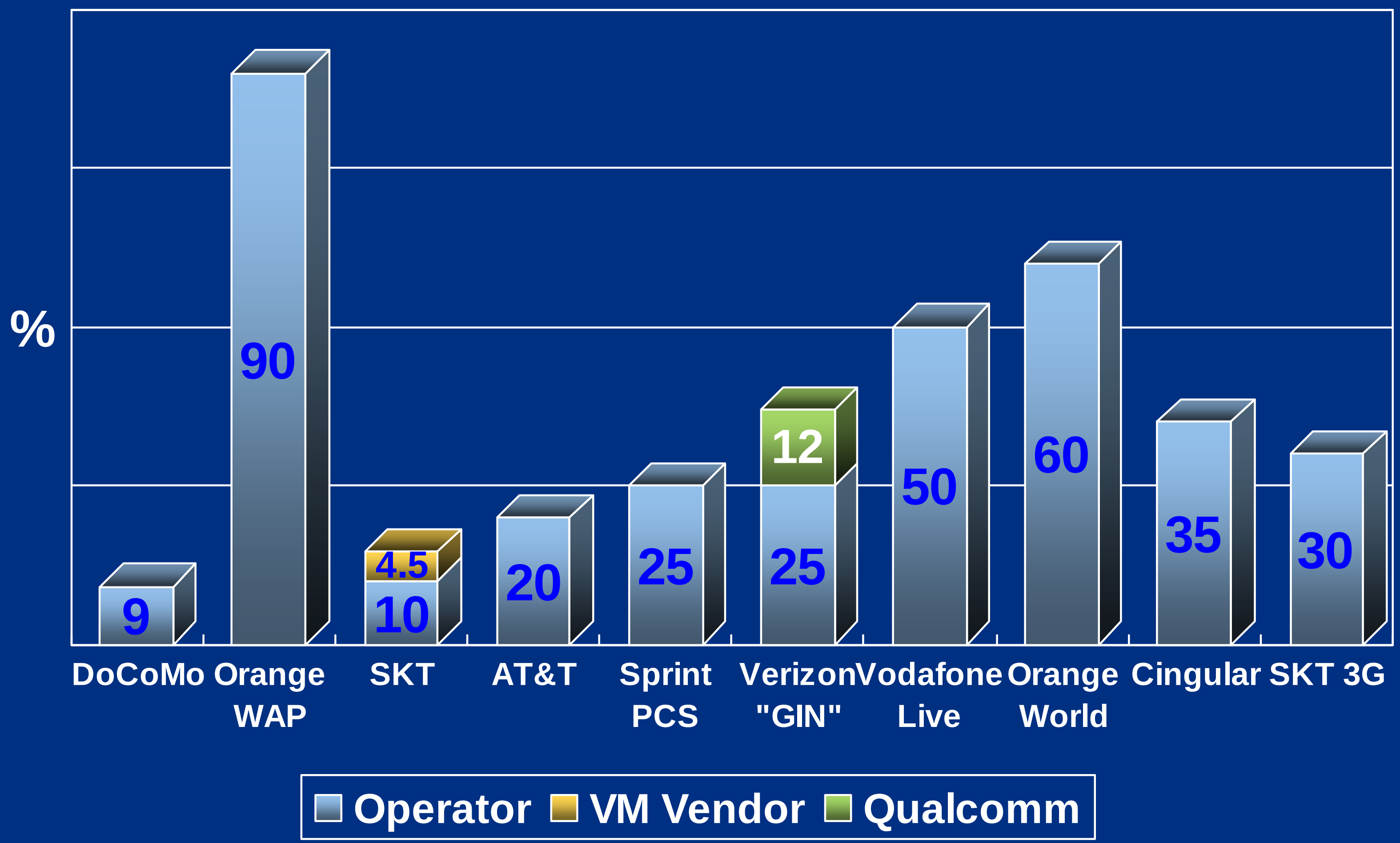
Distribution Channels: off Deck, off Portal

- Very hard for customers to find you
  - Only 4% of customers have managed to buy from the game deck!
- You have to handle billing
  - Typical game prices of $2 - $6 too low for credit cards. Must offer subscription service for CC billing.
  - Nobody is going to enter your url then billing information on a 9-key pad and very few people will use a PC to buy games for their phone.
  - Premium SMS or advertiser funded are about the only ways.
- You take all the risks
- Some handsets/carriers do not permit off-portal downloads

Publishing Your Content
Billing Mechanisms

- One-time purchase via micropayment
  - Flat-rate data? ➔Larger, higher-cost games
- Subscription model via micropayment
  - Episodic games to encourage loyalty
  - Game arcades with new games every month
- Sending Premium SMS
  - Triggers initial download
  - Periodically refills scarce supplies

Operator Revenue Share 1999 - 2004



Source: www.roberttercek.com

Going On-Deck

- Find a publisher and build a good relationship with them
- **Japan:** Square Enix, Bandai Networks, Sega WOW, Namco, Infocom, etc.
- **America:** Bandai America, Digital Chocolate, EA Mobile, MForma, Sorrent
- Europe: Digital Chocolate, Superscape, Macrospace, Upstart Games

Going Off-Deck

- There are off-deck distribution services:
  - thumbplay, www.thumbplay.com
  - playphone, www.playphone.com
  - gamejump, www.gamejump.com free advertiser supported games
- These services may be a good way for an individual developer to get started

Other 3D Java Mobile APIs

Mascot Capsule Micro3D Family APIs

- Motorola iDEN, Sony Ericsson, Sprint, etc.
  - com.mascotcapsule.micro3d.v3 (V3)
- Vodafone KK JSCL
  - com.j_phone.amuse.j3d (V2), com.jblend.graphics.j3d (V3)
- Vodafone Global
  - com.vodafone.amuse.j3d (V2)
- NTT Docomo (DoJa)
  - com.nttdocomo.opt.ui.j3d (DoJa2, DoJa 3) (V2, V3)
  - com.nttdocomo.ui.graphics3D (DoJa 4, DoJa 5) (V4)

(Vx) - Mascot Capsule Micro3D Version Number

Mascot Capsule V3 Game Demo

Copyright 2006, by Interactive Brains, Co., Ltd.

Summary

- Use standard tools to create assets
- Many J2ME SDKs and IDEs are available
- Basic M3G MIDlet is relatively easy
- Programming 3D Games for mobile is hard
- Getting your content marketed, distributed and sold is a huge challenge

Exporters

Not a typo

vapourware?

3ds max

- Simple built-in exporter since 7.0
- www.digi-element.com/Export184/
- www.mascotcapsule.com/M3G/
- www.m3gexporter.com

Maya

- www.mascotcapsule.com/M3G/
- www.m3gexport.com

Softimage|XSI

- www.mascotcapsule.com/M3G/

Cinema 4D

- www.tetracon.de/public_main_modul.php?bm=&ses=&page_id=453&document_id=286&unit=441299c9be098

Lightwave

- www.mascotcapsule.com/M3G/

Blender

- http://www.nelson-games.de/bl2m3g/

SDKs

- Motorola iDEN J2ME SDK
  - idenphones.motorola.com/iden/developer/developer_tools.jsp
- Nokia Series 40, Series 60 & J2ME
  - www.forum.nokia.com/java
- Softbank MEXA & JSCL SDKs
  - developers.softbankmobile.co.jp/dp/tool_dl/java/tech.php
  - developers.softbankmobile.co.jp/dp/tool_dl/java/emu.php

SDKs

- Sony Ericsson
  - developer.sonyericsson.com/java
- Sprint Wireless Toolkit for Java
  - developer.sprintpcs.com
- Sun Java Wireless Toolkit 2.5.1 for CLDC
  - http://java.sun.com/products/sjwtoolkit/index.html
- Vodafone VFX SDK
  - via.vodafone.com/vodafone/via/Home.do

IDE's for Java Mobile

- Eclipse Open Source IDE
  - www.eclipse.org & eclipseme.org
- JBuilder 2005 Developer
  - www.borland.com/jbuilder/developer/index.html
- NetBeans
  - www.netbeans.info/downloads/index.php
  - www.netbeans.org/products/
- Comparison of IDE's for J2ME
  - www.microjava.com/articles/J2ME_IDE_Comparison.pdf

Other Tools

- Macromedia Fireworks
  - www.adobe.com/products/fireworks/
- Adobe Photoshop
  - www.adobe.com/products/photoshop/main.html
- Sony SoundForge
  - www.sonymediasoftware.com/products/showproduct.asp?PID=961
- Steinberg Cubase
  - www.steinberg.de/33_1.html
- Yamaha SMAF Tools
  - smaf-yamaha.com/

