Delivering Compelling User Experiences via Open Standard APIs and State-of-the-art Mobile Silicon

Phil Atkin
NVIDIA Automotive Business Unit
Enabling Compelling Mobile Experiences

Processing Power
To deliver rich content – on battery power!

OS Flexibility
To support sophisticated applications

Rich Media Functionality
Not just audio and video but real-time 3D
- with open standard acceleration APIs

User Accessibility
Compelling user experiences and intuitive user interface
Phone Architecture Shift

1997 – E.g. StarTAC
- Basic OS running on modem
- Limited Performance and functionality
- No media capabilities

2004 – E.g. Motorola E1000
- Baseband processor integrates CPU and modem
- Higher-capability OS
- GPU media acceleration sometimes available as a separate device

2009 – E.g. IPhone
- Application Processor integrates fast, capable CPU with full GPU media processing on one chip
- Modem is a peripheral to decouple OS/applications from wireless transitions
- Full multi-tasking OS

A full computer in the palm of your hand!
Pervasive Mobile Media Computing

- Handsets are becoming personal computing devices - not “just” phones
  - Your most personal computer – mobility, connectedness and numerous sensors

- Sophisticated media processing will be central to handheld revolution
  - Graphics and media will become as pervasive as it is on the PC

- Diverse applications will drive the need for handheld accelerated media
  - User Interface, 2D maps and 3D navigation, TV/Video, games …
Processing Power
To deliver rich content – on battery power!

OS Flexibility
To support sophisticated applications

Rich Media Functionality
Not just audio and video but real-time 3D - with open standard APIs

User Accessibility
Compelling user experiences and intuitive user interface
Media processing is becoming central to mobile experience. Graphics and media will become as pervasive as they are on the PC.
Mobile Media Fragmentation

- Every handset is unique from the programmers perspective
  - Differences in operating system functions, Java implementations and media functionality

Severe platform fragmentation
ISVs need to port to and support 100s (even 1000s) of source variants of each title
Khronos API Standards

- “Foundation-Level” acceleration APIs
  - Needed on every platform to support an ecosystem of middleware and applications

- Low-level access to processor silicon
  - Designed with strong silicon vendor participation

- Cross-vendor software portability
  - API abstractions just high enough to hide implementation specifics

- Established focus on graphics, media and parallel compute acceleration
  - 3D, vector 2D, video, imaging, audio, heterogenous parallel programming APIs…

Khronos APIs create the foundation of an ecosystem that enable applications to be PORTABLE and ACCELERATED on diverse silicon platforms
Over 100 companies creating authoring and acceleration standards

Board of Promoters
The Khronos Mobile API Ecosystem

3D Authoring

Parallel computing and visualization in scientific and consumer applications

OpenCL

Coherent mobile graphics and media stack

Embedded 3D

Streaming Media and Image Processing

Mobile OS Abstraction

Umbrella specifications for mobile application portability

Hundreds of man years invested by industry experts to create coordinated ecosystem
Advantages of Mobile Graphics Acceleration

- Faster Performance at Higher Quality
  Hardware delivers smoother interaction with much better looking graphics

- Power Efficiency
  Hardware accelerators exploit media pipeline parallelism and caching for a x10 increase in power efficiency over software

- Better User Experience
  Smaller screens need more advanced graphics processing per pixel

Software 3D

Accelerated 3D
OpenGL ES

• The leading 3D rendering API for mobile devices
  - Based on desktop OpenGL – but optimized for mobile / handheld devices
  - Removes redundancy & rarely used features - adds mobile-friendly data types
  - The power of OpenGL distilled into a much smaller package

• A smashing success!
  - Widely used in mobile phone handsets from every major handset manufacturer
  - Personal Navigation, Personal Media Player, Automotive, Set-Top Box, Mobile Internet Device
  - Brew, Windows Mobile, Symbian, Android, iPhone OS, Limo

• OpenGL ES has become the most widely deployed 3D API
  - Used in diverse applications, devices and markets

Mobile OS that have adopted OpenGL ES as their native 3D API
OpenMAX IL – Streaming Media

• Enables arbitrary multimedia pipelines by plugging blocks together
  - Componentized architecture abstracts multimedia functionality block interfaces

• Wide variety of building blocks for imaging, video and audio functions
  - Encode, decode, apply an effect, capture, render, split, mix, etc

• Enables blocks from different sources to work together
  - Blocks can be implemented in software or hardware
OpenMAX IL Example Graph

- Standardized component interfaces enable flexible media graphs
- Includes multi-stream synchronization
- Allows for custom plug-ins

