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Developing Mobile 3D Applications with OpenGL ES and M3G

Kari Pulli	Nokia Research Center & MIT CSAIL
Jani Vaarala	Nokia
Ville Miettinen	Hybrid Graphics
Tomi Aarnio	Nokia Research Center
Mark Callow	HI Corporation

Today's program

- Start at 1:45
- Intro
  10 min, Kari Pulli
- OpenGL ES overview
  25 min, Kari Pulli
- Using OpenGL ES
  40 min, Jani Vaarala
- OpenGL ES performance
  30 min, Ville Miettinen
- Break 3:30 – 3:45
- M3G Intro
  5 min, Kari Pulli
- M3G API overview
  50 min, Tomi Aarnio
- Using M3G
  45 min, Mark Callow
- Closing & Q&A
  5 min, Kari Pulli
- End at 5:30

Challenges for mobile gfx

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- Small displays
  - getting much better
- Computation
  - speed
  - power / batteries
  - thermal barrier
- Memory

Mobile graphics applications

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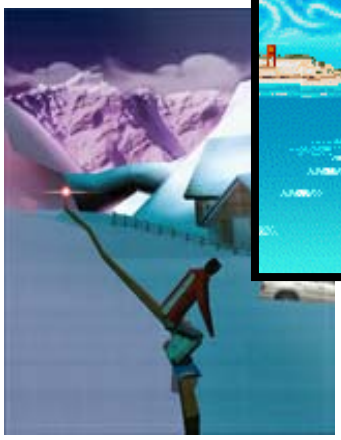
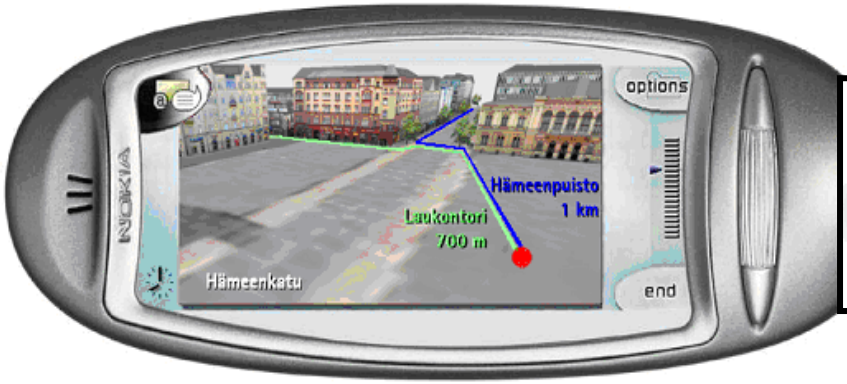
3D Menu



3D Games

3D Animation

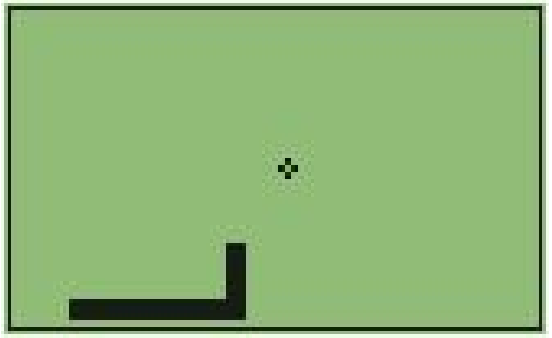
3D Messaging



Location services

Advertising

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



- What's the world's most played electronic game?
  - The Guardian (May 2001)

- Communicator demo 2001
  - Remake of a 1994 Amiga demo
  - <10 year from PC to mobile
- Began SW 3D engine at Nokia

State-of-the-art in 2001: Japan (from April / May)

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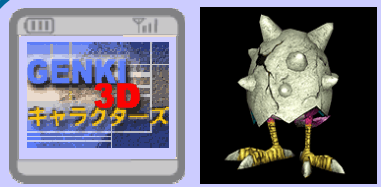


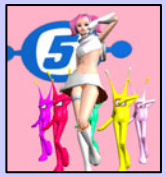
GENKI 3D Characters

(C) 2001 GENKI

ULALA

(c)SEGA/UGA.2001

J-SH07
by SHARP



Space Channel 5

©SEGA/UGA,2001 ©SEGA/UGA,2002

Snowboard Rider

©WOW ENTERTAINMENT INC.,
2000-2002all rights reserved.