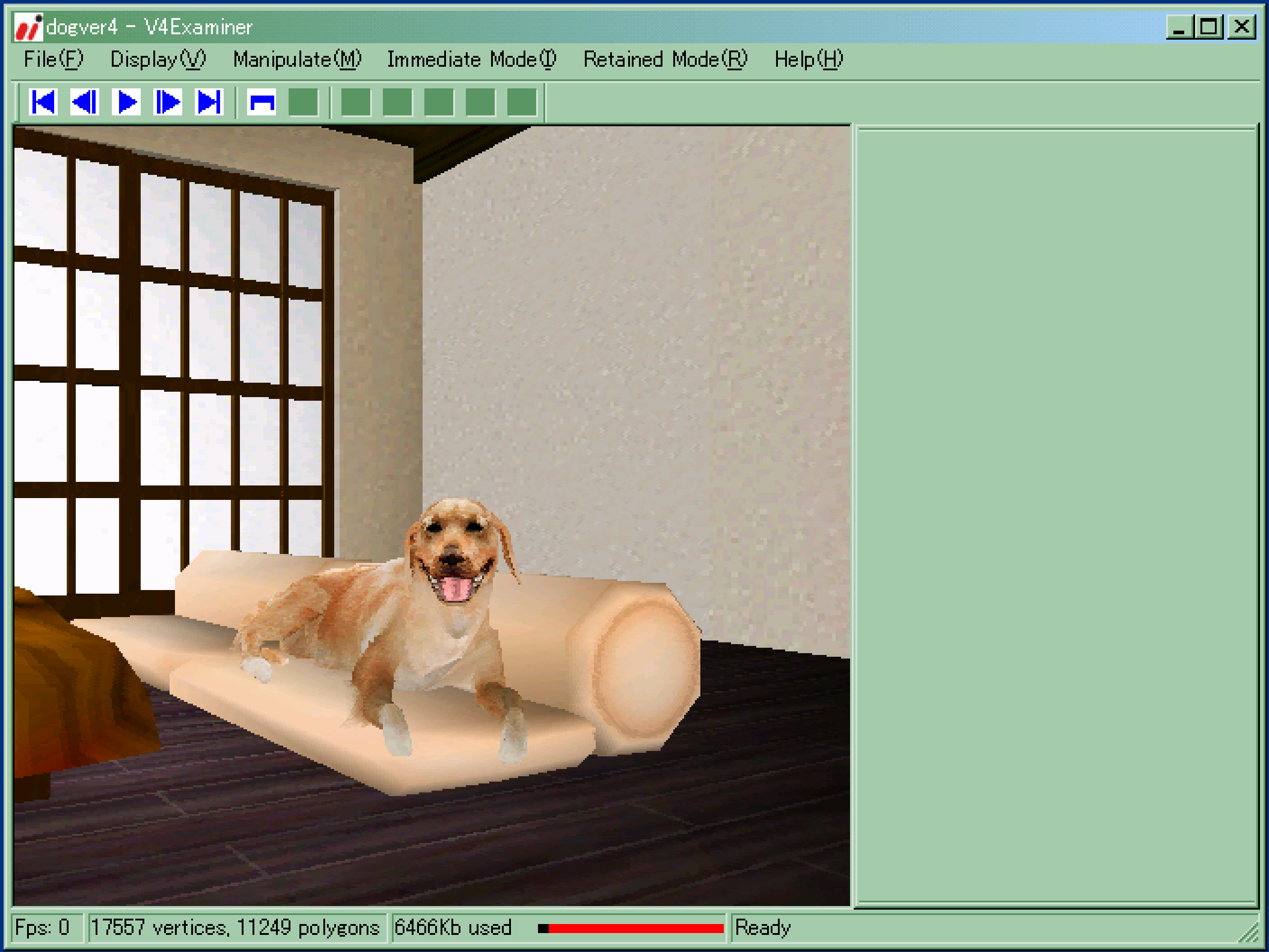
Other Tools

- Java optimizer - Innaworks mBooster
  - www.innaworks.com/mBooster.html
- Porting Platforms
  - www.tirawireless.com
  - www.javaground.com

Services

- MIDlet verification & signing
  - www.javaverified.com
- Porting & testing
  - www.tirawireless.com
- Off deck distribution
  - www.thumbplay.com
  - www.playphone.com
  - www.gamejump.com

犬友 (Dear Dog) Demo



Thanks to: Koichi Hatakeyama; HI’s MascotCapsule Version 4 Development Team; Sean Ellis; JSR-184 & JSR-297 Expert Groups

SIGGRAPH2007

M3G 2.0
Sneak Preview

SIGGRAPH2007

Tomi Aarnio

Nokia Research Center

What is M3G 2.0?

- Mobile 3D Graphics API, version 2.0
  - Java Specification Request 297
  - Successor to M3G 1.1 (JSR 184)
- Work in progress
  - Early Draft is out for review (www.jcp.org)
  - Developer feedback is much appreciated!

Who's Behind It?