Example: MPEG-4 video synchronized with AAC audio decode
EGL

• **EGL abstracts access to rendering surfaces**
  - Interfaces Khronos rendering APIs to native platform window system
  - A derivative of the WGL Windows abstraction API

• **Emerging role as a communication hub between handheld APIs**
  - Sharing images via EGLImage extensions
  - EGLSync objects for inter-API fences and other signalling

• **Can create rendering surfaces into which multiple client APIs can draw**
  - Enables high-performance, accelerated, mixed-mode 2D and 3D rendering
  - Using OpenGL ES and OpenVG

• **EGL 1.3 was released in December 2006 – supports OpenGL ES**
  - OpenKODE 1.0 uses EGL 1.3 PLUS EGL extensions to integrate OpenVG PLUS
  - Lock Surface EGL extension for direct blitting of software rendering applications to the screen

• **EGL 1.4 integrated OpenVG and Lock Surface into core EGL**
  - In spring 2008
Directions for EGL 1.5

- **Create EGLImage within EGL**
  - Pre-declare uses => guaranteed image compatibility

- **Share images with OpenMAX**
  - Add EGLImage video data formats (YUV)

- **Stream images between APIs**
  - Queue of images with producer/consumer operations

- **EGLSync objects**
  - Inter-API fences and other signalling

Without EGLImage the game must copy the OpenMAX buffer into an OpenGL ES texture.

An EGLImage surface can be used as both the destination of the decode and a texture without copying the data.
Mobile Umbrella Specifications

- **Individual APIs define domain specific media acceleration**
  - OpenGL ES for 3D, OpenMAX for video and images etc.

- **Latest mobile applications want to MIX media types**
  - E.g. route live video into a composited 3D user interface

- **For portability of mixed-media need to define how the APIs work together**
  - E.g. how to transfer video data from OpenMAX into OpenGL ES

- **Umbrella specs define and CONFORMANCE TEST trans-API operation**
  - Creates a reliable, cross-vendor media-stack definition
Khronos Mobile Umbrella Specs

- Platform vendors can choose to ship more than just individual APIs
  - Provide *conformance tested* multi-API programming platforms
- 1. OpenKOGS = integrated media stack
  - Defines reliable trans-API interoperability through EGL for OpenGL ES, OpenVG, OpenMAX
- 2. OpenKODE = OpenKOGS *plus* OS abstraction API
  - OpenKODE Core is Posix-like API for application portability across mobile operating systems

<table>
<thead>
<tr>
<th>Native Applications</th>
<th>UI/Widget Toolkits</th>
<th>3D Gaming Engines</th>
<th>Flash/SVG/Font Engines</th>
<th>TV/Video/Audio Engines</th>
</tr>
</thead>
<tbody>
<tr>
<td>(e.g. Browsers, Games, Navigation, Media)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Graphics stack umbrella spec – defines levels of media API and EGL to be present and tests trans-API interoperability

Source portability umbrella specification – adds OpenKODE Core OS abstraction API
OpenKODE – Source Portability

Applications are portable to any OpenKODE-enabled platform

Platforms can use any OS and silicon vendor

OpenKODE Royalty-free open standard for rich media source portability
Raising 2D and 3D Visual Quality

State-of-the-art APIs enable compelling consumer displays
Advanced functionality, fast interactivity and extremely high quality

High-quality 2D graphics and text using OpenVG

Older generation APIs
Provide rudimentary graphics functionality and quality

Video and image processing with OpenMAX

High-quality 3D displays using OpenGL ES

San Francisco
Church & Powell
Processing Power
To deliver rich content – on battery power!

OS Flexibility
To support sophisticated applications

Rich Media Functionality
Not just audio and video but real-time 3D - with open standard APIs

User Accessibility
Compelling user experiences and intuitive user interface
Tegra – Computer on a Chip

- Up to 750MHz ARM11 MPCore
- 32 KB (I/D) L1 Cache
- 256 KB L2 Cache
- HD Video Decode/Encode
- Low Power Audio Decode
- 12MP Camera Processor
- Advanced Image Processing
- OpenGL ES 2.0
- 50M Tri/s
- 600M Pix/s
- H.264 1080p 30fps decode/encode
- Ultra low power audio acceleration AAC, AMR, WMA, MP3, PCM, MIDI
- Dual Display
- HDMI 1.2, TV-out, LCD, CRT
- Baseband Interface
- HSI, SPI, UART

- Windows Mobile 6.X / WinCE and Android
- Unified memory - up to 512MB
- 166MHz LP-DDR (x16 or x32)
- Ultra low-power GeForce core - Xbox performance/PS3 functionality - at a few hundred milliwatts. 45 FPS Quake 3 Arena, WVGA with 5x CSAA, 8x anisotropic
- H.264 1080p 30fps decode/encode
- Ultra low power audio acceleration AAC, AMR, WMA, MP3, PCM, MIDI
- Dual Display
- HDMI 1.2, TV-out, LCD, CRT
- Baseband Interface
- HSI, SPI, UART
Processing Power
To deliver rich content – on battery power!