J-SH51
by SHARP

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

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

- 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

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- 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

3D on GSM in 2003

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- N-Gage ships
- Lots of proprietary 3D engines on various Series 60 phones
  - Starting already in late 2002

Fathammer's Geopod on XForge

State-of-the-art in 2003: Japan

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- Perspective view, low-level API

Ridge Racer

@ Namco

Mission Commander
Multi player Fps Game

© IT Telecom

Mobile 3D in 2004

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

Mobile 3D in 2005

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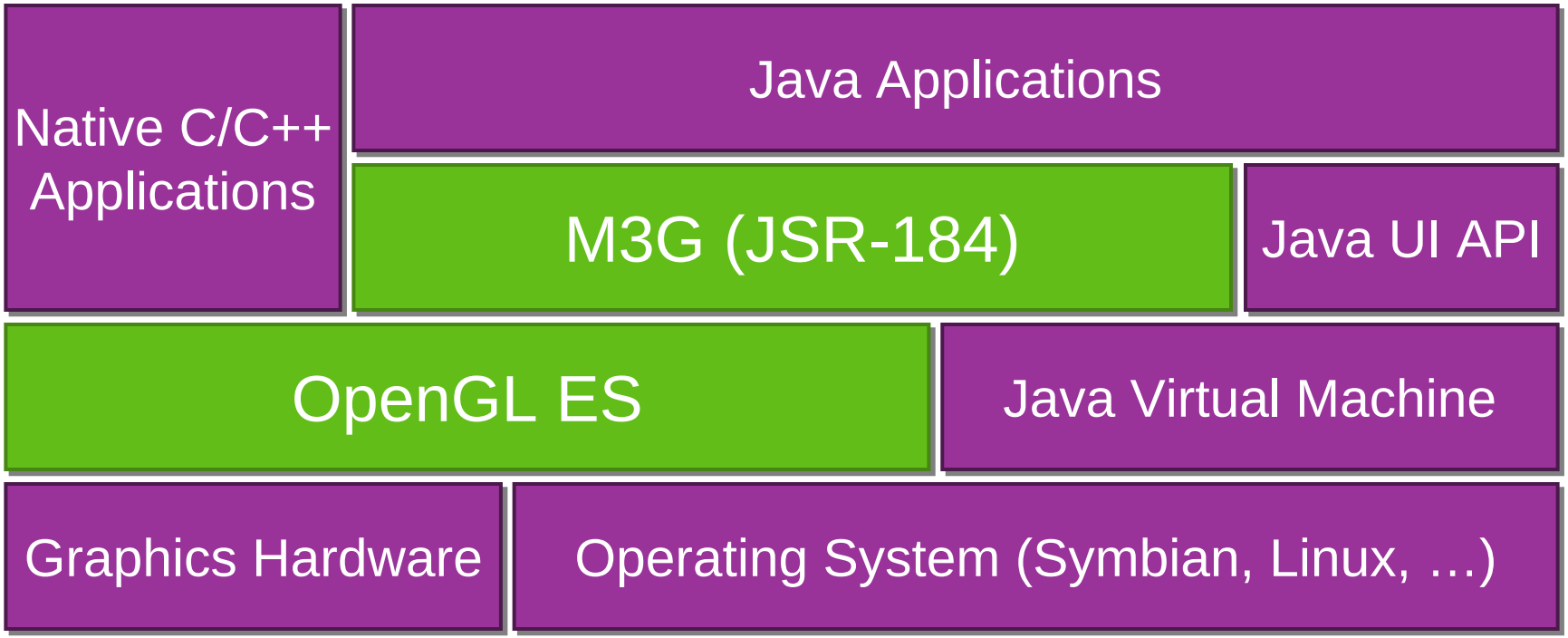
- PSP
- Gaming phones with 3D gfx HW