Hardware vendors

- AMD, ARM
- NVIDIA, PowerVR

Device makers

- Nokia, Sony Ericsson
- Motorola, Samsung

Platform providers

- Sun, Ericsson
- HI, Aplix, Acrodea

Developers

- Digital Chocolate
- RealNetworks
- Superscape

M3G 2.0 Preview

Design

Fixed functionality

Programmable shaders

New high-level features

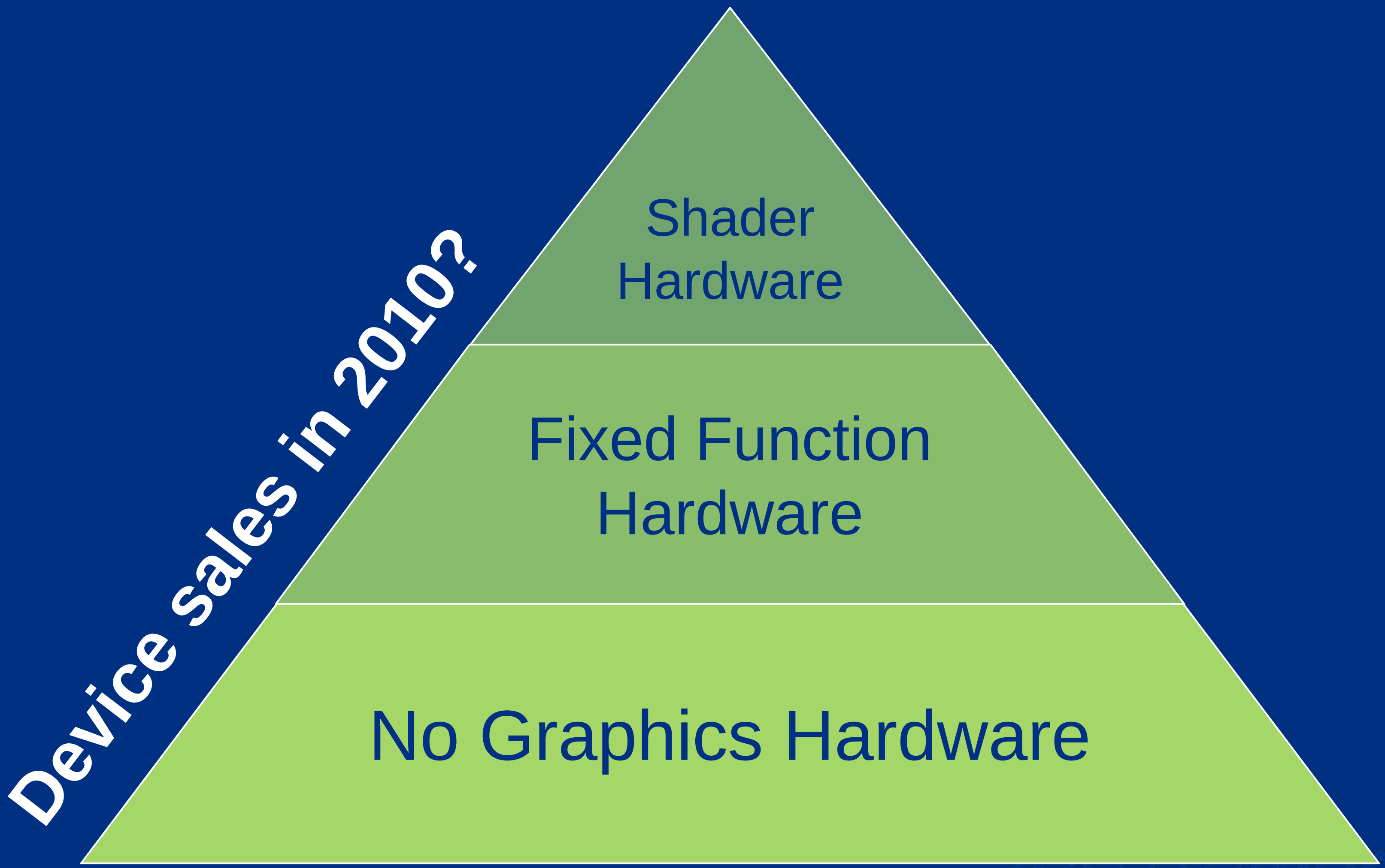
Summary, Q&A

Design Goals & Priorities

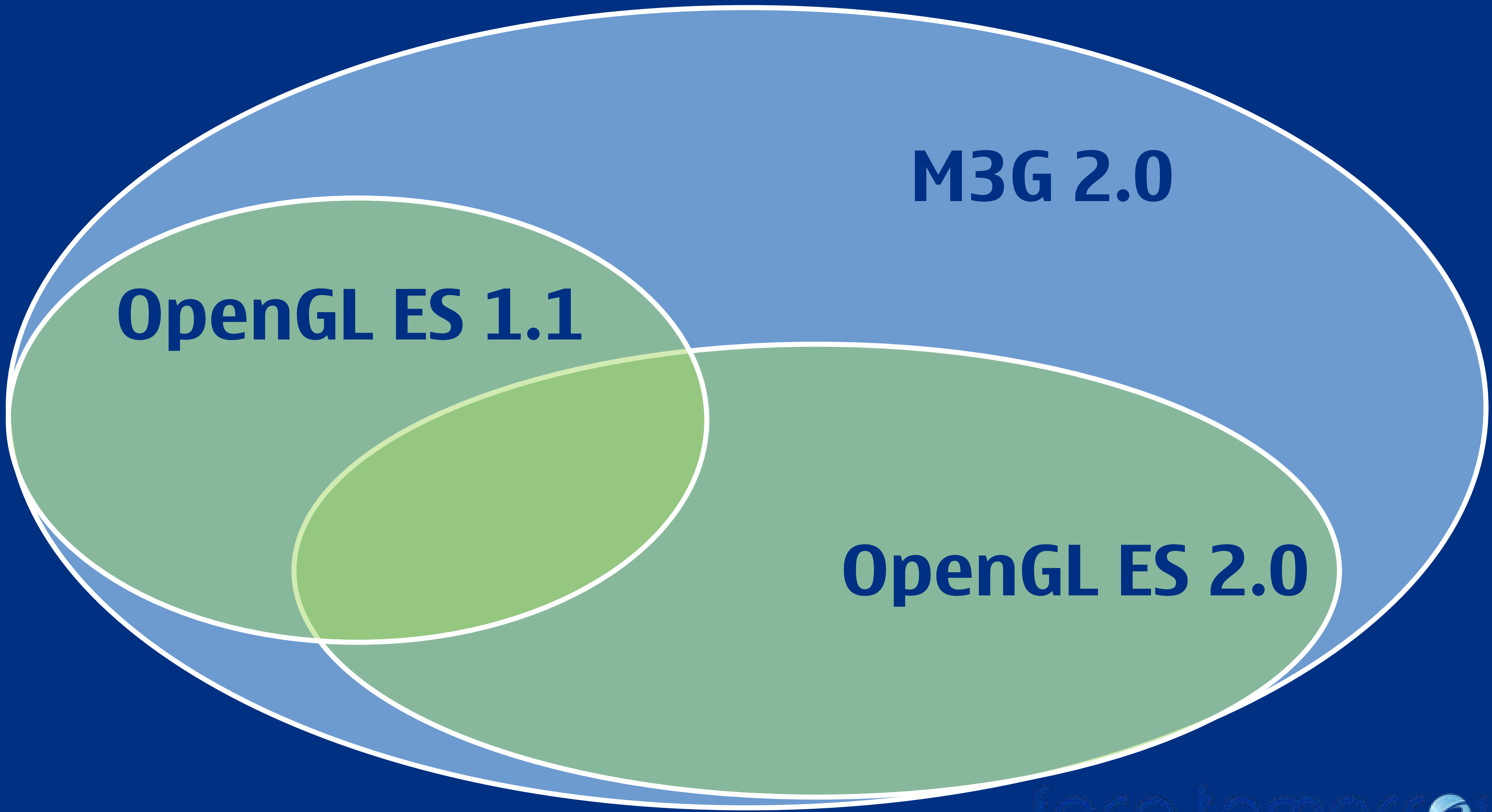
Target <u>all</u> devices

1. Programmable HW
2. No graphics HW
3. Fixed-function HW

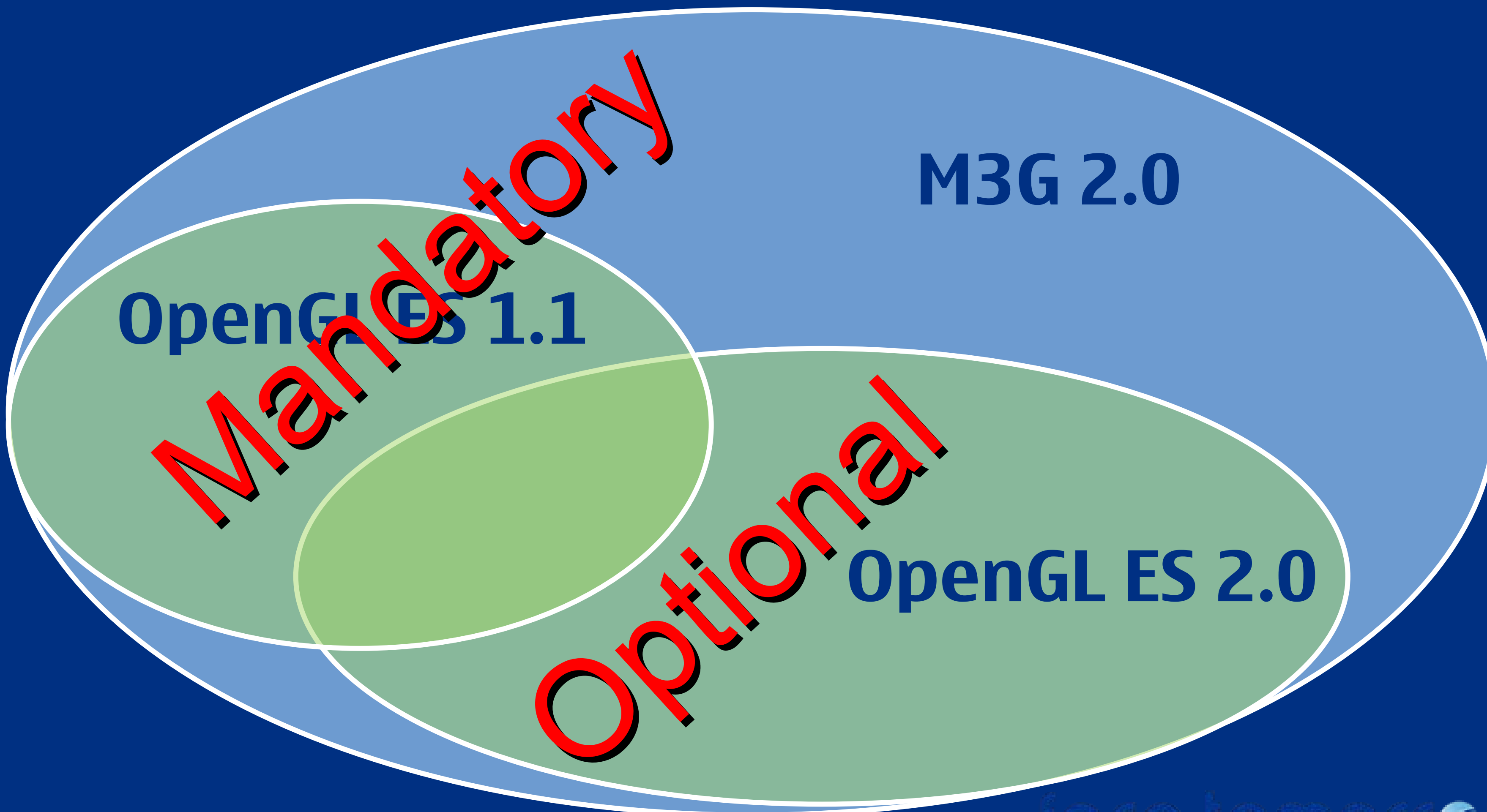
Why Not Shaders Only?



