Bringing Cameras and Graphics to Everybody

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Mobile Visual I/O

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Outline

Mobile phones => ubiquitous computers

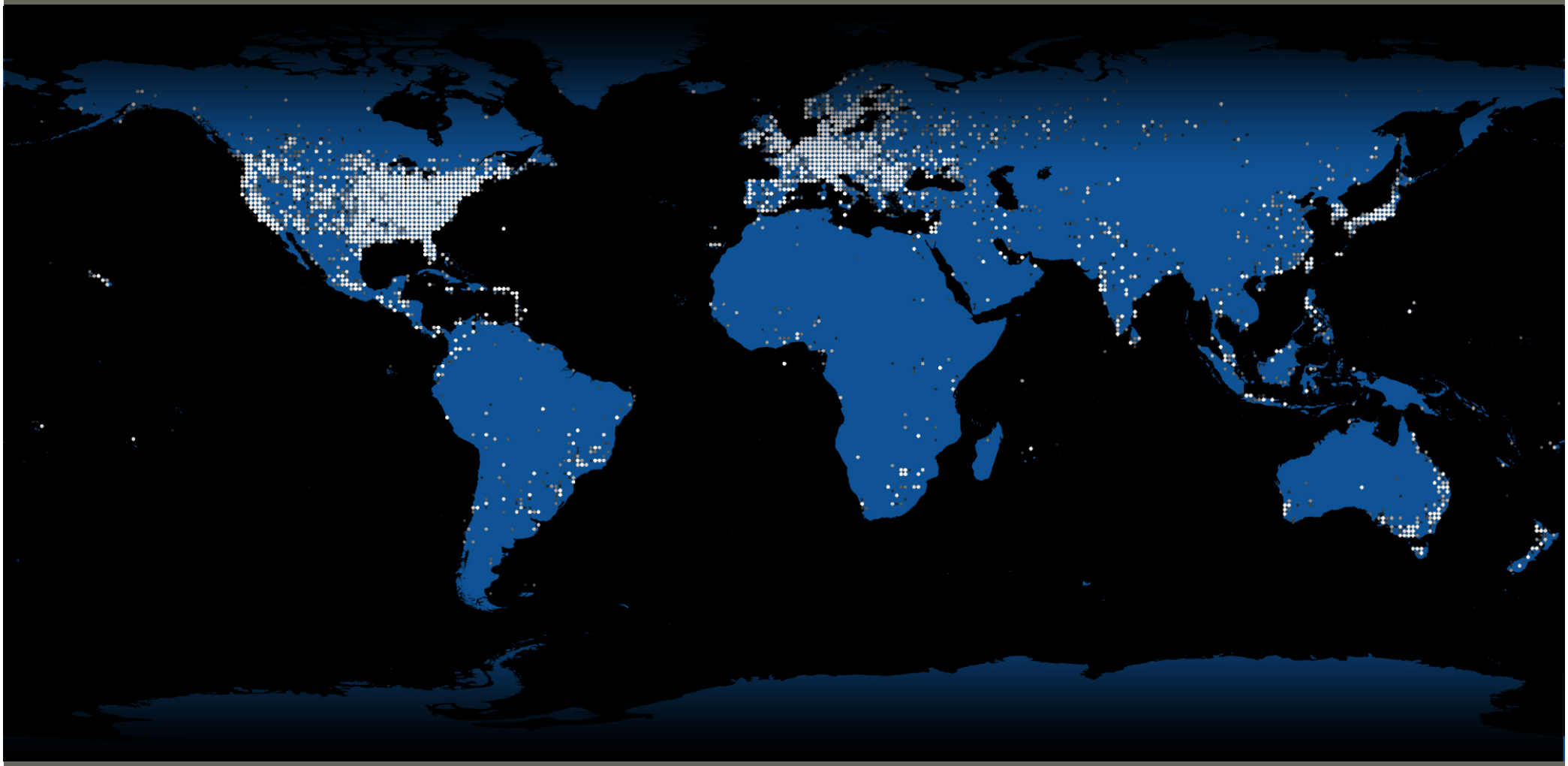
- Key enablers and challenges

Output

- Brief history of mobile 3D
- Mobile graphics standards
- Mobile 3D offering

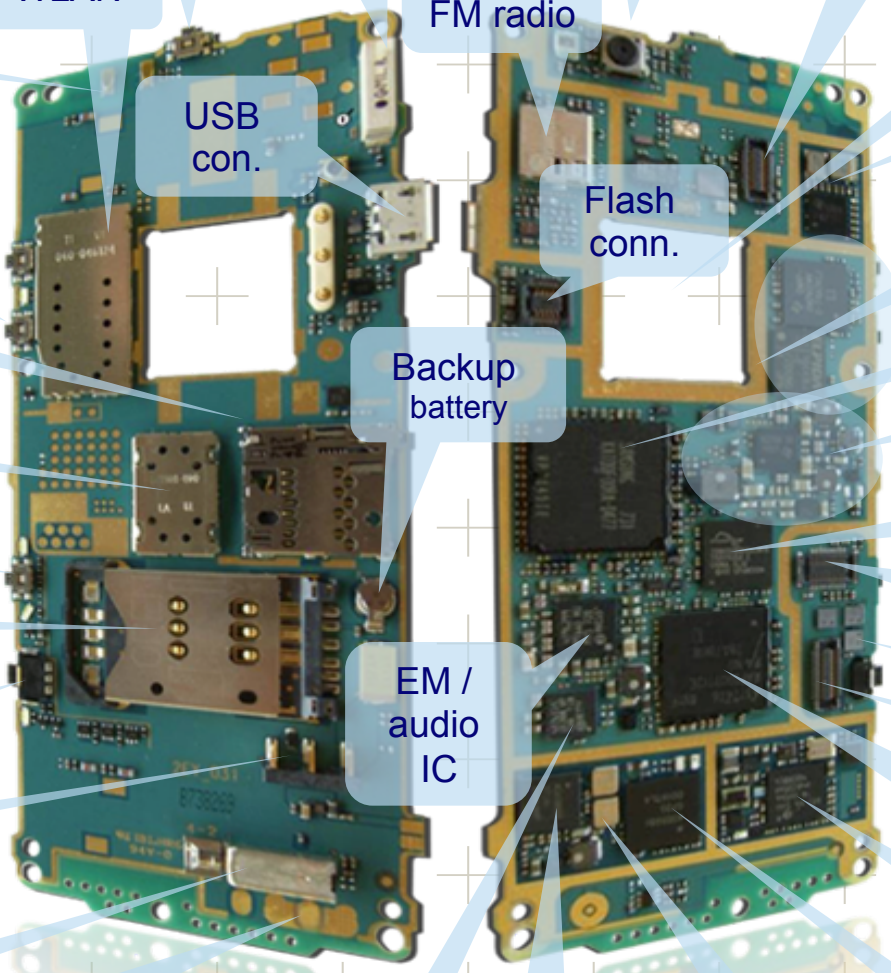
Input

- Mobile Augmented Reality
- Computational Photography




Countries and Territories

The devices are complex



Power Switch
BT / WLAN antenna
2nd camera
Camera connector
Hole for camera
GPS antenna clips
WLAN
BT / FM radio
GPS module
Volume
USB con.
Camera DSP
Volume switches
Flash conn.
µSD card holder
Application µP
Backup battery
Audio comp
Power regulators
Gallery switch
Cellular memory
SIM holder
Display connector
EM / audio IC
Camera switch
EMC IC's
UI connector
Battery connector
Cellular µ-processor
Vibra
RF ASIC
Cellular antenna connector
EM IC
RF amp
RF filters
RF amp

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Challenges and Enablers

Challenge? Power!

Power is the ultimate bottleneck

- Usually not plugged to wall while using, just batteries

Battery improvement doesn't follow Moore's law

- Only 5-10% per year

Gene's law

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

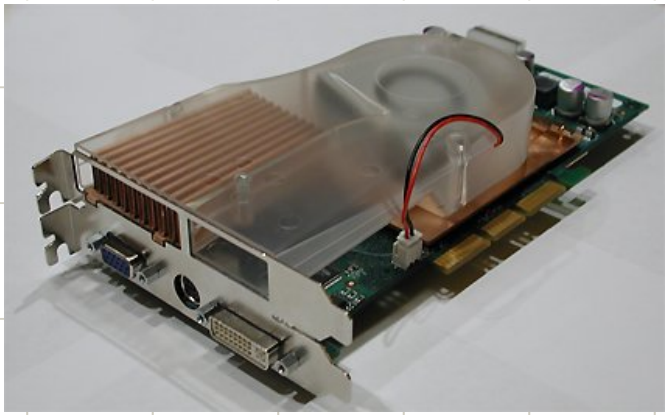
Challenge: Thermal management!

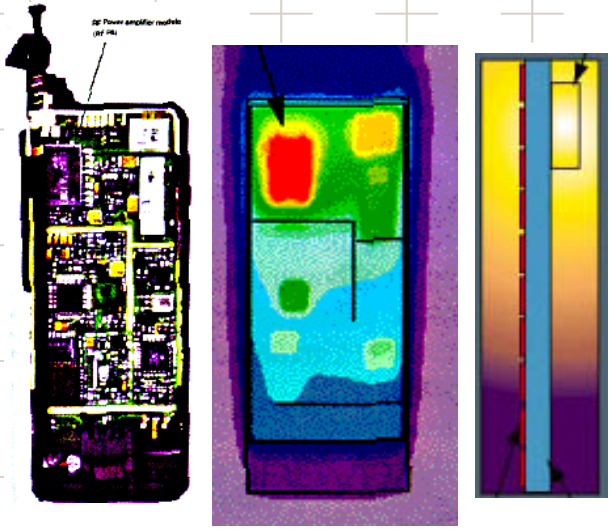
But ridiculously good batteries still won't be the miracle cure

- The devices are small
- Generated power must get out
- No room for fans

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

- 84 x 48 ->176 x 208 -> 320 x 240
- Communicators: 640 x 200 -> 800 x 352
- Internet tablets like N800: 800 x 480

Color depth

- gray scale 1 -> 2 -> 4 -> 8 bit
- RGB 12 -> 16 -> 18 -> 24 bit

Changed? Displays!

Color gamut

2005: 38 % NTSC gamut

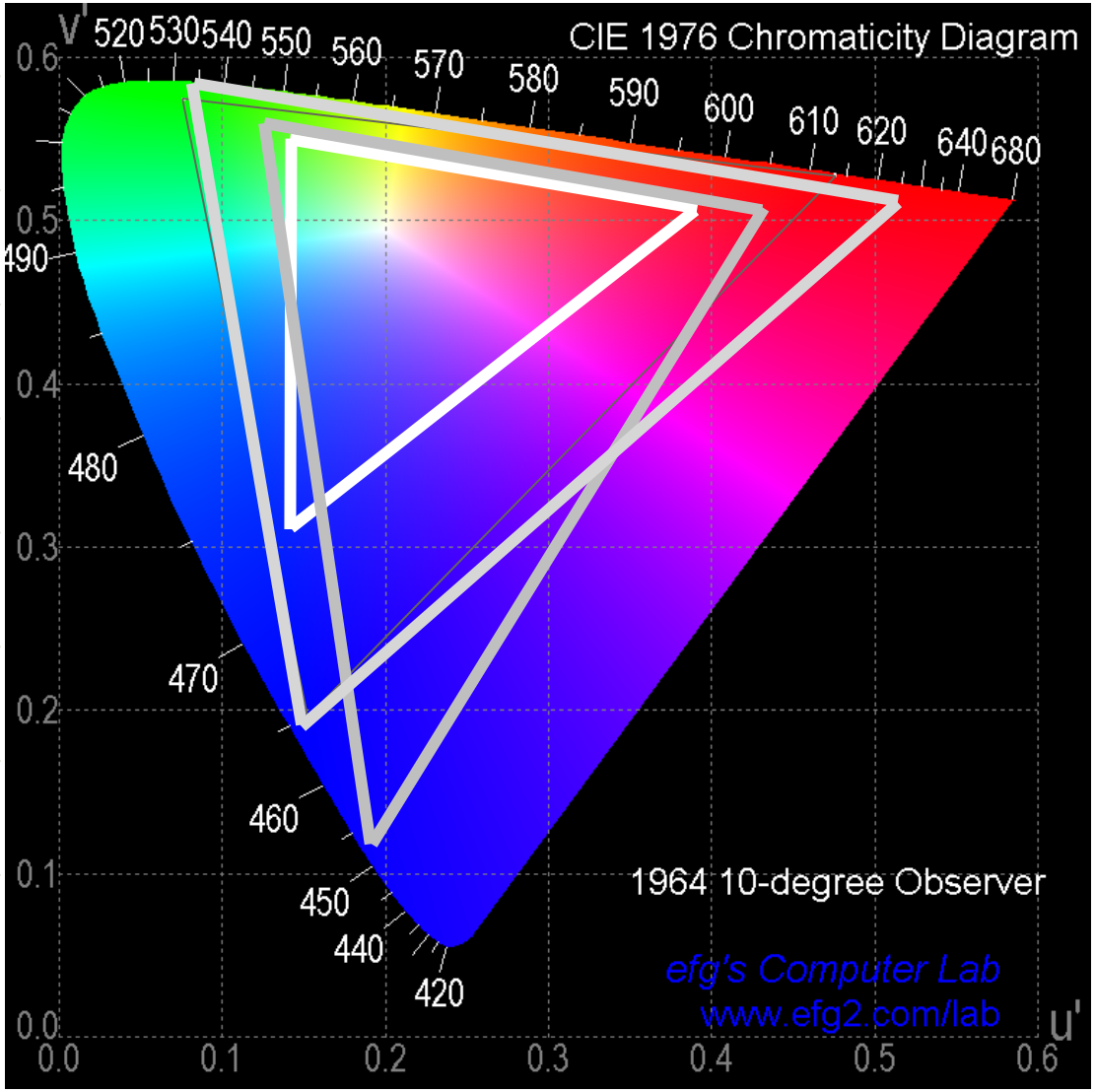
- Nokia 6600

2006: 75 % NTSC gamut

- Nokia 6131

2007: 100 % NTSC gamut

- OLED displays
- Nokia 8300



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Future? Displays!