Mobile 3D APIs

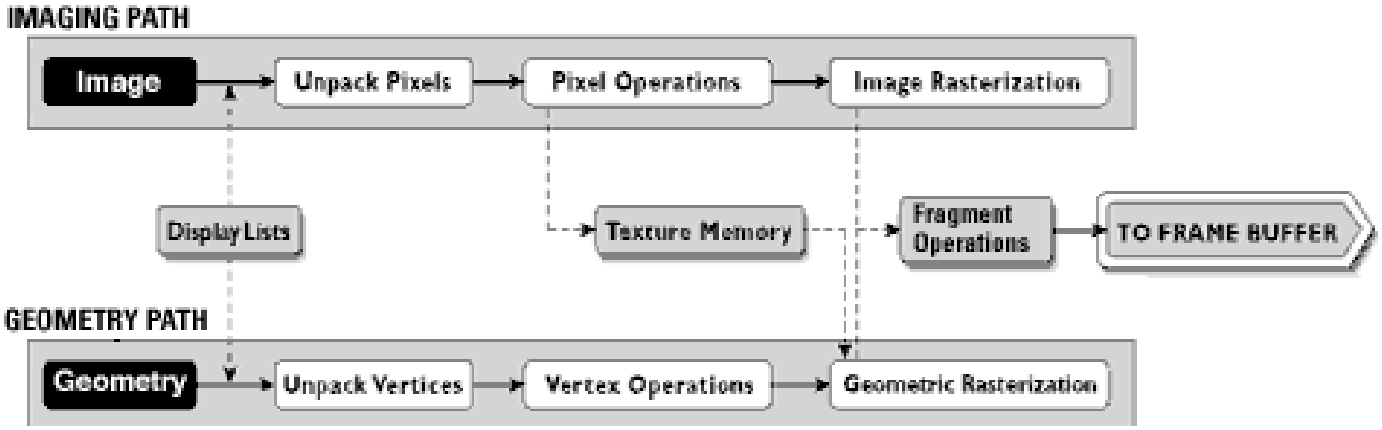


Overview: OpenGL ES

- 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?

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, Series 60
- Brew
- PS3 / Cell architecture

Sony's arguments at GDC: 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
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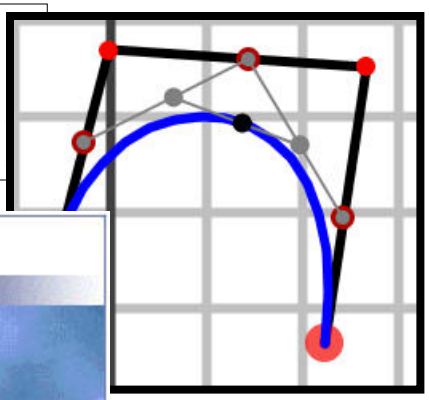
Functionality: in / out? (1/7)