Shaders **and** Fixed Functionality



Shaders <u>and</u> Fixed Functionality



Design Goals & Priorities

Target all devices

1. Programmable HW
2. No graphics HW
3. Fixed-function HW

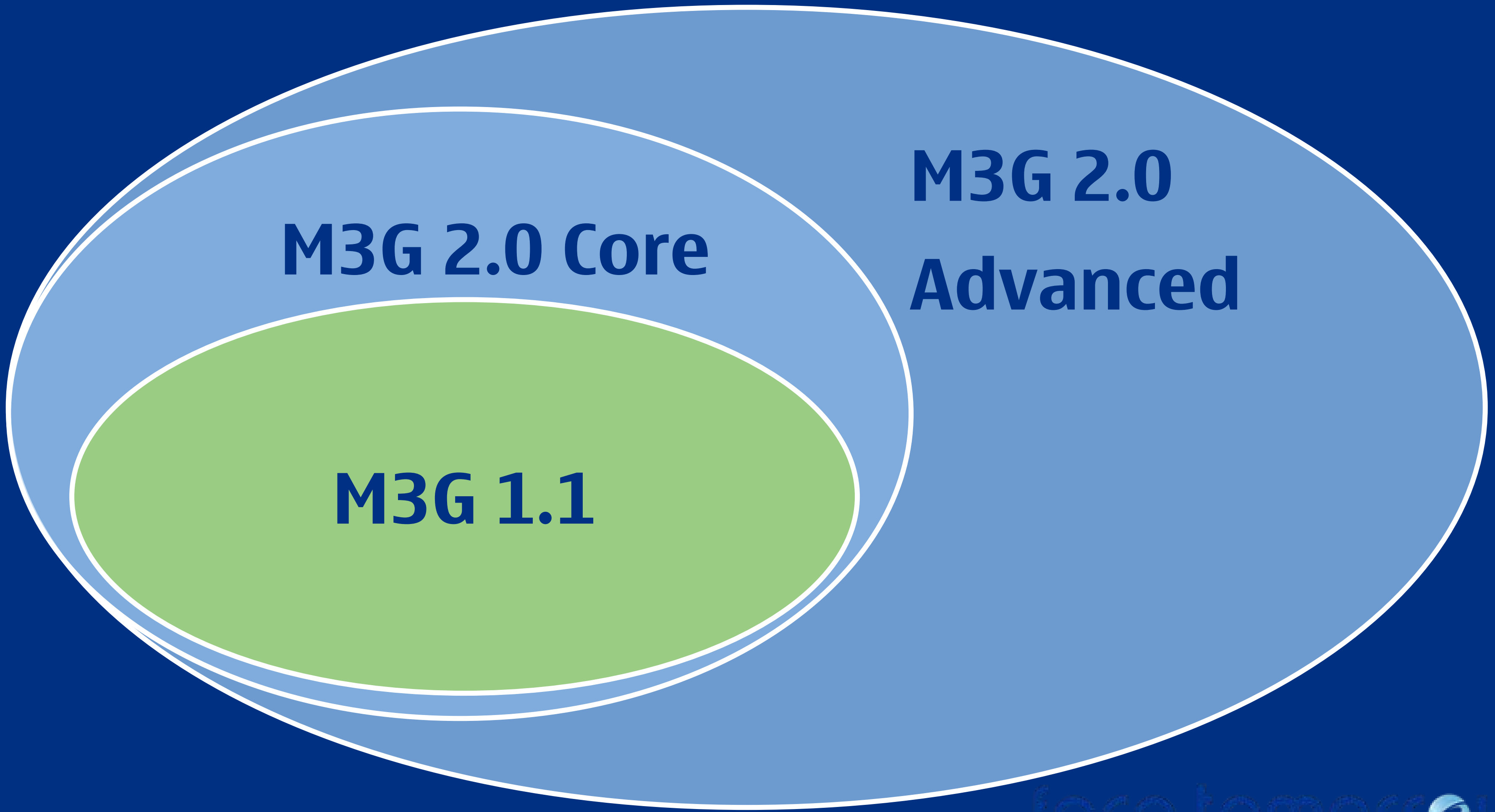
Enable reuse of

1. Assets & tools (.m3g)
2. Source code (.java)
3. Binary code (.class)

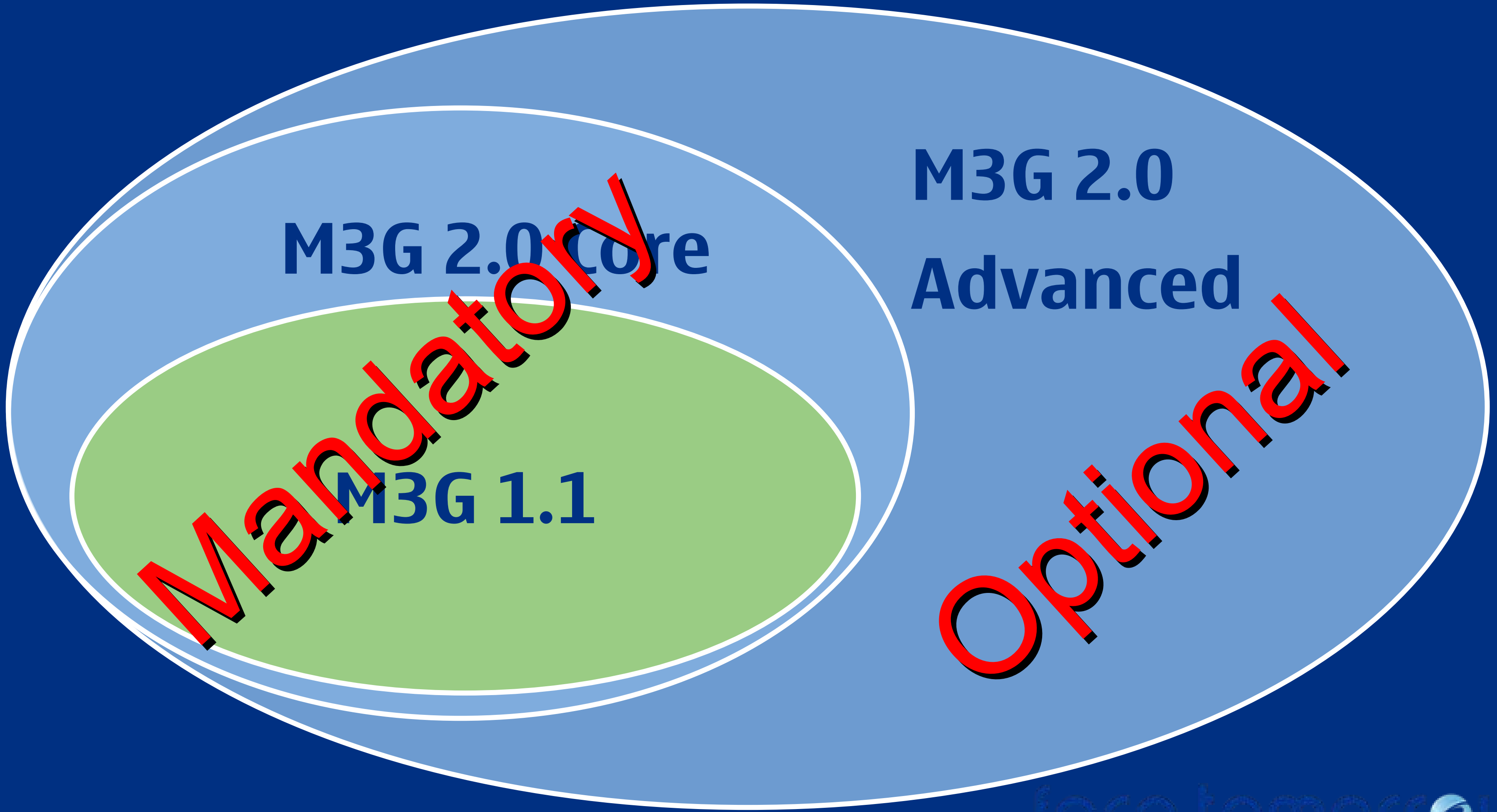
Backwards Compatible – Why?

- Device vendors can drop M3G 1.1
  - Rather than supporting both versions (forever)
  - Cuts integration, testing & maintenance into half
- Developers can upgrade gradually
  - Rather than re-doing all code, art, and tools

Backwards Compatible – How?



Backwards Compatible – How?