Physical size remains limited

- TV-out connection
- Near-eye displays?
- Projectors?
- Roll-up flexible displays?

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

Changed? Imaging

Even faster improvement on cameras

- 3410
  - no camera
- 6600
  - 640 x 480 still images
  - 176 x 144 video 6-15 fps
- 6630
  - 1280 x 960 still images
  - 176 x 144 video 15 fps
- N93
  - 2048 x 1536 still images
  - 640 x 480 video 30 fps
  - 3x optical zoom
  - Carl-Zeiss Vario-Tessar lens

Other advances

Connectivity

- long distance data: GPRS, W-CDMA, …
- short distance data: Bluetooth, W-LAN, …

Locationing

- GPS
- triangulation: cell-tower ID, W-LAN, …

More input modalities

- accelerometers
- touch

Mobile Graphics: Output

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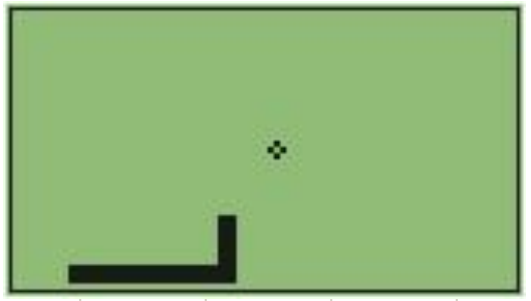
State-of-the-art in 2001: GSM

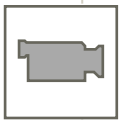


Snake: The world's most played electronic game

- According to The Guardian (May 2001)
  "it took Nintendo 10 years to sell 100m Game Boys whereas Nokia sold 128m handsets last year alone"

Work on mobile 3D engine at Nokia began in 2001

- OpenGL subset
  - perspective camera & textures, lighting, blending
- shipped in 2002



Japan 2001-02

Already color screens

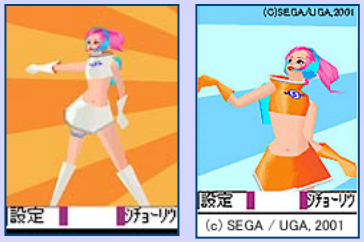
- enables nice content

High-level API

- skinning
- flat shading, orthographic view, no or limited blending

SW engines for the next few years

GENKI 3D Characters
(C) 2001 GENKI



ULALA
(c)SEGA/UGA.2001

Snowboard Rider
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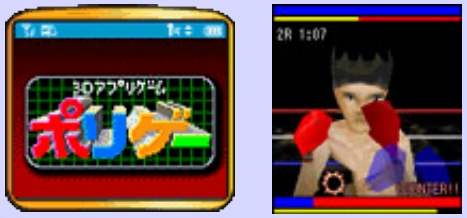

I-3D PolyGame Boxing

@ Hi Vanguard･REZO, BNW

J-SH51
by SHARP

2005 and beyond: With HW

Mobile gaming devices

Phones

with 3D gfx 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

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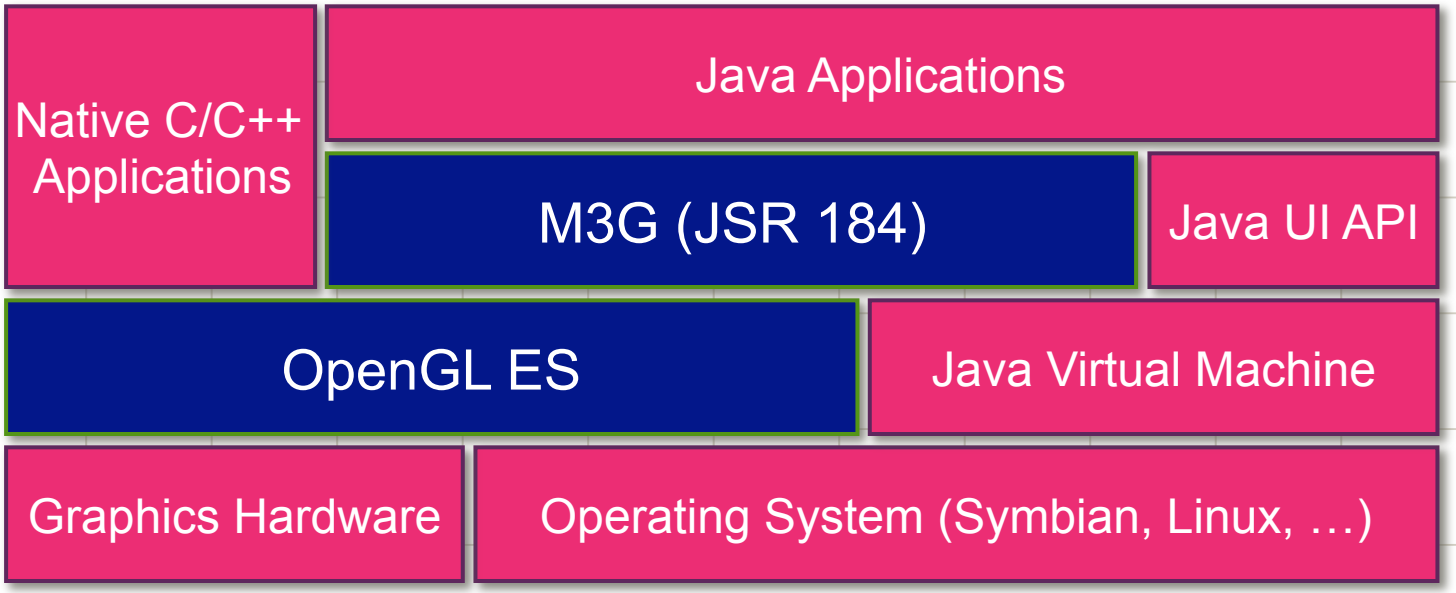
Key mobile 3D APIs

OpenGL ES and M3G

- Designed concurrently (and partly by the same people)
- Influenced each other
- Layered implementation model (immediate benefit of same HW)



What is OpenGL ES?

OpenGL is just too big for Embedded Systems with limited resources

- memory footprint, floating point HW

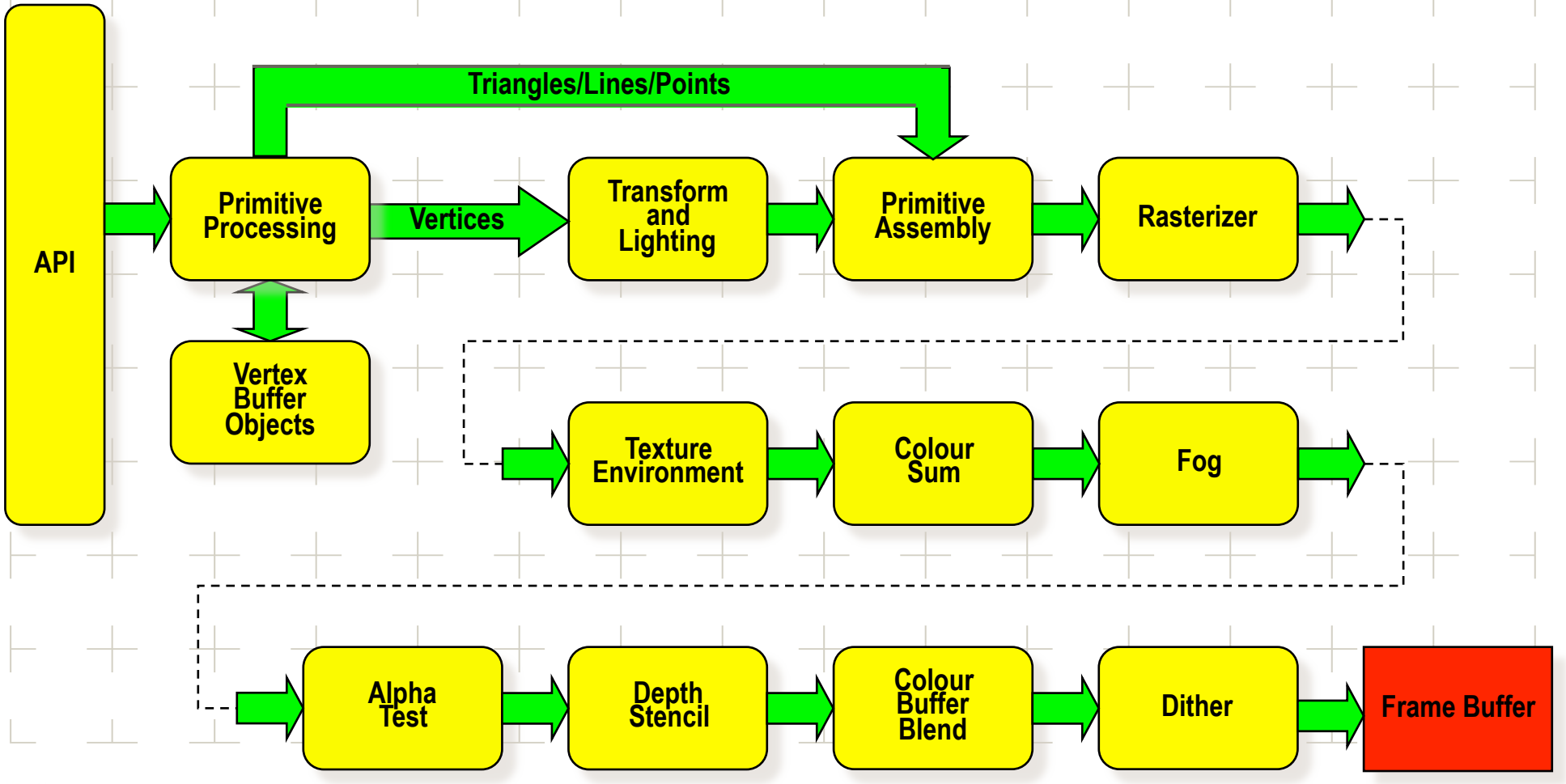
Create a new, compact API

- mostly a subset of OpenGL
- that can still do almost all OpenGL can

Design targets

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

Open GL ES Fixed Function pipeline

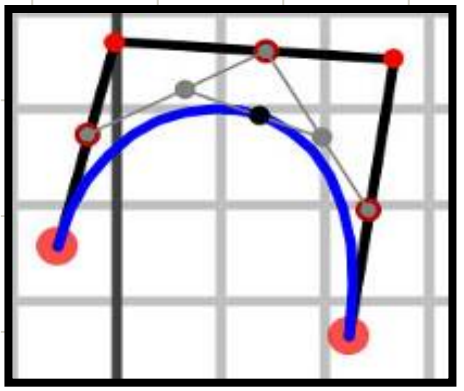


Functionality: in / out? (1/7)