- Convenience functionality is OUT
  - 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_TRIANGLES, 0, 4 );
```

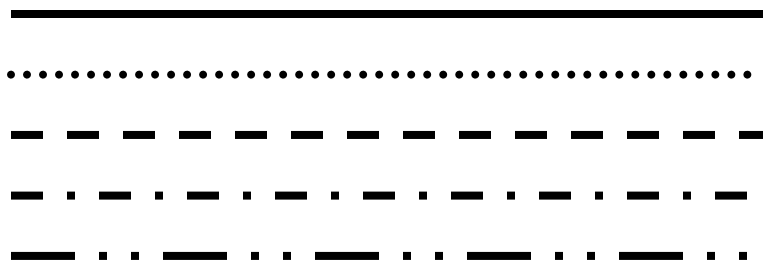
Functionality: in / out? (3/7)

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

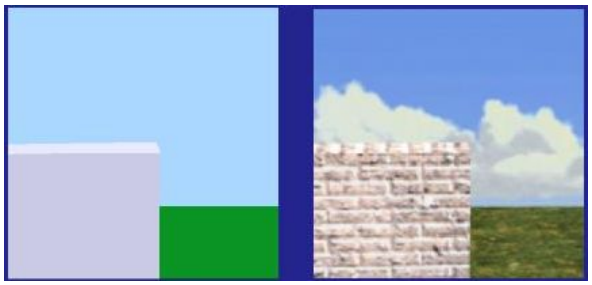
    alpha / depth / scissor / stencil tests,
    multisampling,
    dithering, blending, logic ops)

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 **IN**
  - 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)

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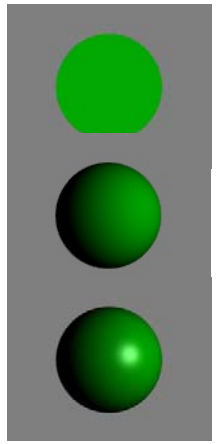
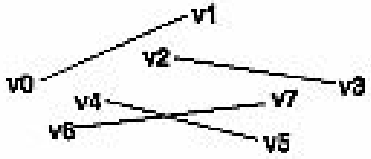
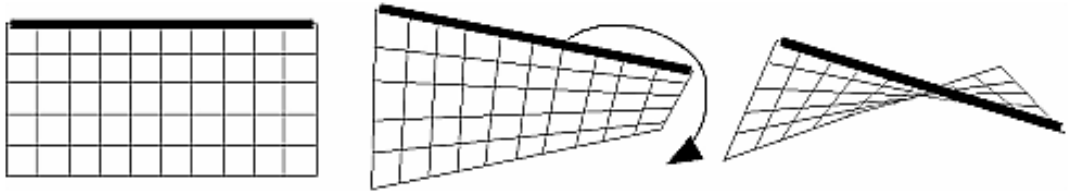
- Almost full OpenGL light model **IN**
  - back materials, local viewer, separate specular **OUT**
- Primitives
  - **IN:** points, lines, triangles
  - **OUT:** polygons and quads

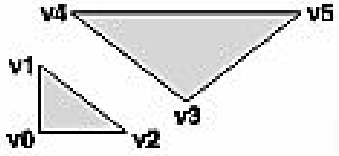


GL_POINTS



GL_LINES





GL_TRIANGLES

OpenGL|ES

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

- OpenGL is strongly based on floats
  - recently even frame buffers
- No HW floating-point in target devices
  - enable also low-end SW implementations
  - didn’t want to wait for floating-point…

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

Profiles: Common Profile

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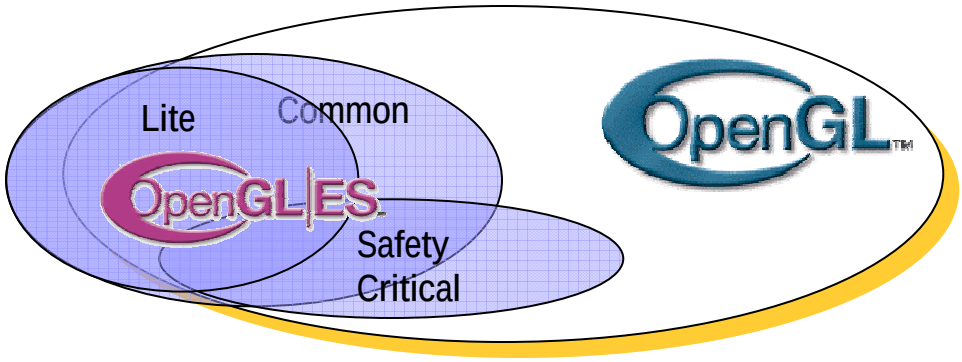
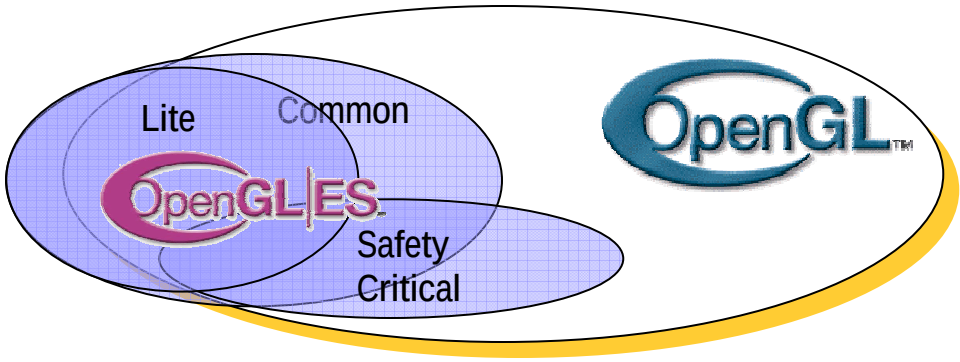
- The full OpenGL ES profile
  - both float and fixed-point function entry points
  - requires desktop OpenGL range and accuracy
- Good platform for gaming and other 3D apps
- Implementable on many platforms, including mobiles



Profiles: Lite & Safety Critical

- Common Lite: “SW implementation-friendly”
  - for extremely limited systems
  - only fixed-point, reduced range requirements
- Safety Critical
  - key criterion: ease safety certifications
  - targeted for avionics and automotive displays