Serving the Low End…

Basic Content

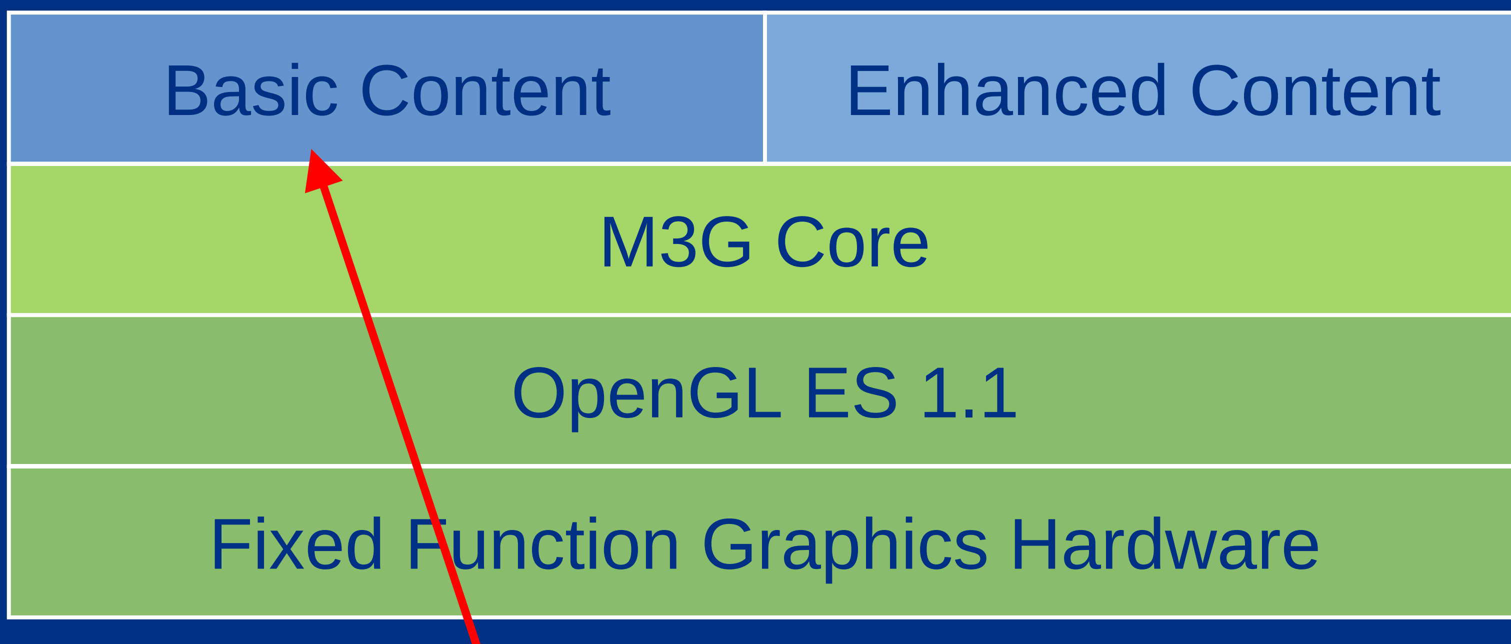
M3G Core

OpenGL ES 1.1

CPU

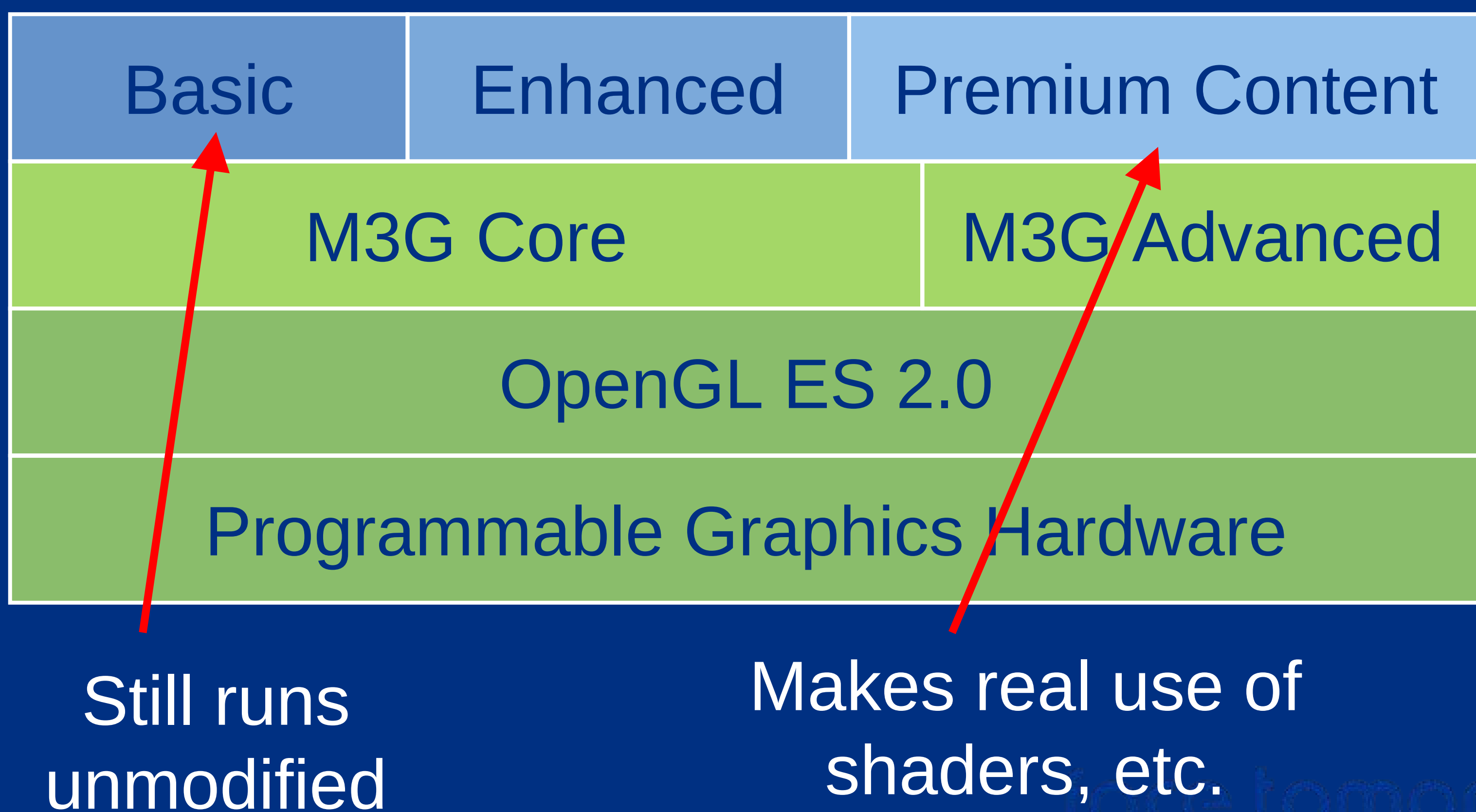
No graphics hardware!

…the Mid Category…



Runs unmodified on
mid-range devices

…and the High End



The Downsides

- Must support fixed functionality on ES 2.0
  - Extra implementation burden
- The API is not as compact as it used to be
  - A pure shader API could have ~20% fewer classes
- Need to drag along obsolete features
  - Flat shading, Sprite3D, Background image
  - Can be deprecated, but not totally removed

Core vs. Advanced

- High-level features are common to both
  - Scene graph
  - Animation
- The differences are in rendering
  - Core → OpenGL ES 1.1
  - Advanced → OpenGL ES 2.0

Packages

- `javax.microedition.m3g`
  - Contains the entire Core Block
  - Also some Advanced features, e.g. cube maps
- `javax.microedition.m3g.shader`
  - Only present in Advanced implementations

What's in the Core?

- Everything that's in M3G 1.1
- Everything that's in OpenGL ES 1.1
  - Except for useless or badly supported stuff
  - Such as points, logic ops, stencil, full blending
- New high-level features

What's in the Advanced Block?

- Everything that's in OpenGL ES 2.0
  - Vertex and fragment shaders
  - Cube maps, advanced blending
  - Stencil buffering

M3G 2.0 Preview

Design

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Summary, Q&A

M3G 2.0 Core vs. 1.1

- Better and faster rendering
- More convenient to use
- Fewer optional features

Point Sprites

- Ideal for particle effects
- Much faster than quads
- Consume less memory
- Easier to set up

Better Quality Texturing

- Upgraded the baseline
  - At least two texture units
  - At least 1024x1024 maximum size
- Mandated optional features
  - Perspective correction
  - Mipmapping
  - Bilinear filtering

Bump Mapping

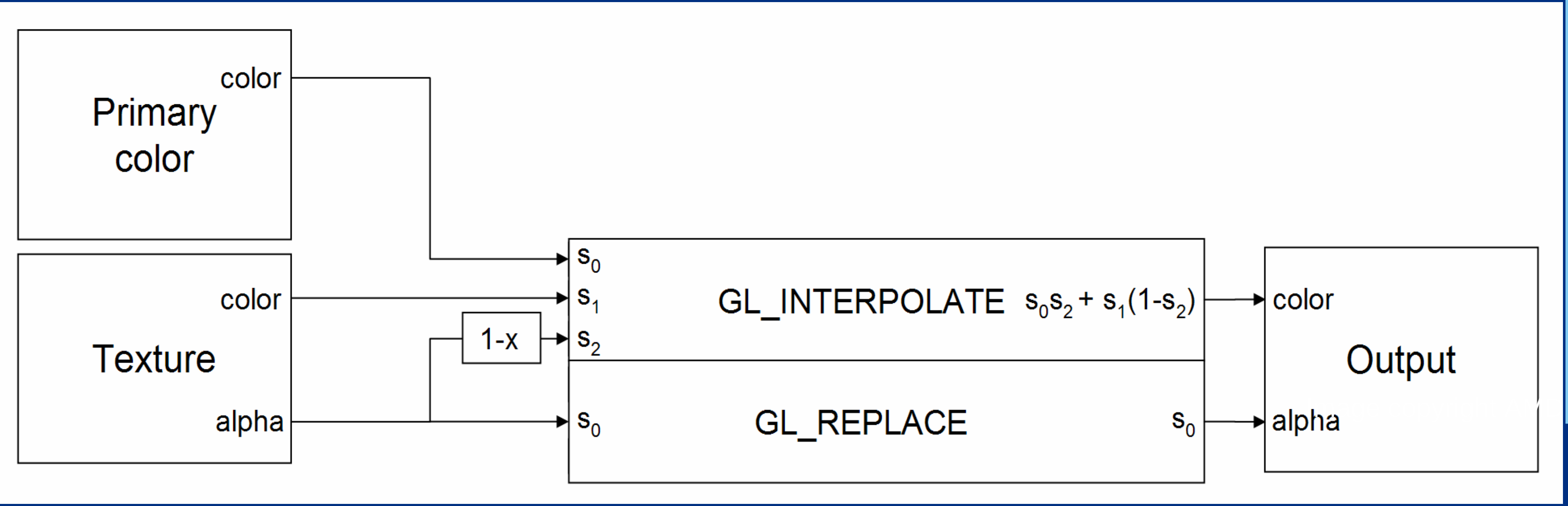
- Fake geometric detail
- Feasible even w/o HW