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_TRIANGLE_STRIP,
                 0, 4 );
```

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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)

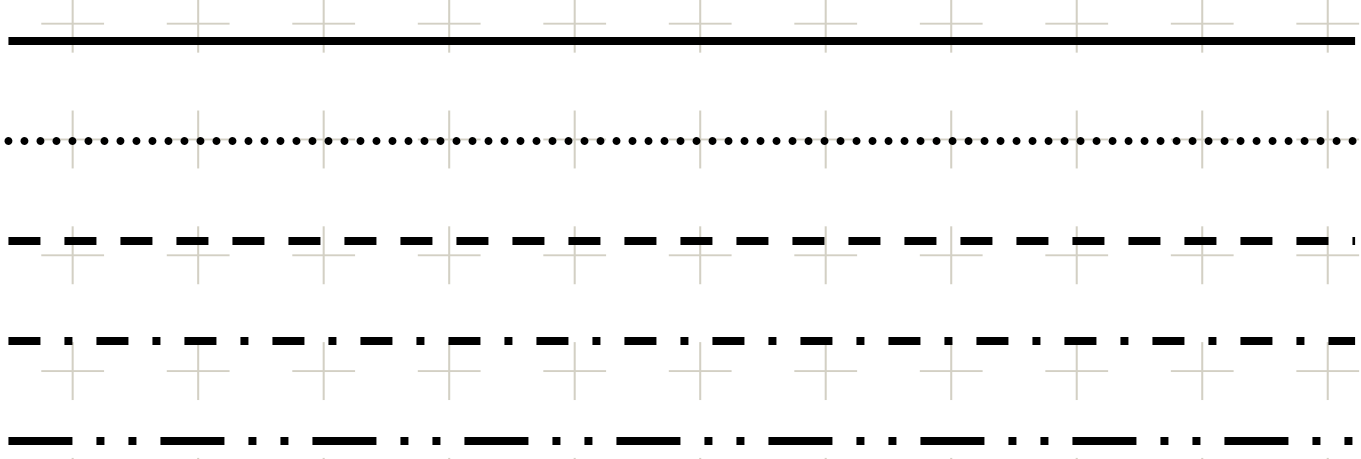
Functionality: in / out? (4/7)

Raster processing

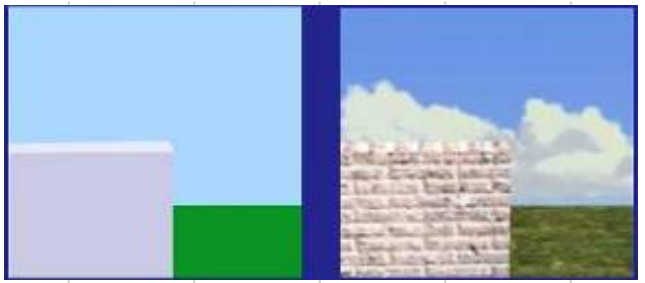
- ReadPixels **IN**, DrawPixels and Bitmap **OUT**

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**

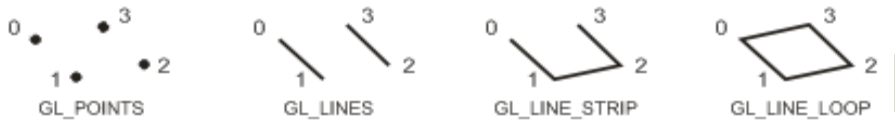
Functionality: in / out? (6/7)

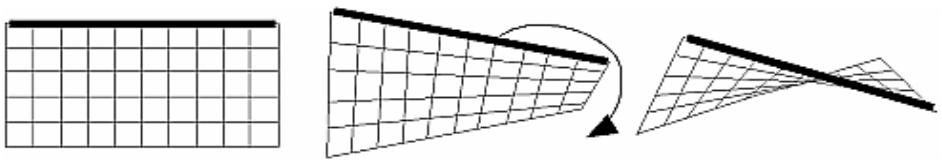
Almost full OpenGL light model **IN**

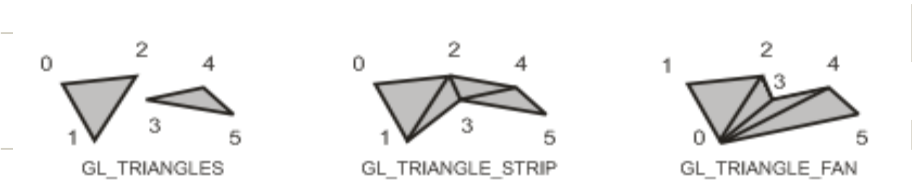
- back materials, local viewer, separate specular **OUT**

Primitives

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



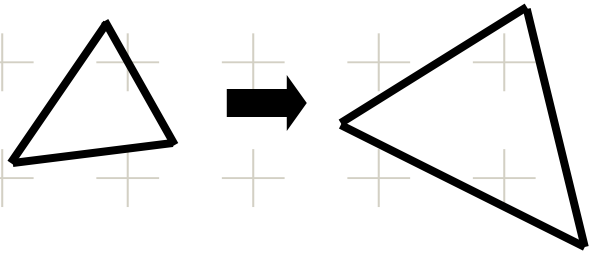




Functionality: in / out? (7/7)

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

OpenGL ES 1.1 in 2004: More HW orientation

Buffer Objects --- allow caching vertex data

Better Textures --- >= 2 tex units, combine (+,-,interp), dot3 bumps

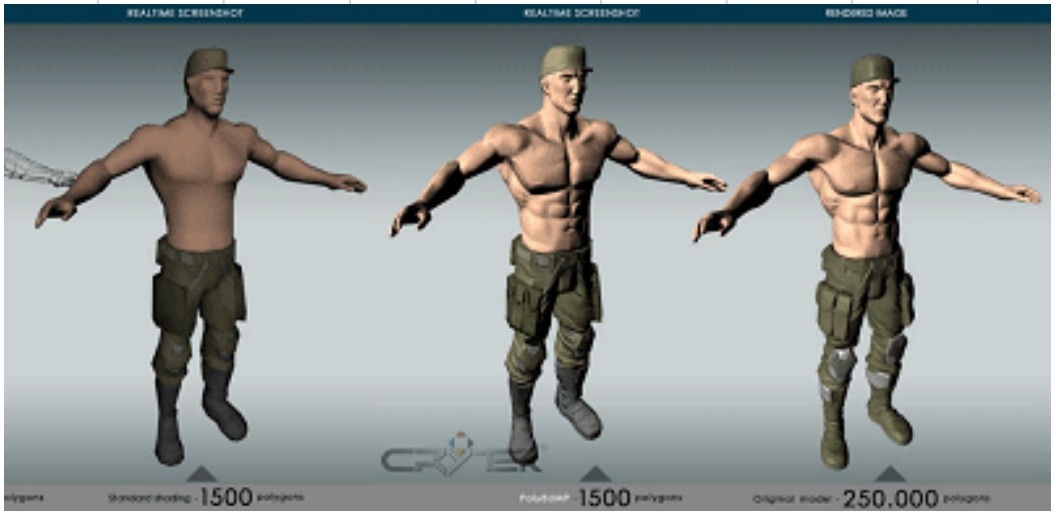
Point Sprites --- particles as points not quads, attenuate size w/ distance

User Clip Planes --- portal culling (>= 1)

State Queries --- enables state save / restore, good for middleware

Optional: Draw Texture --- pixel rectangles using tex units (data can be cached)

Matrix Palette --- vertex skinning (>= 3 M / vtx, palette >= 9)



OpenGL ES 2.0 Design

OpenGL ES 2.0 eliminates all fixed function redundancy

- Fixed function transform and lighting, texturing, fog, etc.
- Not 100% backwards compatible -> much simpler drivers

Adds full Shader Programmability

- Vertex and Fragment Shaders
- Shader Language (GLSL ES) – VERY similar to desktop GLSL

Other features

- Cube Map, 3D and NPOT Textures
- Frame Buffer Objects
- Point Sprites, Float / Half Float Textures
- ETC Texture Compression

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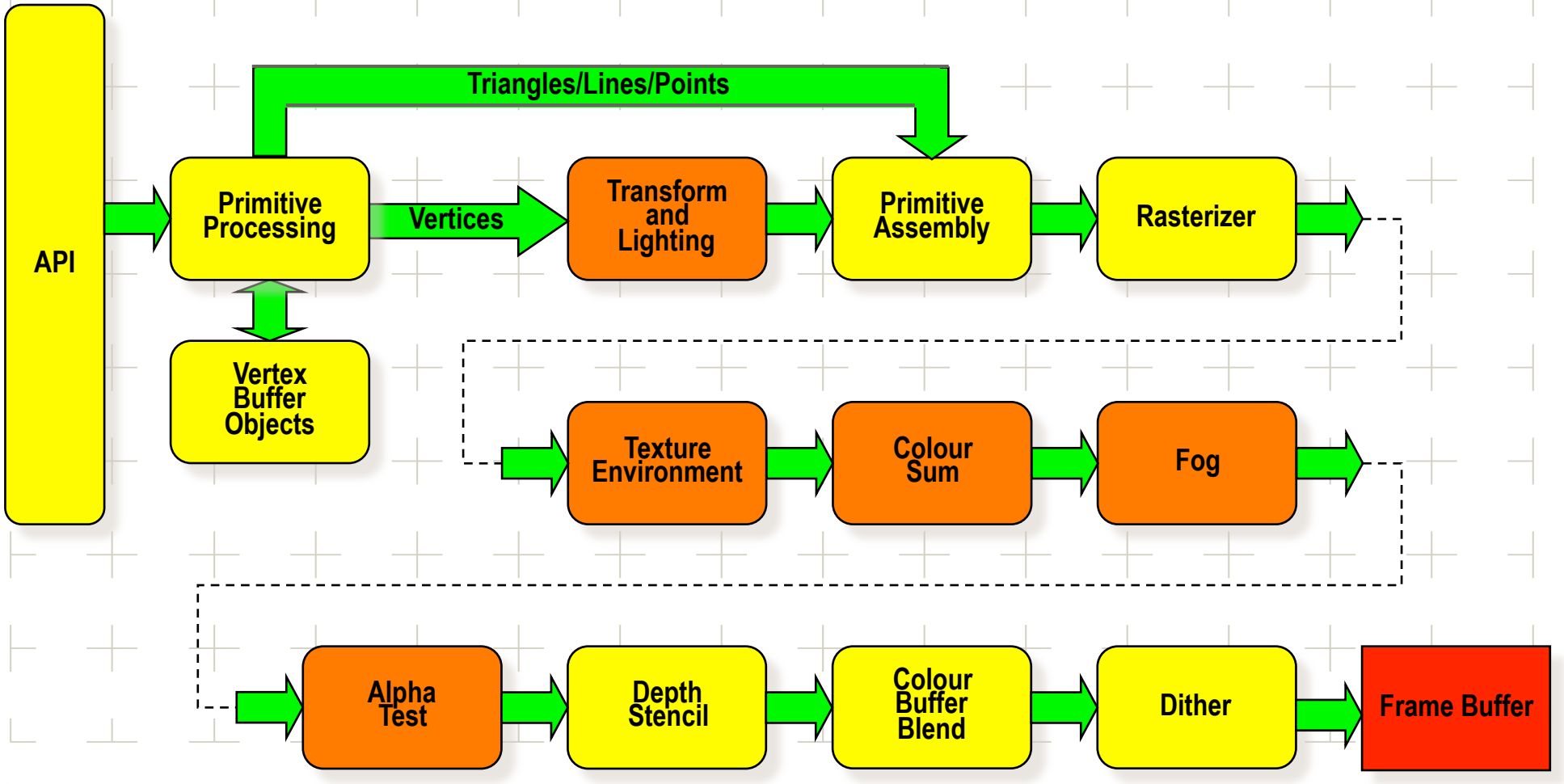
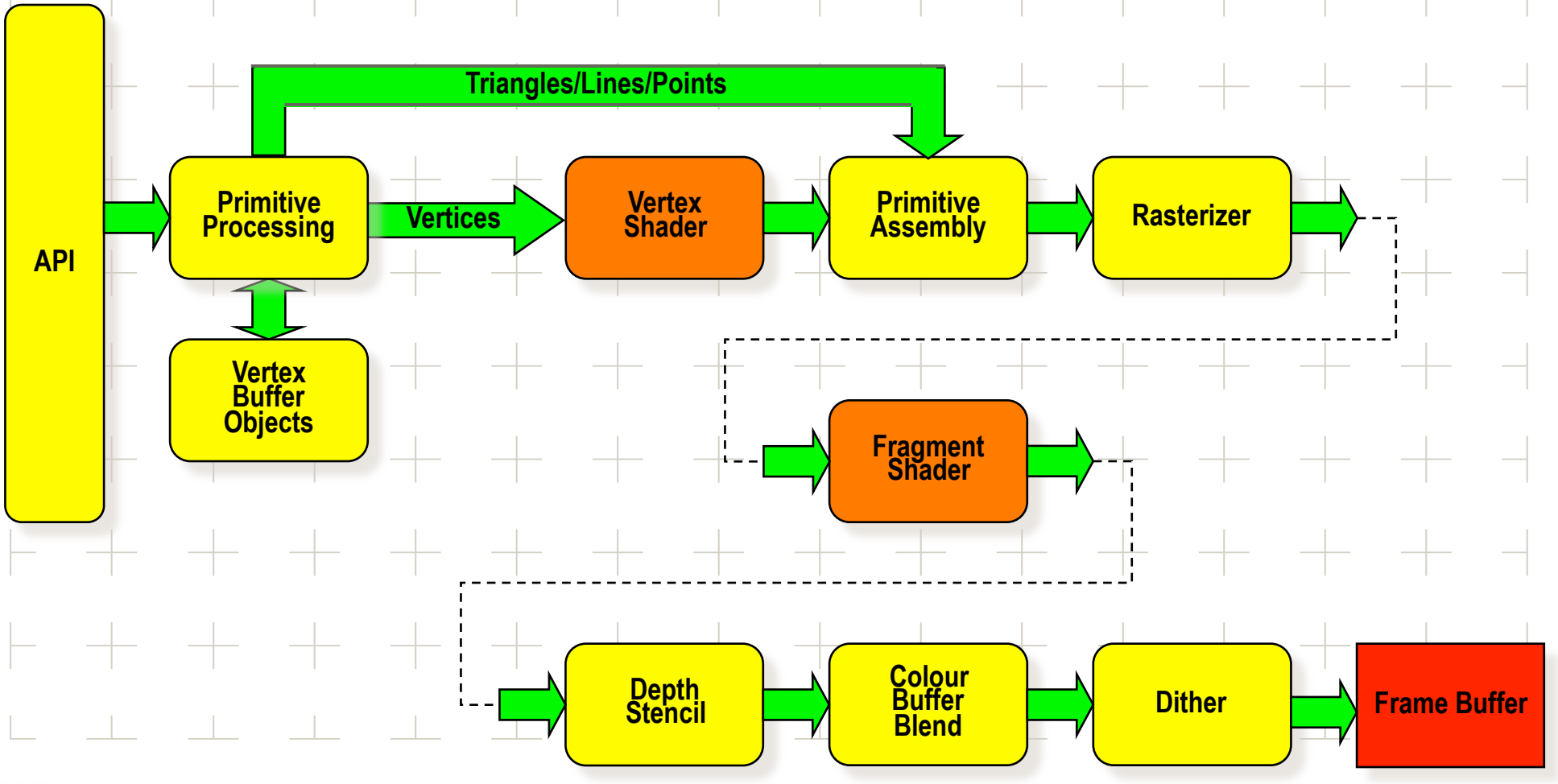
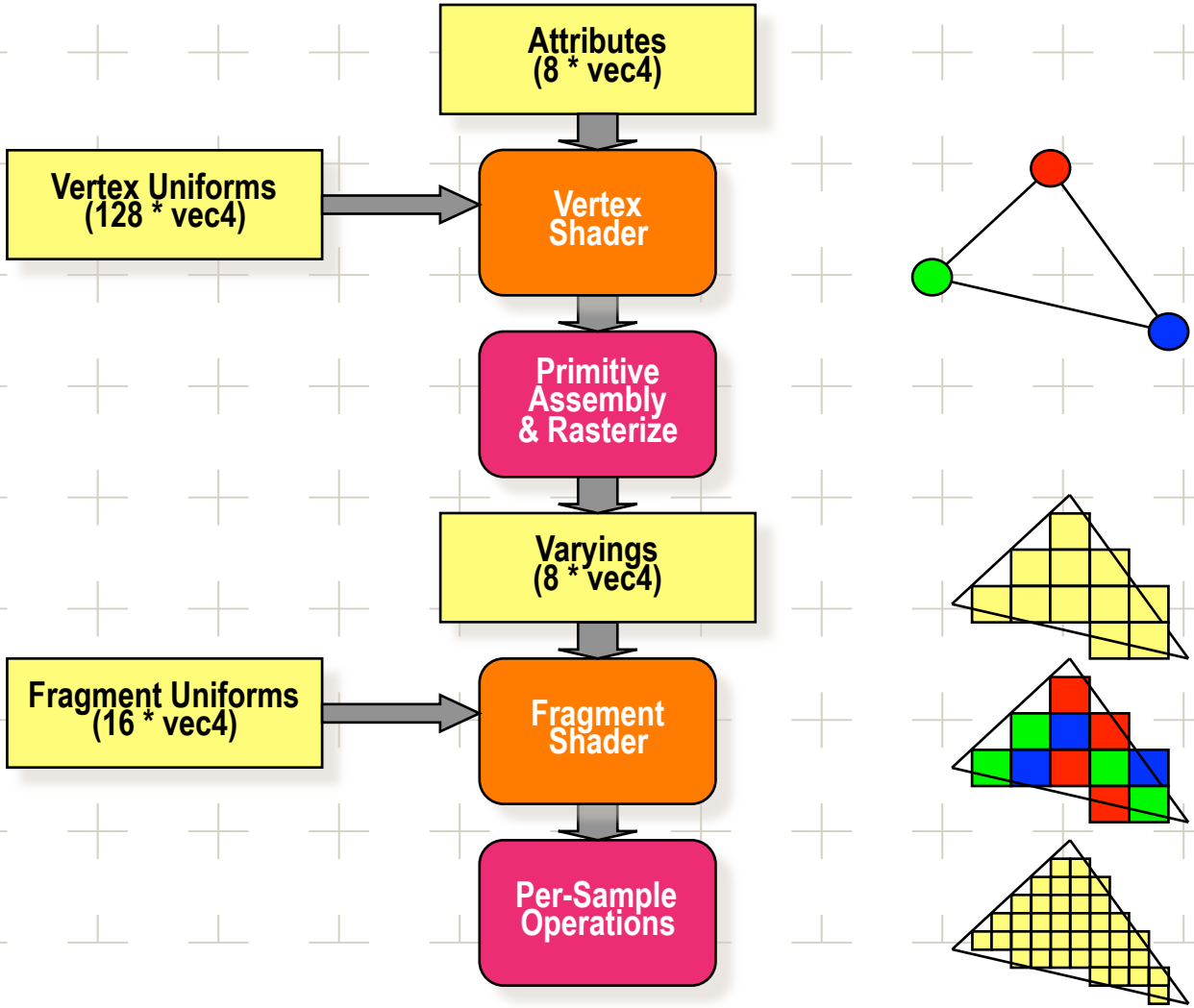
Open GL ES Fixed Function pipeline



Open GL ES Programmable pipeline



Programmer's model



Demo time

Quake II (and I, and III may be on the works)

- http://koti.mbnet.fi/hinkka/
- http://www.allaboutsymbian.com/features/item/How_to_Get_Quake_Running_on_Your_S60_Smartphone.php

Problem

- controls are difficult when the game is designed for PC

N95 images from Olli Hinkka's site

What is N-Gage?

- N-Gage is exceptional, made-for-mobile gaming with friends from across the street or around the world.

The N-Gage Application

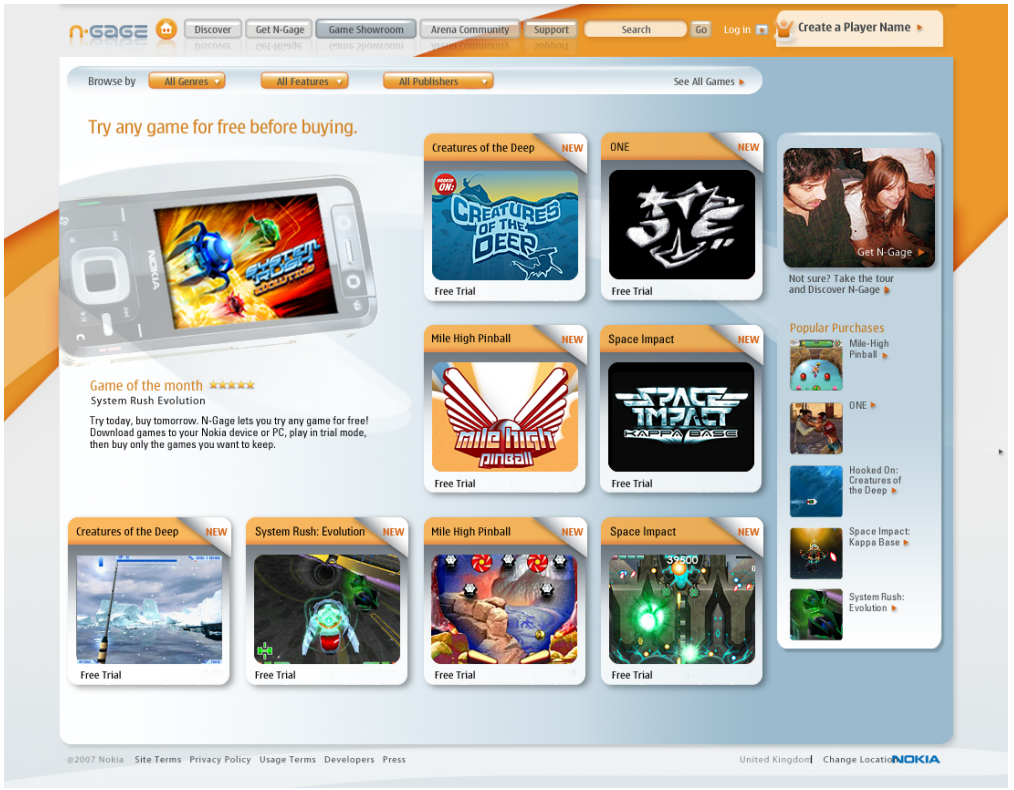
n-gage by Nokia

Try Today and Buy Tomorrow

Showroom on Device and PC

- N-Gage lets you try any game for free. Download games to your compatible device or PC, then buy only the ones you want.

Game Showroom on Device or PC

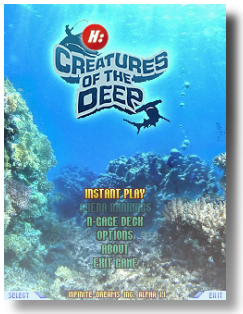


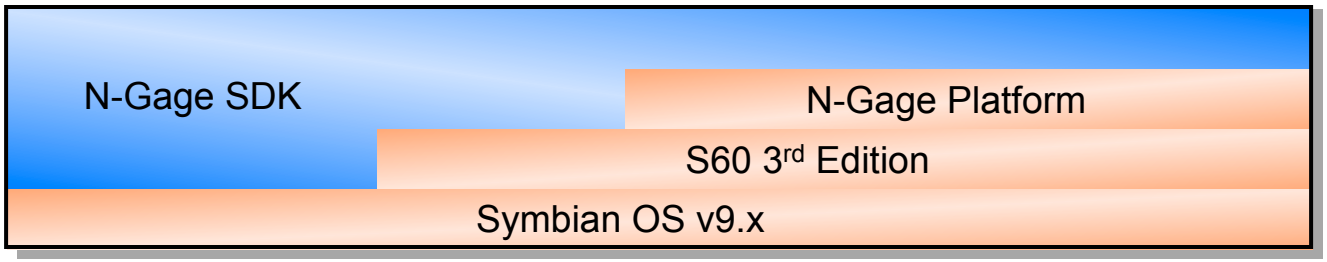
n-gage by Nokia

The N-Gage Application

n·gage by Nokia

SDK Abstraction Layer





n-gage by Nokia

ONE Demo

As the dust of previous fights settles, the ultimate question arises.
There are fighters all around the world claiming to be the ONE.
Can you succeed in the survival of the fittest?





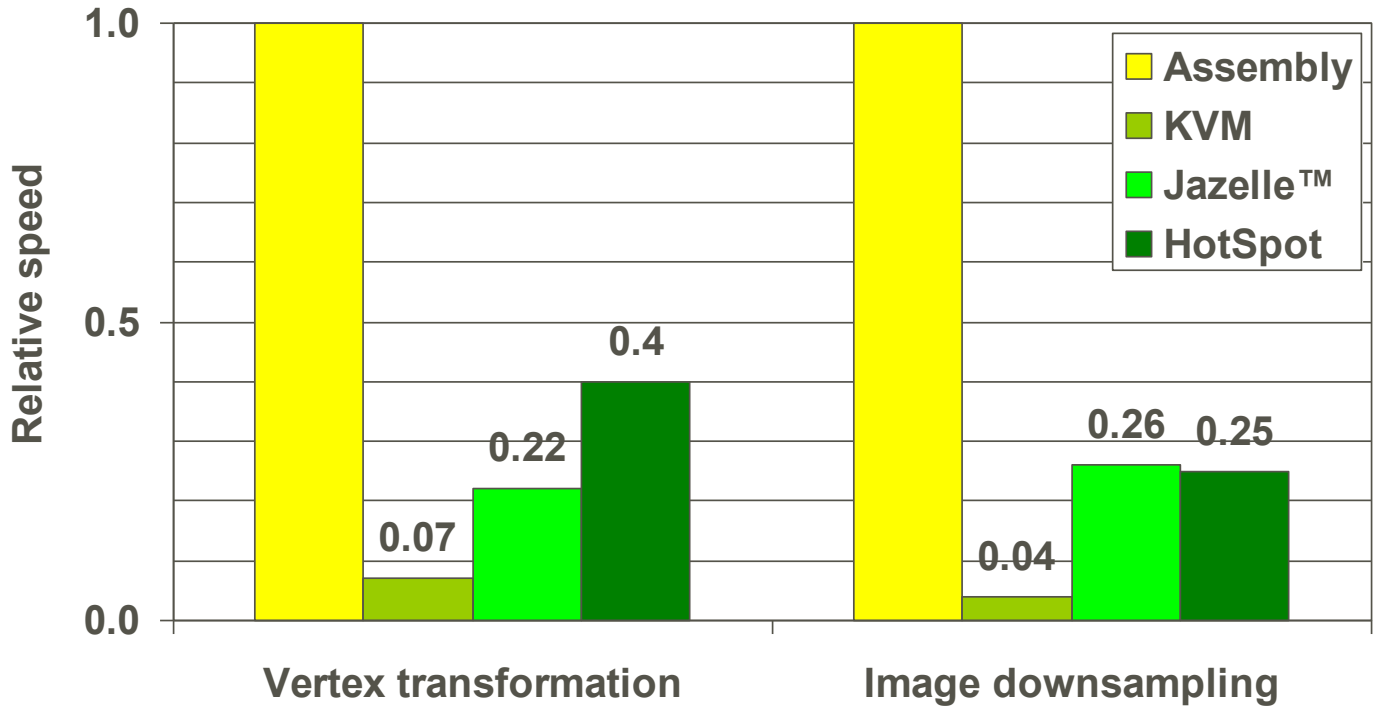
- Amazing 3D fighting! You can even see the movements on character's clothes!
- Motion captured animations to boost the gaming experience.

- Plus
- **Utilizing OpenGL ES 1.1**

What about Java?

On desktop new hotspot compilers are pretty good

- but on mobiles there's a clear difference between C and Java performance



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

Need a higher level API