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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

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)

OpenGL ES 2.0

- Address programmability
  - Vertex and pixel shaders, GL Shading Language
  - No fixed functionality
    - no backwards compatibility
- Mobile 3D features catching up desktop fast!
  - mobile programmable API only a couple of years behind desktop

Towards OpenGL ES 1.2

- Reduce variability of implementations
  - Require stencil bits, make some optional extensions mandatory, …
  - Also some new functionality
- Announce functionality likely to be later in 1.2
  - Allows HW vendors to get ready, and gives time to get market feedback from 1.1

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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, targets for rendering
  - *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

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
  - PM event => all Context lost
  - Disp & Surf remain, Surf contents unspecified
- Render-to-texture [optional]
  - flexible use of texture memory

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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

On-Device Implementations

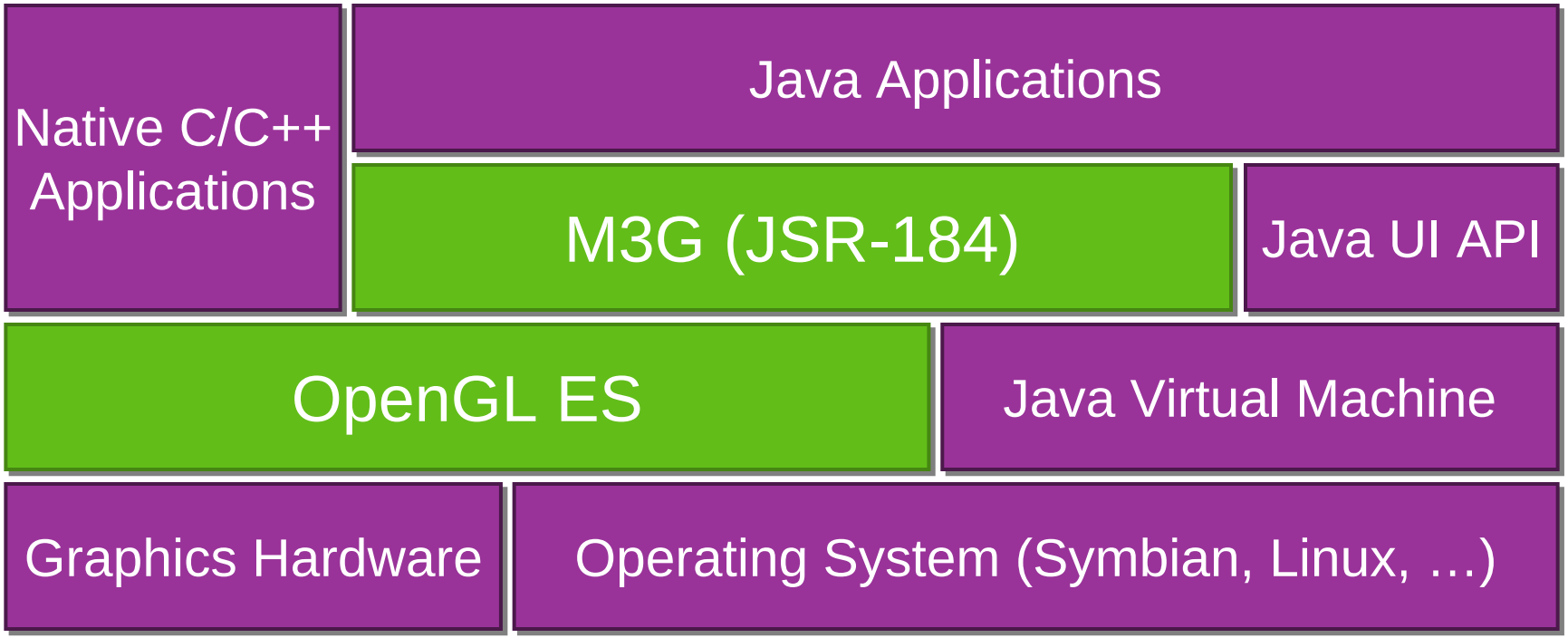
- NokiaGL (SW)
- Imagination MBX
- NVidia GoForce 3D
- ATI Imageon
- Toshiba T4G
- …

SDKs

- Nokia Series 60 FP2 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

Questions?

Mobile 3D Graphics APIs



Why a new standard for J2ME?

- OpenGL (ES) (and D3D) are too low-level
  - Lots of Java code needed for simple things
- Java 3D is too bloated
  - A hundred times larger than M3G
  - Does not fit together with MIDP
- Idea of subsetting Java 3D (but a new API)
  - Basic Java 3D ideas: nodes, scene graph
  - Add file format, keyframe animation
  - Remain compatible with OpenGL ES