Bump Mapping + Light Mapping

- Bump map modulated by projective light map

Texture Combiners

- Precursor to fragment shaders
  - Can do a lot more than bump and light mapping
  - Not very easy to use, though



Floating-Point Vertex Arrays

- **`float (32-bit)`**
  - Easy to use, good for prototyping
  - Viable with hardware acceleration
- **`half (16-bit)`**
  - Savings in file size, memory, bandwidth
  - Trivially expanded to **`float`** if necessary
- **`byte/short`** still likely to be faster

Triangle Lists

- Much easier to set up than strips
  - Good for procedural mesh generation
  - Avoid the expensive stripification
- No performance penalty
  - Can be even faster with good vertex ordering
  - Assuming a vertex cache

Primitives – M3G 1.x

	Byte	Short	Implicit	Strip	Fan	List
Triangles	✓	✓	✓	✓	✗	✗
Lines	✗	✗	✗	✗	✗	✗
Points	✗	✗	✗			✗
Point sprites	✗	✗	✗			✗

Relative to OpenGL ES 1.1

Primitives – M3G 2.0

	Byte	Short	Implicit	Strip	Fan	List
Triangles	✓	✓	✓	✓	✗	✓
Lines	✓	✓	✓	✓	✗	✓
Points	✗	✗	✗			✗
Point sprites	✓	✓	✓			✓

Relative to OpenGL ES 1.1

VertexBuffer Types – M3G 1.x

	Byte	Short	Fixed	Float	2D	3D	4D
Vertices	✓	✓	✗	✗	✗	✓	✗
TexCoords	✓	✓	✗	✗	✓	✓	✗
Normals	✓	✓	✗	✗		✓	
Colors	✓		✗	✗		✓*	✓
PointSizes			✗	✗			

* OpenGL ES 1.1 only supports RGBA colors

VertexBuffer Types – M3G 2.0

	Byte	Short	Fixed	Float Half	2D	3D	4D
Vertices	✓	✓	✓	✓	✓	✓	✓
TexCoords	✓	✓	✓	✓	✓	✓	✓
Normals	✓	✓	✓	✓		✓	
Colors	✓		✓	✓		✓*	✓
PointSizes			✓	✓			

* OpenGL ES 1.1 only supports RGBA colors

Deprecated Features

- Background image
  - Use a sky box instead
- Sprite3D
  - Use textured quads or point sprites instead
- Flat shading
  - Can’t have this on OpenGL ES 2.0!

Deprecated Features Cont'd

- Two-sided lighting
  - Requires duplicated geometry on OpenGL ES 2.0
- Local camera lighting (a.k.a. local viewer)
  - Only a hint that was poorly supported
- Less accurate picking
  - Skinning and morphing not taken into account

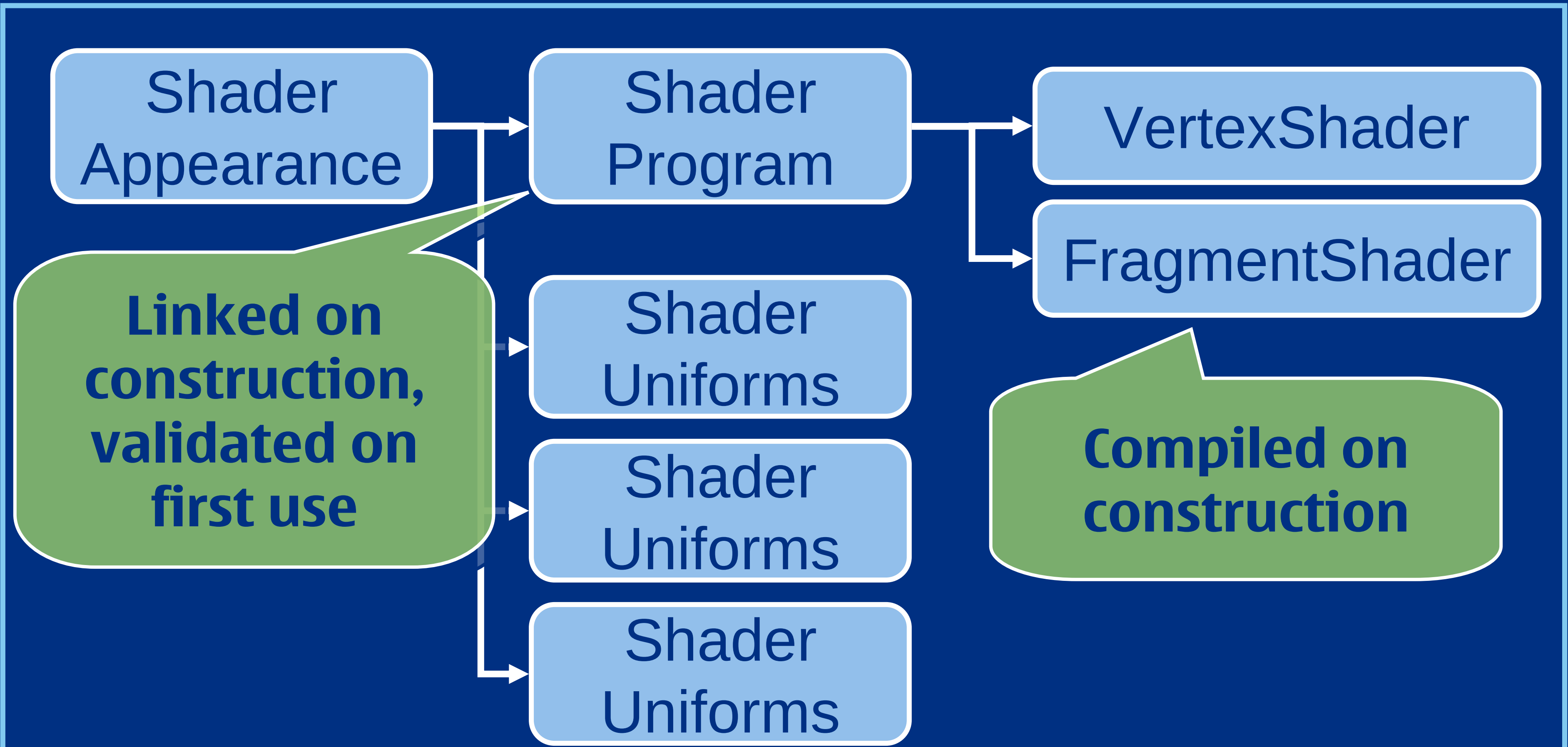
M3G 2.0 Preview

- Design
- Fixed functionality
- **Programmable shaders**
- New high-level features
- Summary, Q&A

Shading Language

- GLSL ES v1.00
  - Source code only
  - Binary shaders would break the Java sandbox
- Added a few preprocessor `#pragma`'s
  - To enable skinning, morphing, etc.
  - Apply for vertex shaders only

The Shader Package



Why Multiple ShaderUniforms?