A game is much more than just 3D rendering

- Objects, properties, relations (scene graph)
- Keyframe and other animations
- Etc. (game logic, sounds, …)
- Even if rendering was 100% in HW, total acceleration remains limited

A higher level API could help

- More of the functionality could be implemented in native (=faster) code
- Only the game logic must remain in Java

Java3D ES? No, M3G = Mobile 3D Graphics for Java

Java3D seemed a good starting point

- But "Java3D ES" didn't work out
- Java3D was designed for large-resource systems
  - Java3D distribution is ~40MB (~300x too big for us)
- Didn't really fit together with MIDP
  - a large redesign necessary

M3G (JSR 184), a new API (NOT mobile Java3D!)

- Nodes and scene graph
- Extensive animation support
- Binary file format and loader

Scene graphs from nodes

The tree encodes structure

- Data (vertices, textures, animation data, …) can be shared
- Nodes encode relative transformations and inherited alpha

World is the root

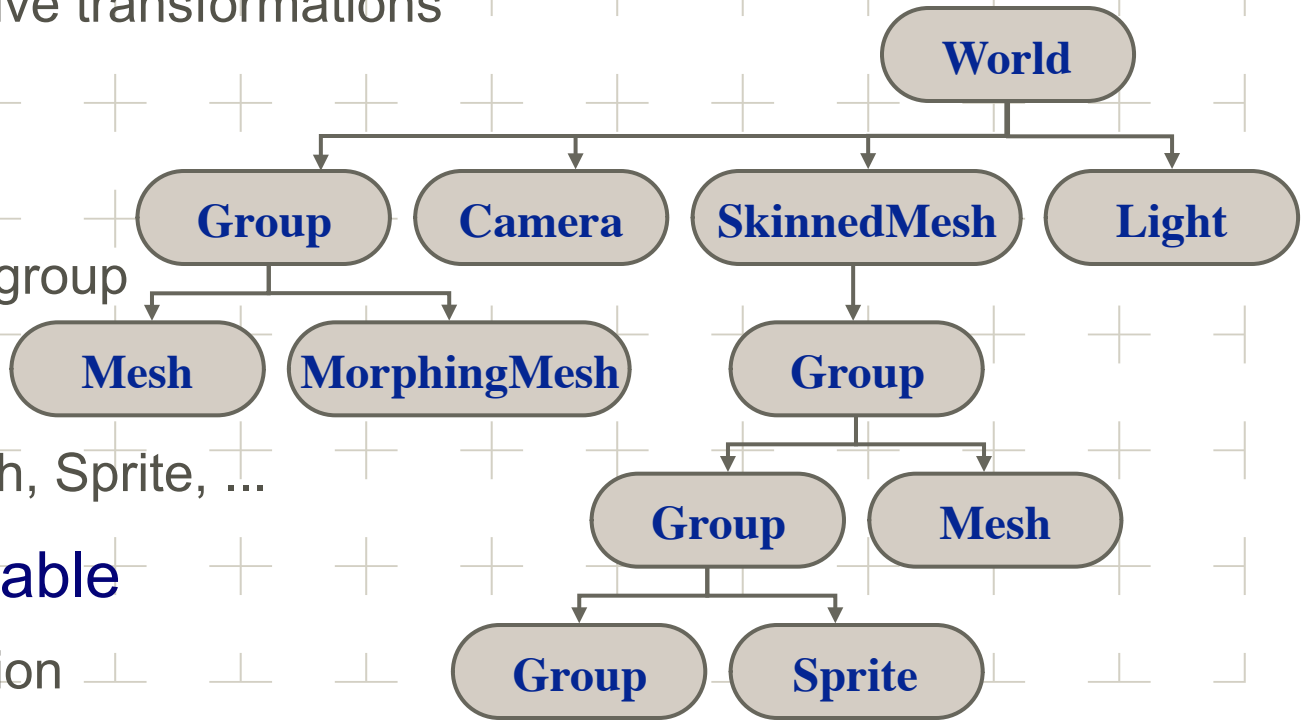
- A special case of a group

Other nodes

- Camera, Light, Mesh, Sprite, ...

Every property animatable

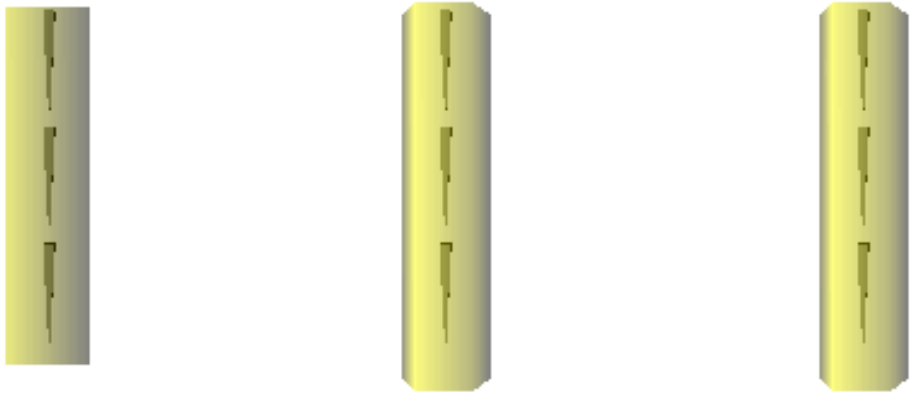
- Keyframe interpolation



Special meshes

SkinnedMesh

- For articulated motions
- Bones have weighted associations to vertices



MorphingMesh

- For unarticulated animations
- Base mesh, weighted interpolation towards / away from targets

Example M3G content

M3G 2.0

Still on-going

- may finish this year

Features

- still high level API
- backwards compatible
- basic block
  - evolution from M3G 1.1, on OpenGL ES 1.1 HW
- advanced block
  - requires OpenGL ES 2.0
  - ES 2.0 shading language

OpenVG – Low-level API for accelerated Vector Graphics

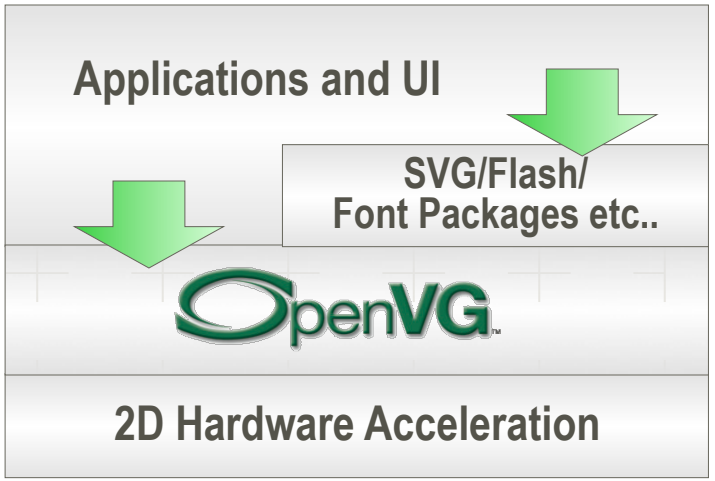
Vector graphics - basis of popular formats such as Flash and SVG

- Bezier curves - scaled and positioned at full quality - not polygon based

But 2D vector graphics historically run un-accelerated!

- Not effective on low-powered handset CPUs

OpenVG is the industry's first native Bezier acceleration API



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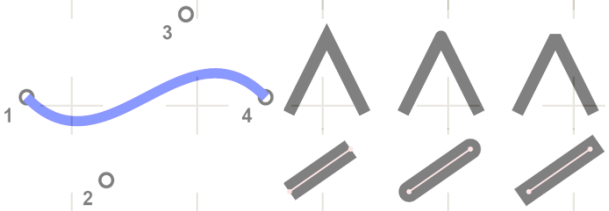
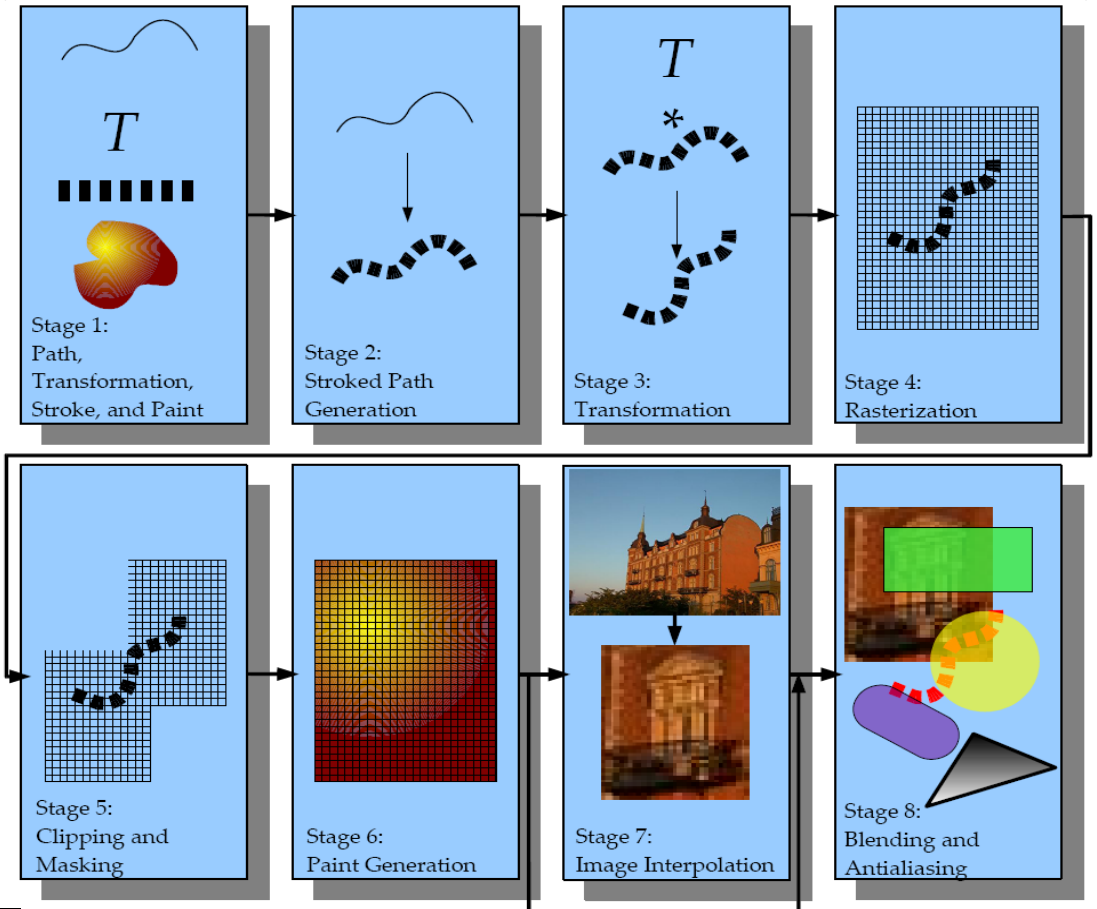
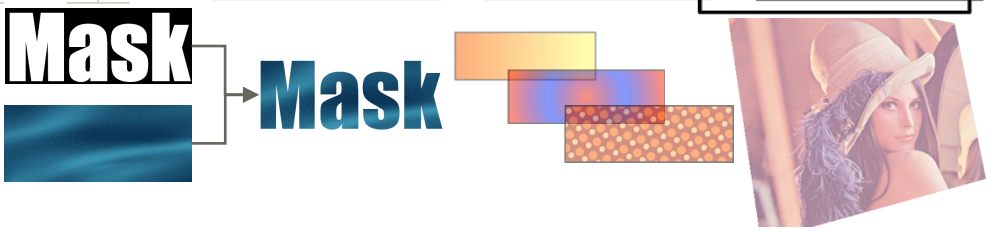
OpenVG Pipeline



- Define path, transformation, stroke, and paint
- Stroked path generation
- Transformation
- Rasterization
- Clipping and Masking
- Paint Generation
- Image Interpolation
- Blending & Antialiasing





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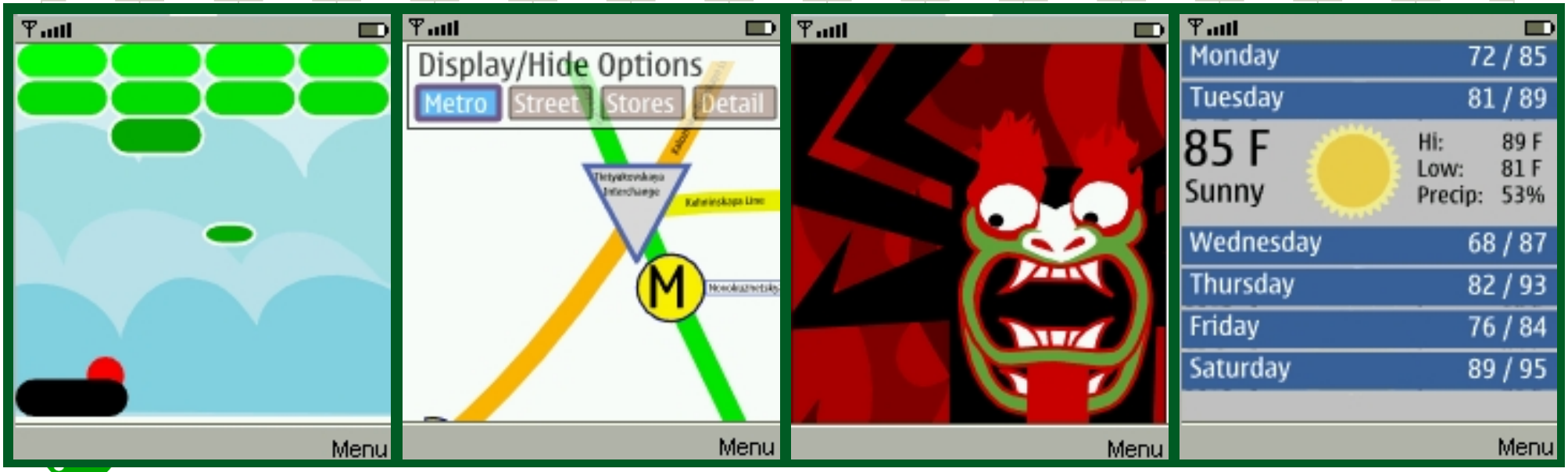
JSR 226: 2D vector graphics for Java

- Compatible with SVG Tiny 1.1
- Support XML / SVG Micro-DOM (subset)
- Two rendering modes
  - One-shot mode (Application control)
  - Playback mode (SVG 'Player')



Game, with skins Scalable maps Cartoon Weather info

JSR 287: 2D Vector Graphics for Java 2.0

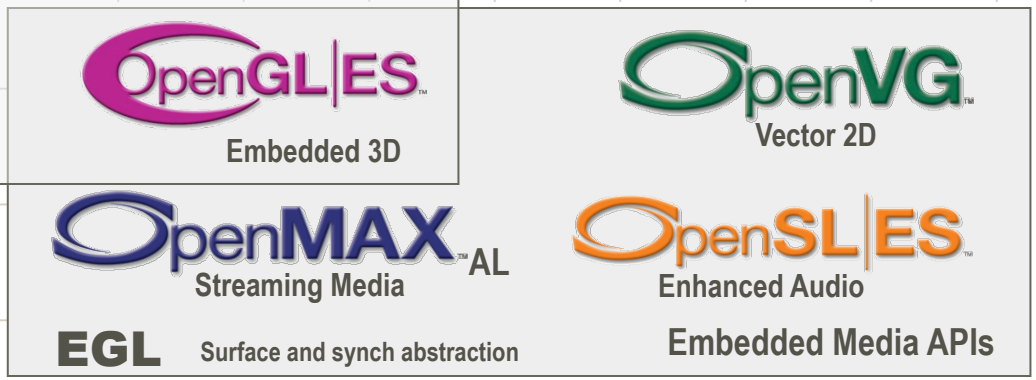
Features

- rich media support
  - embedding media such as audio and video inside SVG-mobile 1.2
- API to update rich media content over HTTP connection
  - that is, streaming
- complete Micro-DOM
  - for dynamic manipulation of SVG content

Khronos Media Standards

Dynamic Media **Authoring** Standards

Bridging 3D Authoring and Acceleration for advanced visual effects



Application Acceleration APIs

System Integration Standards

Nokia Research Center

Mobile HW offering

There's quite a bit out there

- many of them are already shipping
- here's just a quick overview of some solutions

Marketing performance figures in the following pages

- Scaled to 100MHz
- Usually tri/s means vtx/s, actual number of triangle setups is sometimes taken into account, sometimes not, some numbers estimated some measured, MHz vary, …