Status July 05 (www.jbenchmark.com)

- **CECT**
  - GS900
- **LG**
  - MM-535
- **Motorola**
  - A780, C975, E680, E680i, E1000, i605, V980
- **Nokia**
  - 6230i, 6255, 6255i, 6630, 6680, 6681, 6682
- **Panasonic**
  - VS3
- **Samsung**
  - SGH-Z130, SGH-Z300, SGH-Z500, SPH-A880
- **Sanyo**
  - MM-7400, MM-8300, S103
- **Sharp**
  - V902sh, SX813
- **Siemens**
  - CX65, CX70, CX75, M65, M65i, S65
- **SonyEricsson**
  - F500i, K300c, K300i, K500c, K500i, K508c, K508i, K700i, K750c, K750i, S700i, V800, Z500a, Z800
- **Toshiba**
  - TS921

Today's program

- M3G Intro
  5 min, Kari Pulli
- M3G API overview
  50 min, Tomi Aarnio
- Using M3G
  45 min, Mark Callow
- Closing & Q&A
  5 min, Kari Pulli
- End at 5:30

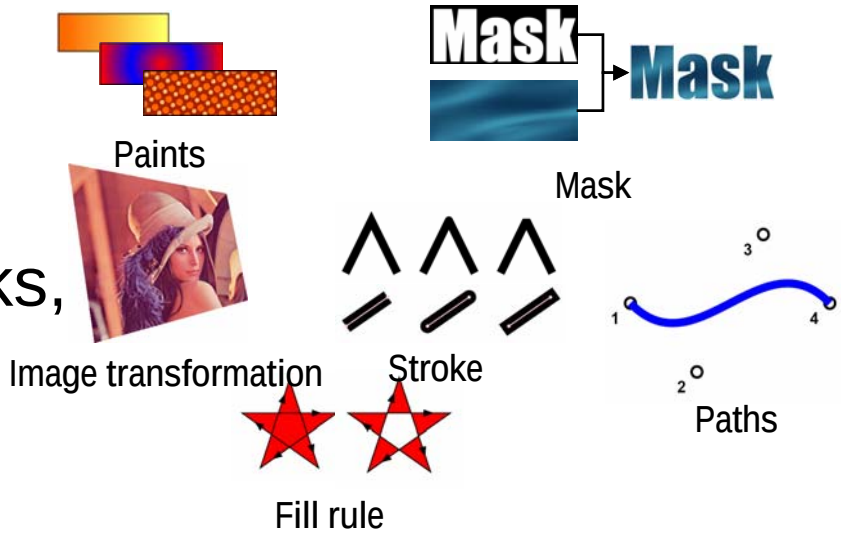
- Tomi: M3G API Overview
  - design principles
  - basic structure
  - scene graphs & animation
  - M3G file format
- Mark: Using M3G
  - development process, tools
  - midlets, simple -> complex
  - performance tips
  - publishing

Closing & Summary

- We have covered
  - OpenGL ES
  - M3G

Khronos embedded API palette

- OpenGL ES family
  - fixed functionality (1.x)
  - programmable (2.x)
- OpenVG
  - 2D vector graphics
  - SVG players, UI frameworks, low-level OS graphics



Khronos embedded API palette

- OpenMAX
  - building-blocks for multimedia codecs
- Audio API
  - working group just approved
- Collada
  - interchangeable interactive 3D content
  - working group just approved

Mobile Java

- M3G (JSR 184)
  - first maintenance release out
  - second generation API work can start next as OpenGL ES 2.0 is completed
- JSR 239: Java Bindings for OpenGL ES
- JSR 226: 2D vector graphics for Java
  - SVG-Tiny compatible features

Summary

- Fixed functionality mobile 3D is reality NOW
  - these APIs and devices are out there
  - go get them, start developing!
- Solid roadmap to programmable 3D
  - OpenGL ES 2.0
  - M3G 2.0 work to start next winter