- So that uniforms can be grouped
  - Global constants – e.g. look-up tables
  - Per-mesh constants – e.g. rustiness
  - Per-frame constants – e.g. time of day
  - Dynamic variables – e.g. position, orientation
- Potential benefits of grouping
  - Java object reuse – less memory, less garbage
  - Can be faster to bind a group of variables to GL

A Fixed-Function Vertex Shader

- A small example shader
- Replicates the fixed-function pipeline using the predefined `#pragma`'s

Necessary Declarations

```
#pragma M3Gvertex(myVertex)
#pragma M3Gnormal(myNormal)
#pragma M3Gtexcoord0(myTexCoord0)
#pragma M3Gcolor(myColor)

#pragma M3Gvertexstage(clipspace)

varying vec2 texcoord0;
varying vec4 color;
```

Names & roles for vertex attributes

Transform all the way to clip space

Variables to pass to the fragment shader

The Shader Code

Does morphing, skinning, lighting, texture transform

```
void main() {
    m3g_ffunction();
    gl_Position = myVertex;
    texcoord0 = myTexCoord0.xy;
    color = myColor;
}
```

Results passed to the fragment shader

M3G 2.0 Preview

Design

Fixed functionality

Programmable shaders

New high-level features

Summary, Q&A

Scene Graph

- Added automatic render-to-texture
- Otherwise mostly unchanged
- Some convenience methods
  - Can use quaternions instead of axis/angle
  - Can enable/disable animations hierarchically

File Format

- Updated to match the new API
  – File structure remains the same
  – Same parser can handle both old & new
- Better compression for
  – Textures (ETC, JPEG)
  – SkinnedMesh, IndexBuffer

Multichannel Keyframe Sequences

- *N* channels per KeyframeSequence object
  - Same number of keyframes in all channels
  - Shared interpolation mode
  - Shared time stamps
- Huge memory savings with skinning
  - M3G 1.1: two Java objects per bone
  - M3G 2.0: two Java objects per mesh

Things Under Consideration

- Bounding volumes (provided by user)
- Texture compression (run-time encoding)
- Combined morphing and skinning

- Less likely to be included
  - Texture generation
  - Collision detection
  - Particle systems
  - Mesh modifiers

M3G 2.0 Preview

Design

Fixed functionality

Programmable shaders

New high-level features

Summary, Q&A

Summary

- M3G 2.0 will <u>replace</u> 1.1, starting next year
  - Existing code & assets will continue to work
  - Developers can upgrade at their own pace
- Several key improvements
  - Expanded fixed-function feature set
  - Programmable shaders to the mass market
  - Better performance across all device categories

Q&A

Thanks:

M3G 2.0 Expert Group

Dan Ginsburg (AMD)

Kimmo Roimela (Nokia)

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Closing & Summary

- We have covered
  - OpenGL ES
  - M3G

Khronos API family

Cross-platform graphics authoring/acceleration Ecosystem

OpenGL

Cross platform 2D/3D

OpenGL SC

Safety Critical 2D/3D

COLLADA

3D Authoring

OpenML

Dynamic Media Authoring

Dynamic Media Authoring Standards

OpenGL ES

2D/3D

OpenVG

Vector 2D

OpenMAX

Streaming Media

OpenSL ES

Enhanced Audio

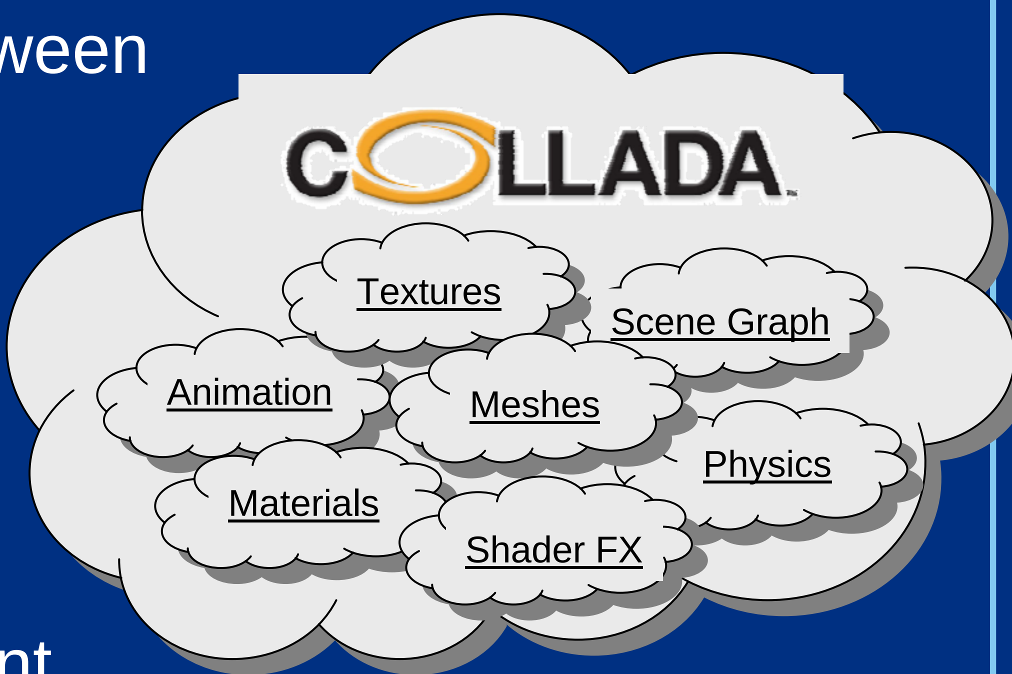
Embedded Media Acceleration APIs

OS portability API

OpenKODE

COLLADA

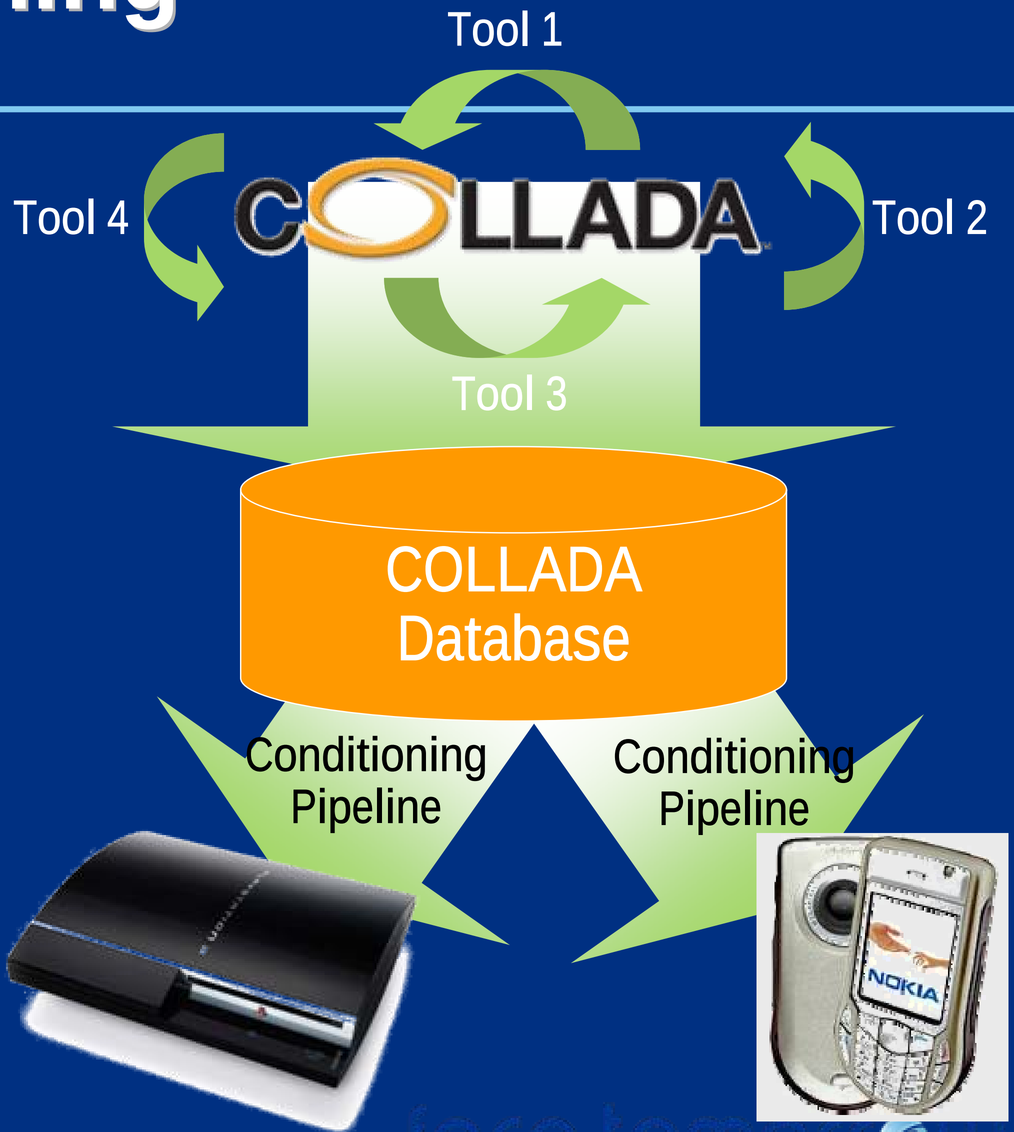
- An open interchange format
  - to exchange data between content tools
  - allows mixing and matching tools for the same project
  - allows using desktop tools for mobile content



Collada conditioning

- Conditioning pipelines take authored assets and:
- 1. Strips out authoring-only information
- 2. Re-sizes to suit the target platform
- 3. Compresses and formats binary data for the target platform

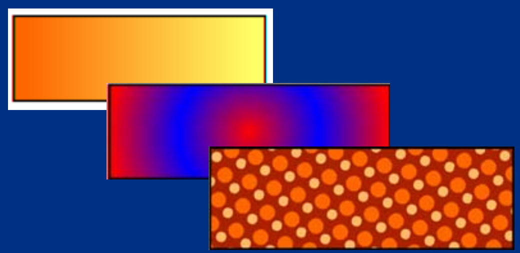
- Different target platforms can use the same asset database with the appropriate conditioning pipeline