- So don't take the numbers too seriously

BITBOYS

Graphics processors

- **G12:** OpenVG 1.0
- **G34:** OpenGL ES 1.1
  vertex shader
- **G40:** [illegible]
  [illegible]
- Flipquad antialiasing
- Max clock 200MHz

ATI bought BB

Partners / Customers

- NEC Electronics
- Hybrid Graphics (drivers)

ATI IMAGEON 3D

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 [illegible] for Qualcomm

- [illegible] ES
- [illegible],10
- [illegible]deo
- [illegible] ES
- [illegible]ac
- [illegible]odecs, 3D audio

Partners, customers

- Qualcomm
- LG SV360, KV3600
- Zodiac

AMD bought ATI

ATI IMAGEON 3D

AMD Graphics IP

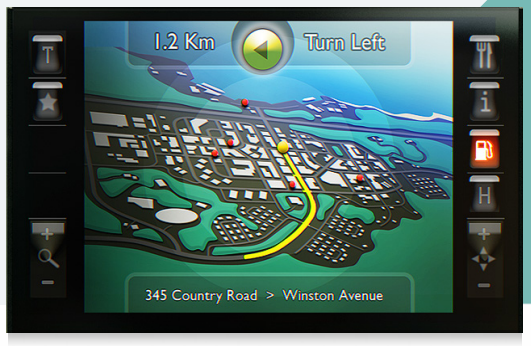
3D Processors

- AMD Z430 & Z460
  - Unified Shader architecture derived from the Xbox 360 Xenos core
  - OpenGL ES 2.0
  - OpenGL ES 1.1 backwards compatible
  - OpenVG 1.x

Vector Graphics Processors

- AMD Z160 & Z180
  - Native, high-performance OpenVG acceleration
  - OpenVG 1.x
  - 16 x antialiasing

All processors are designed to be combined to achieve native HW acceleration of both OpenGL ES 2.0 and OpenVG 1.x for unrivalled performance and image quality.



Falanx

- **Mali 110**
  - » OpenGL ES 1.1 + extensions
  - » 4x / 16x full screen anti-aliasing
  - » Video codecs (e.g., MPEG-4)
  - » 170-40[illegible]
  - » 2.8M T[illegible]
- **Mali 200**
  - » OpenG[illegible]
  - » 5M Tri / s, 100M Pix / s, 11 instr. / cycle
- **Partners / Customer**
  - » Zoran

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

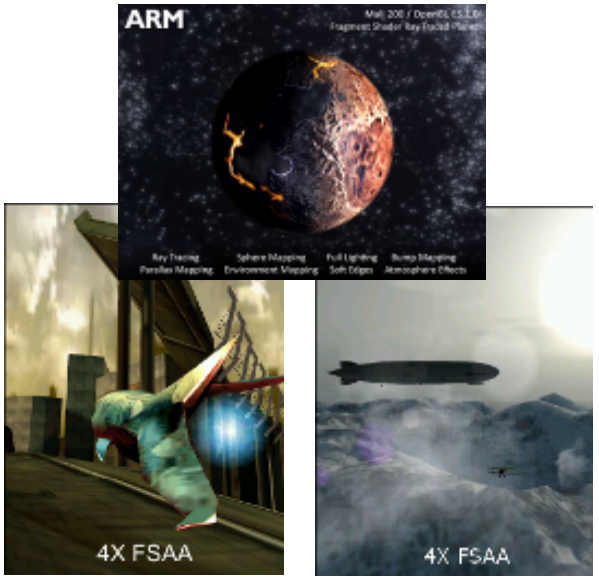
*available in Mali[illegible]Mali110V and Mali200V Configuration

ARM bought Falanx

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

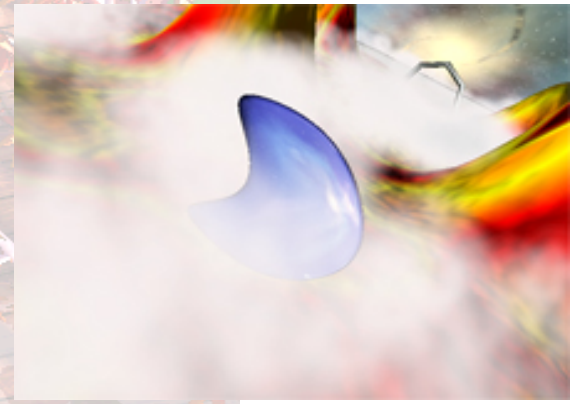
DMP Inc.

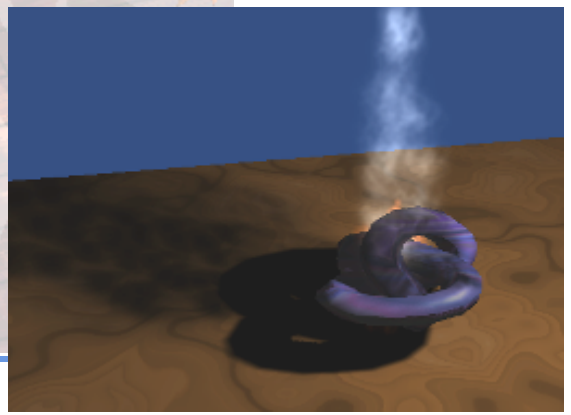
Visualize the future

- **PICA graphics core**
  - 3D Features
    - OpenGLES 1.1
    - DMP's proprietary "Maestro" shader extensions
      - **Very high quality graphics with easier programming interface**

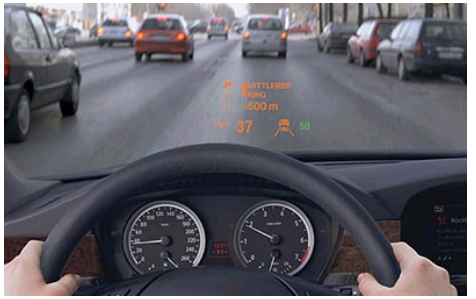
MAESTRO™ **Per-fragment lighting,**
- **Shadow-mapping,**
- **Procedural texture,**
- **Polygon subdivision (Geo shader), and**
- **Gaseous object rendering.**

  - Hardware Features
    - **Performance: 40Mtri/s, 400Mpixel/s@100MHz**
    - **Power consumption: 0.5-1mW/MHz**
    - **Max. clock freq. 400MHz (65nm)**





Fujitsu Graphics Controllers



Optimized for automotive environment

- Extended temp range (-40...+85degC or -40...+105degC)
- No external active or passive cooling required
- Long term availability (devices from 1998 still in full mass production!)
- Fulfills the latest qualification requirements from automotive industry
- Automotive network interfaces included on-chip
- Dedicated competence center in Munich for automotive graphics

Used in many major car brands for :

- Onboard navigation systems (2D and 3D)
- Cluster Instrumentation (incl. virtual dashboards)
- Rear seat entertainment systems
- Head-up displays
- Night vision systems

Also used today in :

- Flight instrumentation
- Marine displays
- Medical, etc...

Feature	This generation (in MP)	Next generation (tba)
Bandwidth	**~2 GB/s**	**~6 GB/s**
Performance	**~5MT/s ; 200Mpix/s**	**~10MT/s ; 500Mpix/s**
Graphic processing	**OpenGL ES 1.1**	**OpenGL ES 2.0 ; OpenVG**
# of video inputs	**2 video inputs**	**4 video inputs (up to HD)**
# of display outputs	**2 display outputs**	**2 display outputs with dual view option**

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

- **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

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

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