OS Flexibility
To support sophisticated applications

Rich Media Functionality
Not just audio and video but real-time 3D - with open standard APIs

User Accessibility
Compelling user experiences and intuitive user interface
Usability Matters!

- The iPhone demonstrates the importance of good UI
  - Ease of discovery and use of device capabilities and resources drives revenue
Composited User Interfaces

- **Multiple accelerated applications render off-screen**
  - Bring multiple screen elements together with software flexibility onto the display
- **Uses 3D GPU to composite application outputs and UI elements to screen**
  - Needs multi-process-capable OpenGL ES graphics acceleration
- **Composition enables unlimited multiple virtual UI layers**
  - With software driven blending, merging and 3D transitions
Screen Composition

Multiple application processes render into off-screen, cross-process texture surfaces.

Client applications never need to realize they are being composited.

Multiple off-screen surfaces are composited to the screen using OpenGL ES for flexible screen layout and transitions.

Native OS Window Manager or a Launcher application creating a custom UI experience.

Compositor and Applications need to transparently communicate EVENTS and off-screen BUFFER HANDLES.

Client applications never need to realize they are being composited.
Khronos Composition UI Initiative

• KDWM – “the Compositors OpenKODE”
  - Extensions to OpenKODE Core - based on existing EGL and OpenKODE mechanisms
  - Off-screen surface allocation and cross process surface handle communication
  - Cross-process event dispatch

• Developed by NVIDIA – contributed for standardization by Khronos
3D UI Authoring Tools

- Many device OEMs now demanding 3D UI
  - Provides powerful capabilities compared to “2.5D”
  - Genuine lighting, animation and camera control enables emergent UI properties
  - Increased user context and navigational awareness
  - Emotionally compelling touch interaction
  - WOW-factor differentiation

- But 3D coding expertise is rare
  - Expensive, time consuming to program content

- 2D UI Solutions have great tools
  - Enable the designer / creative talent

- 3D UI needs intuitive authoring
  - Arrange assets in 3D
  - Animate in 3D
  - Link to user inputs

NVIDIA’s UI Composer 3D UI Authoring Tool
UI Composer Workflow

Asset Creation
- Max
- Maya
- Photoshop
- After Effects
- ...

Composition
- 3D Asset Composition
  - Import multiple 3D assets
  - Arrange and animate in WYSIWYG 3D
  - Link animations to user inputs

Deployment
- Conditioner
  - .amw
  - .bgf/

3D Asset Composition

Application/User Interface
- Tegra Driver Stack
- After Effects
- Adobe Premiere
- OpenKODE
- NVIDIA 3D Vision

UI Composer Runtime Playback
- Embed into any application
- Battle-proven, high-performance
- Lightweight C++ code base
- Strong memory management
- Fully 3D

Deployment
- Conditioner
  - .amw
  - .bgf/

UI Composer Runtime Playback
- Embed into any application
- Battle-proven, high-performance
- Lightweight C++ code base
- Strong memory management
- Fully 3D
NVIDIA UI Stack

UI Composer - 3D UI authoring tool.
Third party applications – including Browser.
UI and media application source code

Pre-integrated and optimized tools, applications and
UI source code

KDWM Composition framework, UI Composer
run-time engine, Accelerated Flash engine

Proven UI framework,
libraries and engines

Multi-Process, Mixed Media Driver Stack

Fully EGL- integrated,
seamlessly multi-tasking to
provide multiple “virtual GPUs”

Tegra Application Processors with OS BSPs

Media IP, optimized drivers and
OS BSP from a single vendor
3D “Spinner” UI Demo

- Running on Tegra Development System
  - Projecting to 1280x768 resolution

- Multi-process composition
  - Uses OpenGL ES 2.0 for real-time screen composition

- Fully implemented on OpenKODE open-standard APIs
  - Using KDWM Composition framework

- Fully virtualized 3D GPU and video acceleration
  - Multiple OpenGL ES 2.0 and OpenMAX IL applications
Conclusion

• Mobile phones are evolving into powerful, general-purpose computers with advanced media acceleration and user interfaces
• Soon many people in the world will be getting most of their pixels delivered in the palm of their hand
• Mobile silicon has the capability to deliver the high-end desktop graphics performance of just 2-3 years ago on a battery-powered device
• Delivering an advanced composition-based UI needs a full stack of drivers, engines and tools designed and tested to work together