2D Vector Graphics

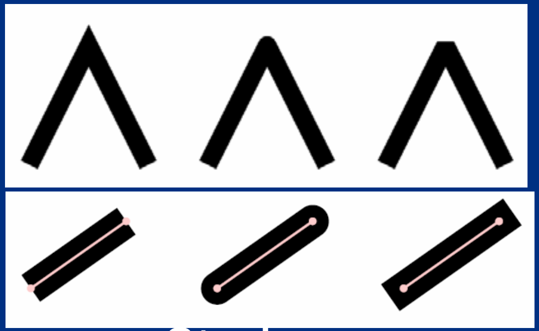
- OpenVG
  - low-level API, HW acceleration
  - spec draft at SIGGRAPH 05, conformance tests summer 06
- JSR 226: 2D vector graphics for Java
  - SVG-Tiny compatible features
  - completed Mar 05
- JSR 287: 2D vector graphics for Java 2.0
  - rich media (audio, video) support, streaming
  - may still complete in 07

OpenVG features

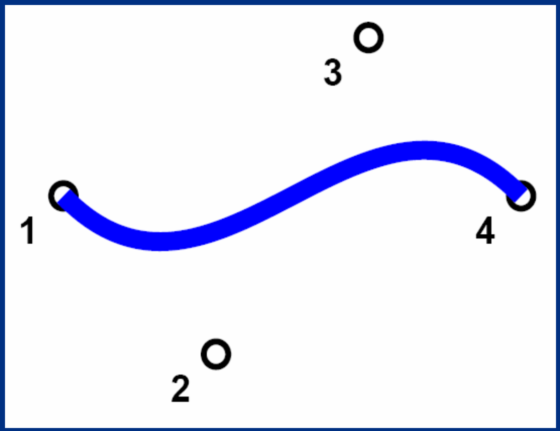


Paints

Mask



Stroke



Paths

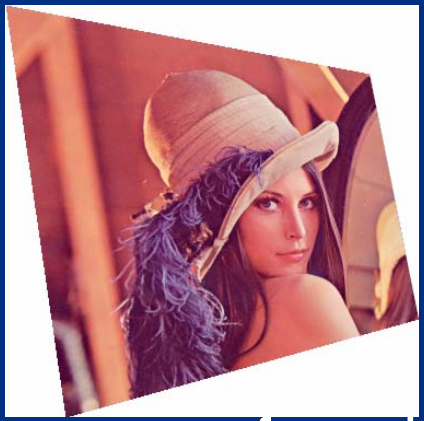
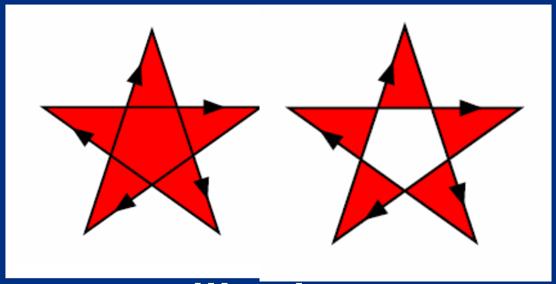


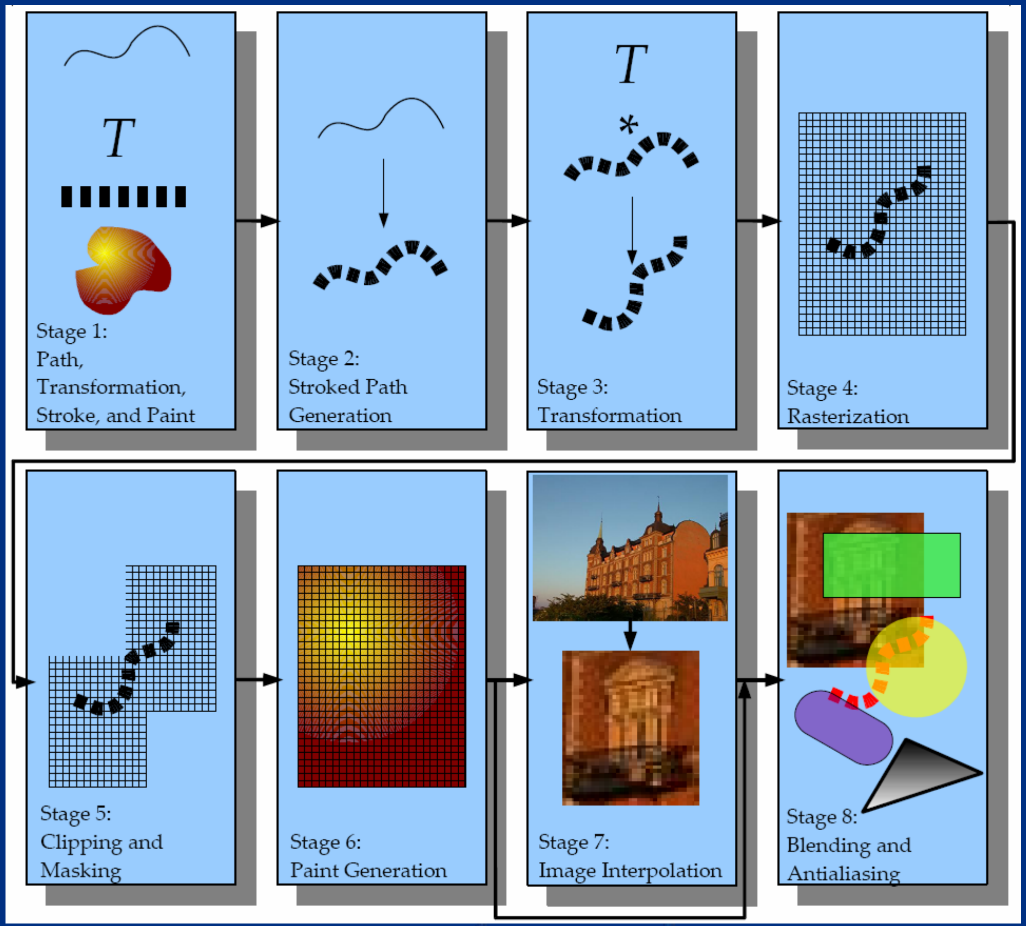
Image transformation



Fill rule

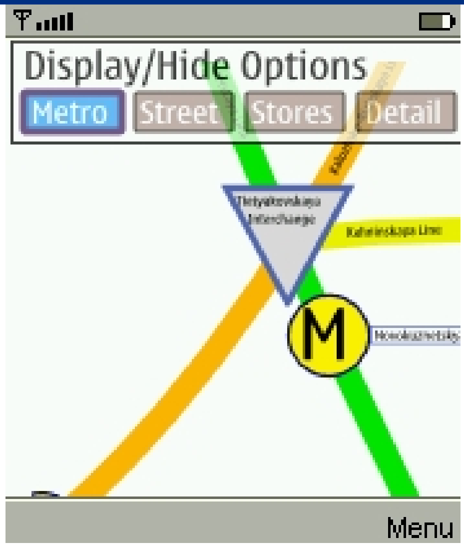
OpenVG pipeline

- Definition of path, transformation, stroke and paint
- Stroked path generation
- Transformation
- Rasterization
- Clipping and Masking
- Paint Generation
- Image Interpolation
- Blending



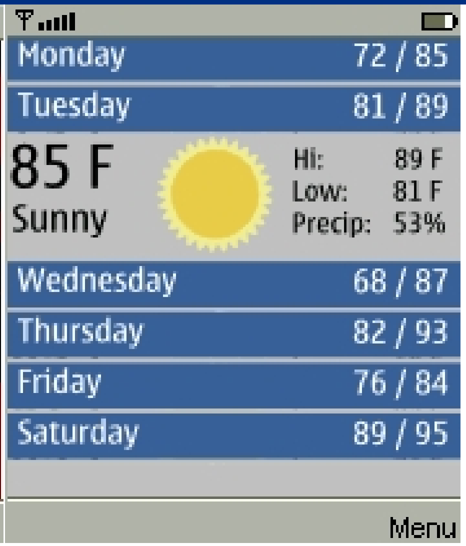
JSR-226 examples

Game, with skins



Scalable maps, variable detail

Cartoon



Weather info

Combining various APIs

- It's not trivial to efficiently combine use of various multimedia APIs in a single application
- EGL is evolving towards simultaneous support of several APIs
  - OpenGL ES and OpenVG now
  - all Khronos APIs later

OpenGL ES and OpenVG

OpenGL ES
Accurately represents
PERSPECTIVE and
LIGHTING

OpenVG
Accurately represents
SHAPE and
COLOR

OpenVG ideal for advanced composting user interfaces
OpenGL ES for powerful 3D UI effects

Summary

- Fixed functionality mobile 3D is reality NOW
  - these APIs and devices are out there
  - go get them, start developing!
- Better content with Collada
- Solid roadmap to programmable 3D
- New standards for 2D vector graphics

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