	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 SGX530 to SGX540.
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.

Z3D family

- Z3D and Z3D2 out in 2002, 2003
  - Pre-OpenGL ES 1.0
  - Embedded SRAM architecture
- Current offering Z3D3
  - 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

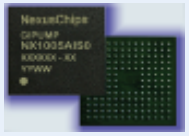
First mobile 3D HW?

Z3D Graphics Engine

NexusChips

3D Digital Innovation

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.

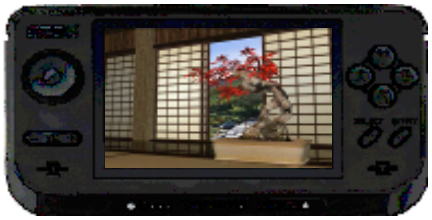
GiPump™ NX1007
; High end 3D graphics acc. for mobile
- OpenGL ES 1.1 + Ext. / GIGA / JSR184
- 12.5M poly/s, 200M pix/s @ 100MHz, ~SVGA display, PIP supports
- PND, PMP, game device, mobile device, etc.

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.

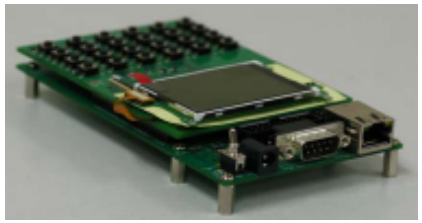
GiPump™ NX2001
; 3D Graphics enhanced multimedia processor
- OpenGL ES 2.0 / 1.1 Ext. / JSR184 / D3DM
- 10M poly/s, 200M pix/s @ 200MHz, ~SVGA display
- PND, PMP, game device, mobile device, etc.

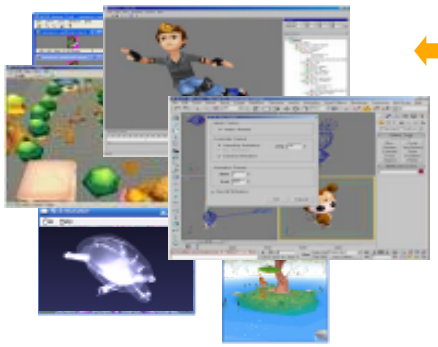
Service Solutions



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

New Wave Digital Paradigm

NVidia

- APX 2500 application processor
  - Single chip, Xbox-class experience
  - At less than 200mW
- Up to 750MHz ARM 11
  - MP Core, 256KB L2 Cache
- 47 Mtris/sec, 600 Mpix/sec
  - With typical early Z mix
- 45 FPS Quake 3 Arena
  - WVGA with 5x CSAA, 8x anisotropic
- Media Processing Hardware
  - 720P H.264 encode/decode
  - 12 Mpixel camera ISP
  - 100 hours audio on one battery
- Khronos media API stack
  - OpenGL ES 2.0 superset
  - OpenVG, OpenMAX, EGL
- Composition UI framework

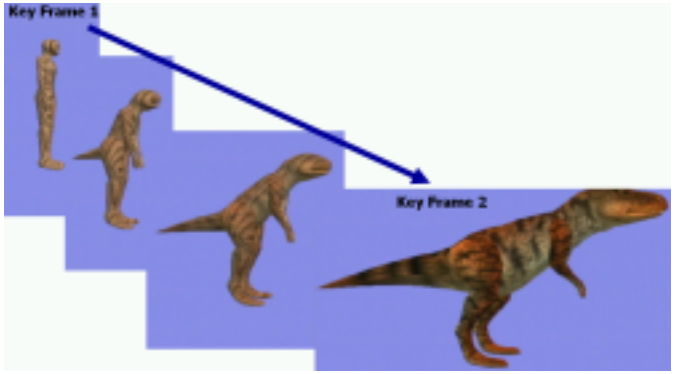
Sony PSP

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)

Media processing engine

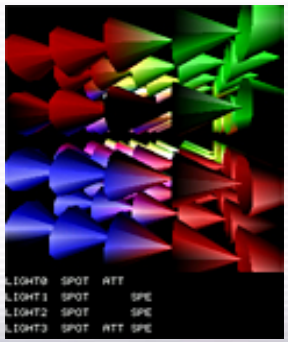
- H.264 (AVC) video up to 720x480 @ 30fps
- VME reconfigurable audio/video decoder



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

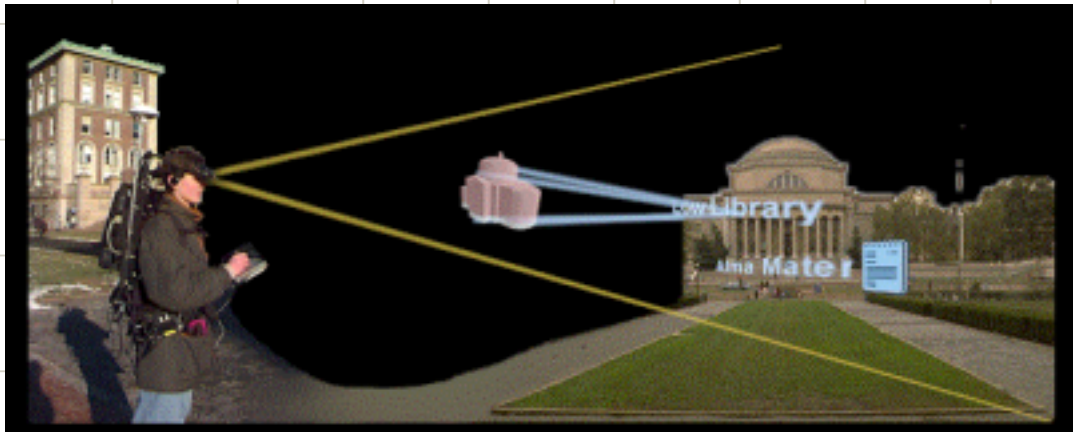
- OpenGL ES 1.1 & 2.0 and D3D 9.0
- Unified vertex & pixel shader
- Anti-Aliasing
- AXI/AHB interface
- GC500
  - 3 mm^2 die area in 65nm (1.8mm x 1.2mm)
  - 10 MPolygons/s and 100 MPixel/s at 200 MHz
  - 50mW GPU core power
- Scalable solution to 50 MPolygons/s and 1 GPixels/s (GC1000, GC4000)
- **Silicon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

VIVANTE

Mobile Imaging:

Input

Mobile Augmented Reality



Combine location, graphics, real-time image processing

Used to require a large backpack

- now all that functionality is available in a mobile phone!

Applications

- Finding and advertising location-based services (LBS)
- Tourist guide, navigation
- Real-world gaming, geo-caching / treasure hunts

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Mobile Augmented Reality (with Prof. Bernd Girod)

From an image…

…to information

Snapshot Mode

GPS

Memorial Church

Server

Image matching

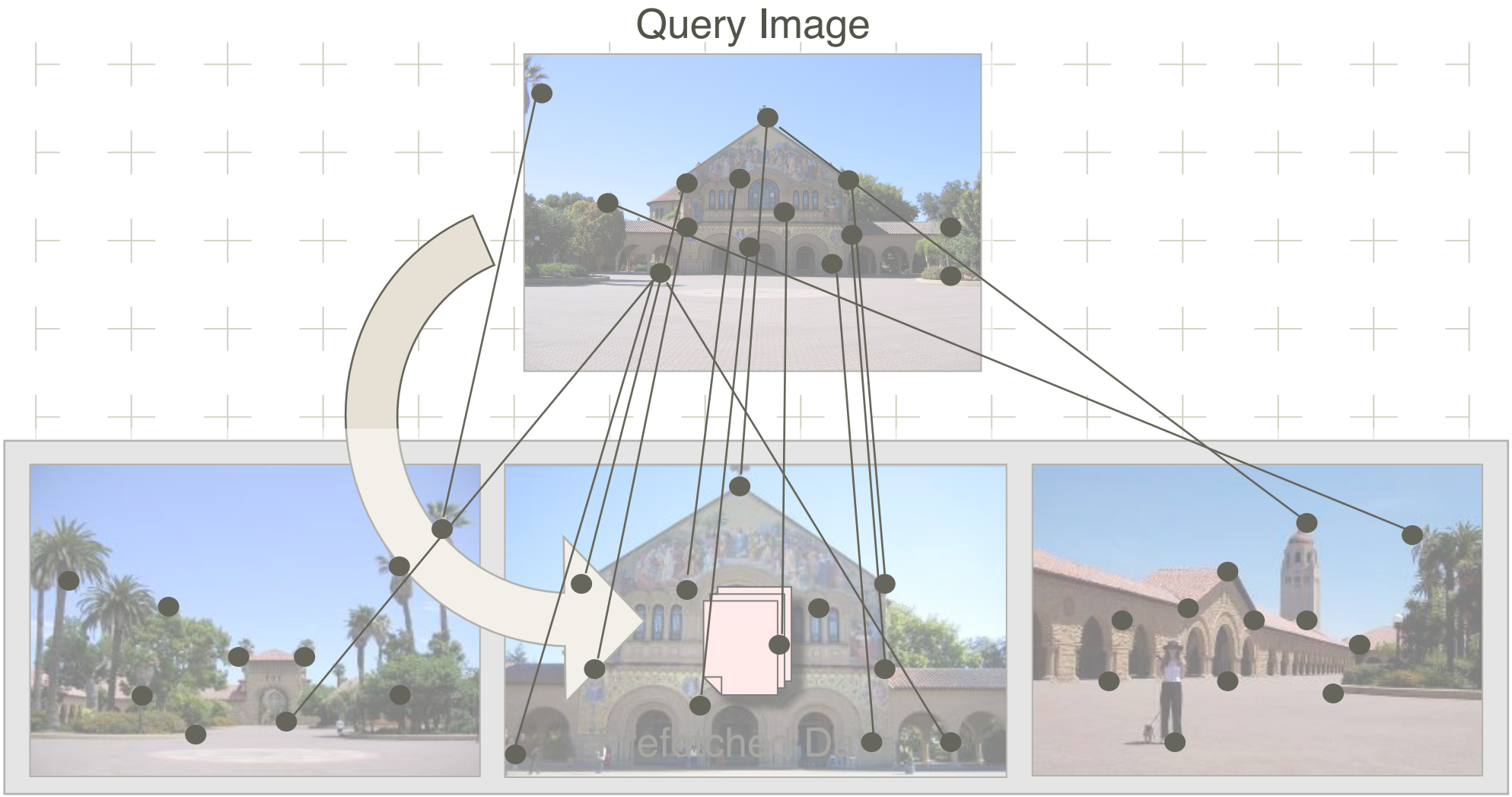
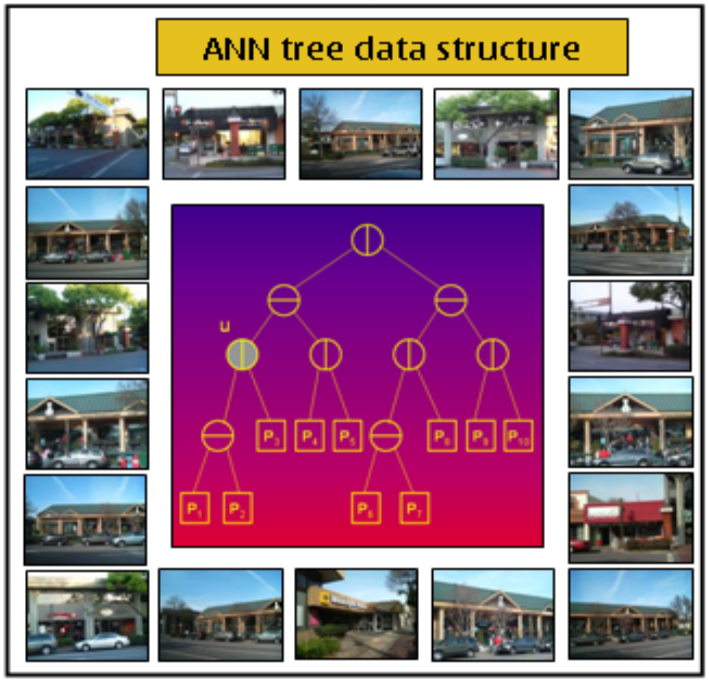


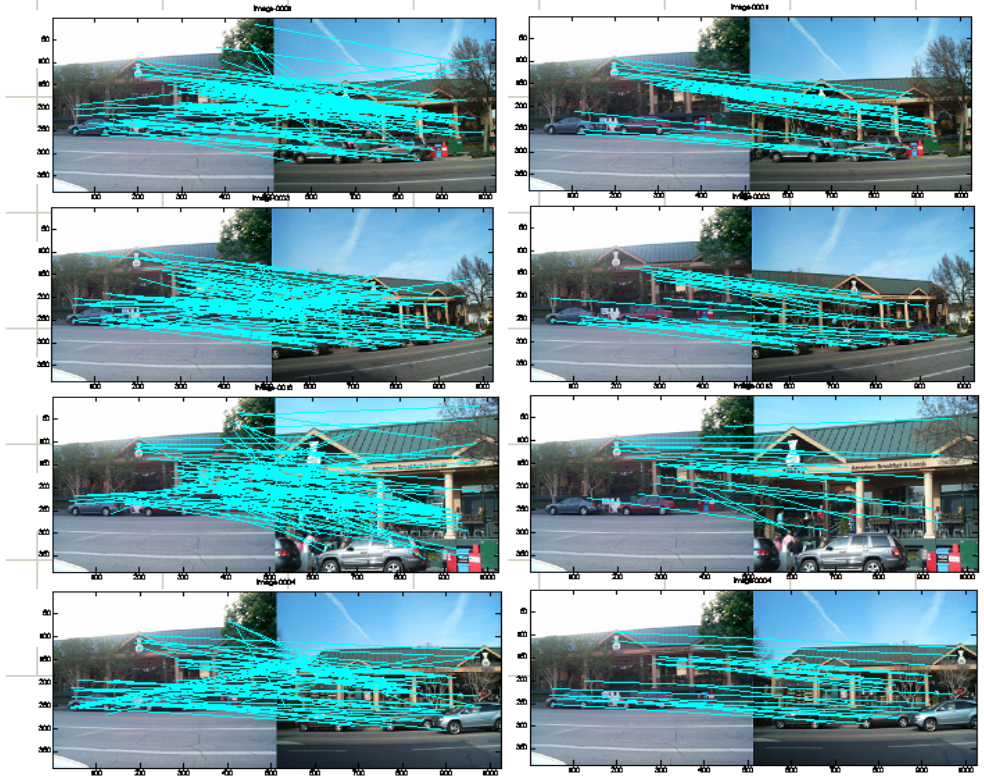
Image Ranking with Approximate Nearest Neighbor (ANN) Tree



Feature matching with ANN

Outlier Rejection

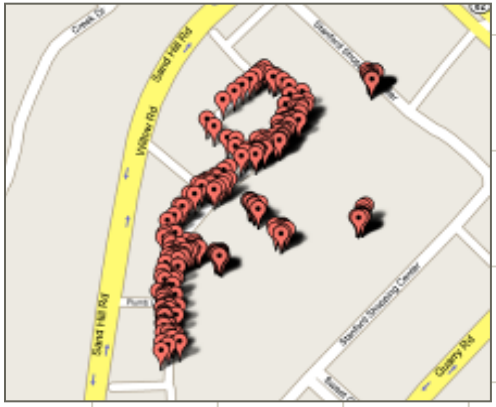
Image Ranking



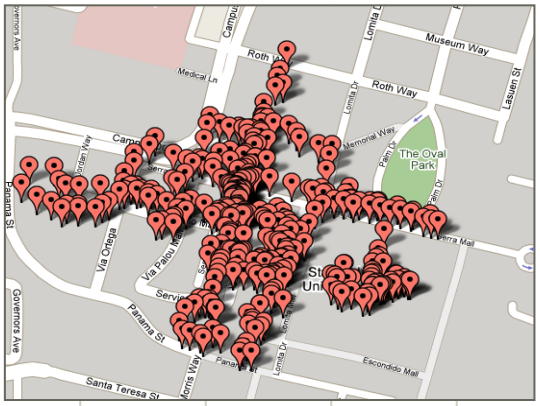
Nokia Research Center

NOKIA

Santa Cruz Ave, Menlo Park, CA



Stanford Shopping Mall



Stanford Campus

Nokia Research Center

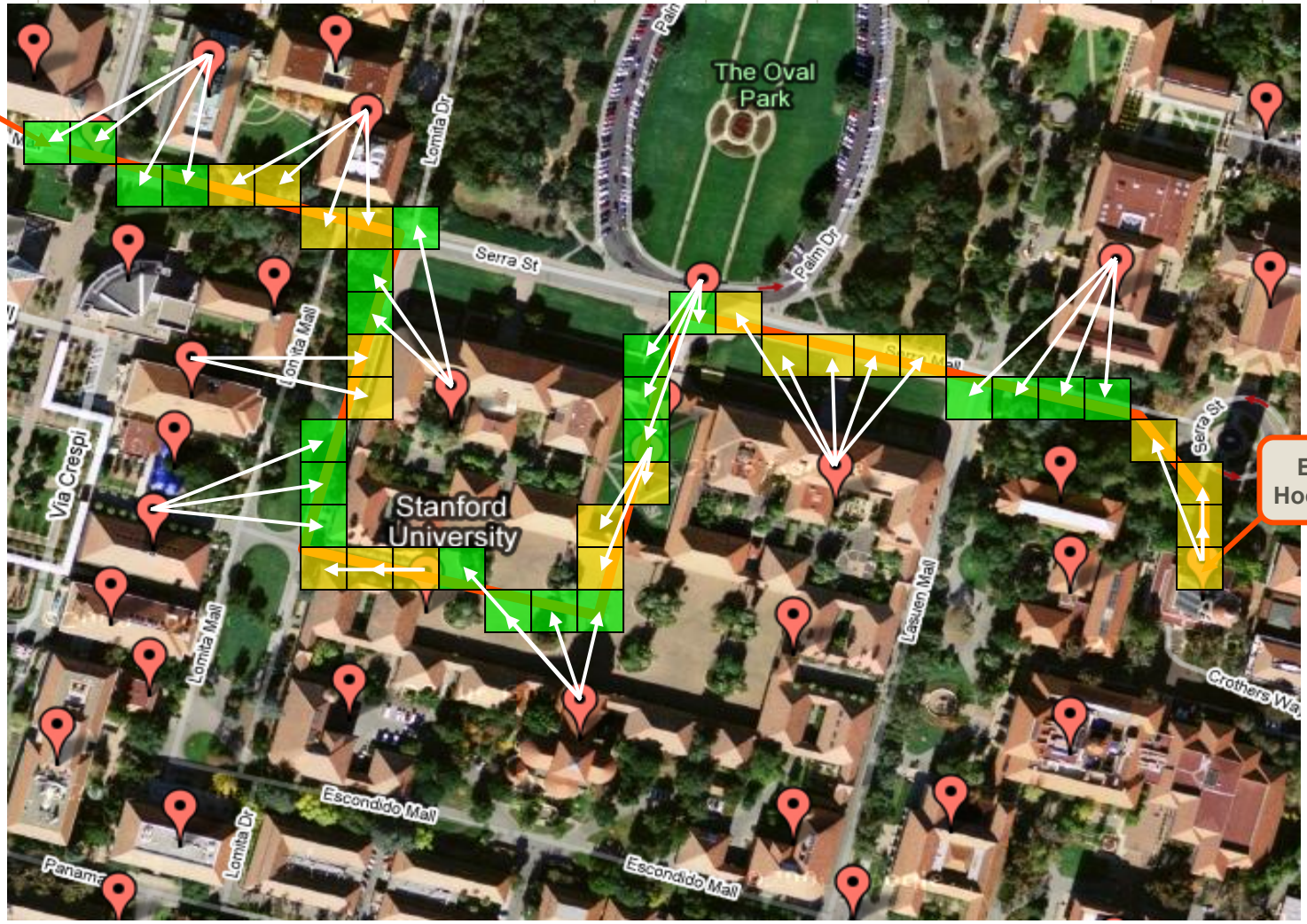
NOKIA

Other Usage Models

Movie Posters

Point & Wine

Visual Navigation



Goal: Find Direction from Gates Building to Hoover Tower
Hint: Maximize the number of tourist attractions

Nokia Research Center

NOKIA

Visual Navigation

Start Point Gates Bldg.

Locate Gates Bldg. (shown in the picture). Additional landmark info: Gates Bldg.

Gilbert Bldg.

Turn Right 90 degrees, walk for 120 meters towards Gilbert Bldg. (shown in the picture).

Herrin Hall

Walk forward for 200m until you pass on the left Herrin Hall (shown in the picture).

Main Quad Math Corner

Turn right 90 deg, walk for 100m towards Main Quad's Math Corner (shown in the picture).

Additional historical Info: Main Quad Math Corner

Physics and Astrophysics

Walk straight for 100m until you pass Physics and Astrophysics Bldg. on the right.

Moore Material Research

Walk straight for 50m until you pass Moore's Material Research Bldg. on the right.

West Gate

Turn Left 90 degrees, walk for 120 meters towards West Gate (shown in the picture).

Memorial Church

Walk straight for 100m until you pass memorial Church (shown in the picture) on the left.

Additional historical Info: Memorial Church

Memorial Court

Walk towards and across the arch dividing Memorial Quad and Main Quad.

Additional tourist Info: Burghers of Calais

The Oval

Walk across Memorial Court towards the Oval.

End Point Hover Tower

After exiting Memorial Court turn right and walk for 500m towards Hoover Tower.

Additional historical Info: Hoover Tower

Nokia Research Center

NOKIA

MAR Future Directions

Higher Resolution Images

- Might want to use 4x number of pixels for better recognition rate
- Performance scales roughly linearly with number of pixels

Real-Time Feature Tracking

- Get the current system working at 10 fps would qualify
- Might want to modify algorithms to make tracking more efficient
- Use different features, image alignment, image regions

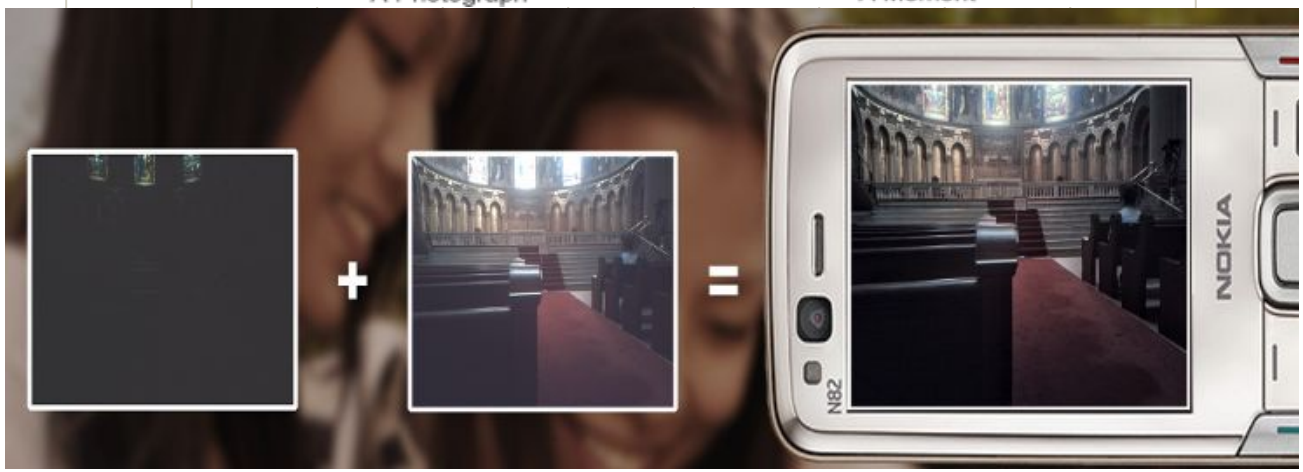
3D Graphics Overlays

- Perspectively-correct 3D graphics overlayed in video stream
- 3D world models, 3D mapping information, hyperlinks following physical objects
- Combines robust feature computation with real-time tracking, 3D graphics rendering
- Needs to have Camera, CPU and GPU tightly working together

Camera 2.0 (with Prof. Marc Levoy)

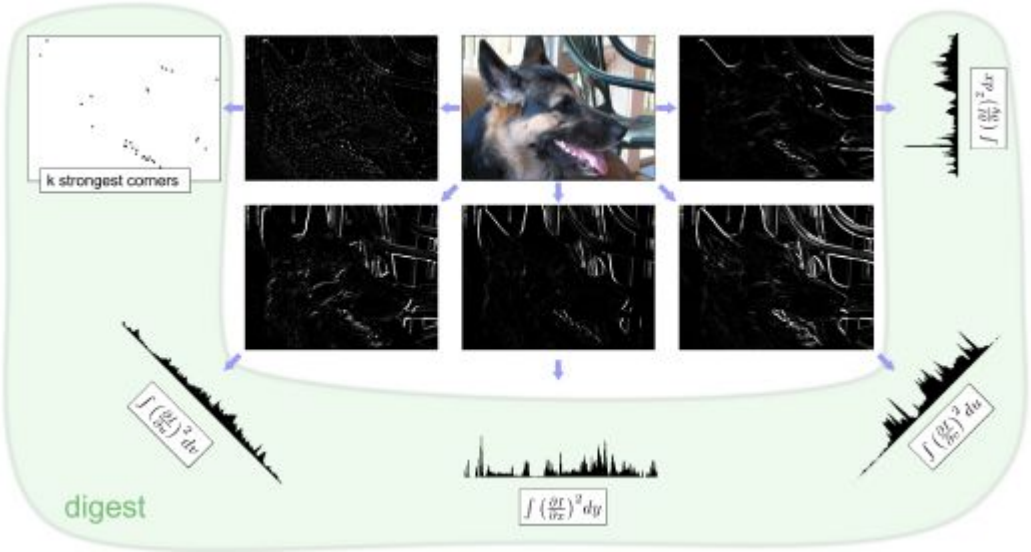
Computational photography

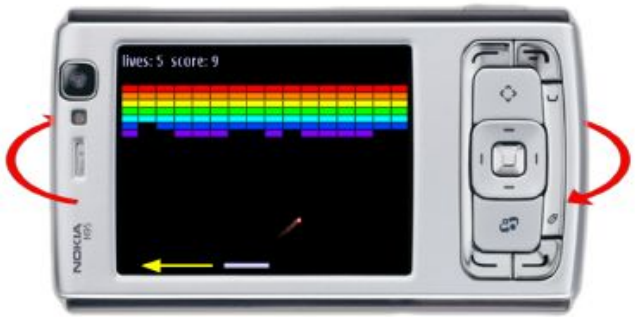
- takes several input images
- combines them into a new image that is better / interesting / cooler / etc. than any of the individual inputs

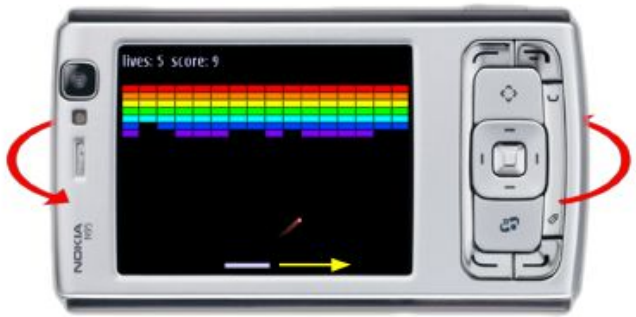


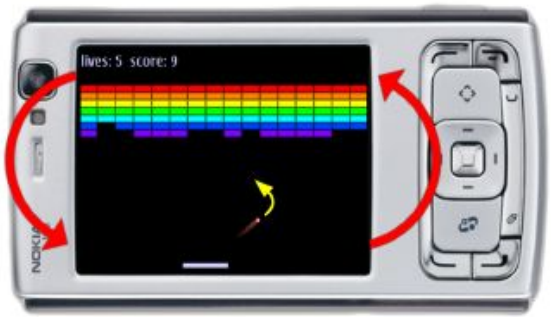
Nokia Research Center

Real-time viewfinder alignment (Andrew Adams)









Interactive mobile panorama

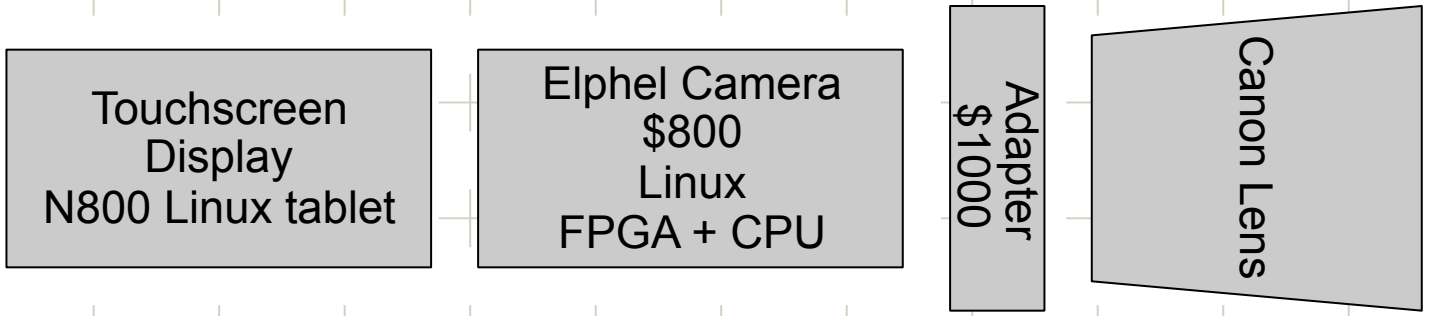
Automatic capture

- based on camera motion tracking (2D)
- High resolution images for panorama stitching

On-site interactive evaluation of panorama result

- Guided re-capture of problematic areas

“Frankencamera” (Andrew Adams, Eddy Talvala)



Allows more control than is currently available on cell phone cameras

- experiment on things feasible on mobile camera 3-5 years from now

Elphel: http://wiki.elphel.com/index.php?title=10353

Adapter: http://www.birger.com/Merchant2/merchant.mvc?Screen=ef232_home

File Edit View History Bookmarks Tools Help del.icio.us

http://graphics.stanford.edu/courses/cs448a-08-spring/

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CS 448A - Topics in Computer Gr... http://cto.nokia.com/

CS 448A - Topics in Computer Graphics

Computational photography on mobile computing platforms (cell phones)

This Nokia N95 smartphone has a 5-megapixel camera with Carl Zeiss optics. The phone also contains a 2nd video camera and 5 radios: cell, WiFi, Bluetooth, GPS, and FM!

The cell phone at left took this picture, shown here at reduced resolution. Can your point-and-shoot camera do any better? Here is an album of nature pictures taken by the N95, and one of the Stanford campus.

The boat harbor doesn't belong in this picture. It was found on the Internet and inserted into the photograph. For details, see this SIGGRAPH 2007 paper.

By inserting a microlens array into a handheld camera, one can create a plenoptic camera, which can record a light field in a single snapshot.

The photographs produced by this camera can be refocused after they are captured. Click above for an example of digital refocusing.

Quarter
Spring, 2008

Units
3-4 (+/NC or letter grade)

Time
Tue/Thu 2:45 - 4:00

Place
392 Gates Hall (graphics lab conference room)

Instructors
Marc Levoy, Andrew Adams, Kari Pulli (Nokia)

Office hours
Marc Levoy: Tue/Thu, 11:00 - 12:15
Andrew Adams: TBA

Prerequisite
Any introductory course in computer graphics or computer vision

Televised?
No

Tue, April 1	Introduction (Marc and Andrew)
Thu, April 3	The art of photography (Marc)
	Mobile platform technology
Tue, April 8	Cell phone hardware (Kari)
Thu, April 10	Call phone software (Kari)
	Digital camera technology
Tue, April 15	Image sensors (guest lecture by Eddy Talvala)
Thu, April 17	Optics for photography (Marc)
Tue, April 22	Focusing, metering, and other in-camera systems (Andrew)
Thu, April 24	*Discussion of research papers*
	Computational photography algorithms
Tue, April 29	Computer vision for mobile platforms (alignment, pose estimation, mosaicing) (Andrew)
Thu, May 1	Multi-image methods (joint X, bilateral filtering) (Andrew)
Tue, May 6	High dynamic range imaging, tone mapping (Kari)
Thu, May 8	*Students present project ideas*
Tue, May 13	Multi-aperture and coded aperture imaging, related scientific imaging techniques (Marc)
Thu, May 15	Computational illumination (flash-noflash, structured illumination) (Andrew)
	Light field imaging
Tue, May 20	Plenoptic functions and light fields (Marc)
Thu, May 22	Geometry-assisted light fields, passive and active shape reconstruction (Marc)
Tue, May 27	*Discussion of research papers*
Thu, May 29	Debate: what limits should society place on ubiquitous sensing?
	Endgame
Tue, June 3	*Project presentations (2:30pm - 5:30pm)*
	Writeups due Friday, June 6

UC Santa Cruz course on mobile imaging (Prof. James Davis)

Supercub RC Airplane

FM Link

Radio Control

Hig

Standard Imaging APIs?

Standard APIs / HALs have been useful for graphics

Still imaging doesn't have anything like OpenGL

- is there real need for that?
- would it be camera – image pipe, 2D image processing lib, both?
- work at Khronos starting

Summary

Mobile graphics key enablers are there

- good standards: OpenGL ES, M3G, and others
- HW acceleration

Mobile imaging is a fertile research area

- exploit tech enablers
  - camera, display & graphics, positioning, connectivity, …
- and of course the mobility: always-on, always-with-you
  - the best picture is the one you actually took
    - not the one you might have if you just had your DSLR with you

Acknowledgements

Nokia graphics standardization guys

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Mobile 3D course co-organizers (EG, SIGGRAPH)

· Tomi Aarnio, Mark Callow, Ville Miettinen, Robert Simpson, Jani Vaaral

Khronos & JCP graphics community

Nokia gaming guys

· Peter Nielsen, Patric Ojala, Jani Vaarala, …

Book co-authors

VCUI team

· Wei-Chao Chen, Dean Eckless, Jiang Gao, Natasha Gelfand, Radek Grzeszczuk, Marius Tico, Ramakrishna Vedantham, Shawn Wang, Yingen Xiong

· + alumni + interns + colleagues + …

Academic partners

· Bernd Girod, Vijay Chandrasekhar, Gabriel Takacs

· Mark Levoy, Andrew Adams, Eddy Talvala

· Gaetano Borriello, Harlan Hile

· James Davis, Leo Guibas, …

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