QUALCOMM®

Digital Signal Processing Applications for Mobile Computing Devices

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Challenges for
Smartphones

DSP Enables Today's Most Popular Mobile Use Cases

Audio and Speech
Processing

DSP for Mobile Speech and Audio

Past: Playback, Record and Audio Post-Proc	**Today**: Speech Post-Proc and CE Audio	**Tomorrow**: What's Next
▪ Voice processing for mobile devices with standards-based codecs	▪ Increasing demand for ambient and uplink noise cancellation	▪ Skype-enabled and WB/Super-WB Voice ("HD Voice")
▪ Music playback in various formats in low-power mode	▪ Advanced multi-channel formats as found in consumer electronics and PCs (Dolby and DTS)	▪ Enhanced UI controlled by voice
▪ Audio post-processing from wide ranging sources		▪ Concurrency—audio anytime, anywhere, with anything

DSP Acceleration Enables Competitive Differentiation by Increasing and Freeing Up CPU Performance as Well as Enabling More Audio Effects

DSP Audio Processing Applications
Powerful DSP for Low Power and Highly Concurrent Processing

Low-Power Audio + Concurrency	Multi-Mic Speakerphone + Echo Cancellation	Gaming Audio with Ringtone and Music over Bluetooth

In-Call Music

MIDI Ringtone Alert for an Incoming Call (Call Waiting)

Multi-Mic Speakerphone

Checking Emails (UI Key Beeps)

MIDI Ringtone Alert for Incoming Call (Call Waiting)

Stereo Music over Bluetooth

Game Sounds to Both Handset Speakers and BT headsets

MIDI Ringtone Alert for Incoming Call (Call Waiting)

Enhanced Speech with WB Codecs and Multi-Mics

Circuit-Switched (3G), VoIP, VoLTE

Wideband Codecs

Doubles Voice Bandwidth

HD Voice

=
Wideband Speech Codecs +
Noise Cancelation

Noise Cancelation

Multi-Mic Technology Improving
MOS Score

Customers make more, or longer, calls with HD Voice.
Surveys confirm that customers place a high value on HD Voice.

DSP for Surround Sound (SRS®, Dolby®) Processing

- Expanded sound image and richer bass from mobile device speakers

- Create 5.1 multichannel audio experience from stereo or composite Lt/Rt content on any stereo headset

- Convert device audio to 5.1 Dolby Digital signal, enabling playback through your home theater system

- Suppress interference, enhance dialogues, and maintaining consistent, clear sound levels

DSP Acceleration Helps Optimize Performance and Deliver Lower Power

Digital Signal Processors
Heterogeneous Processing

The Immersive Use of Digital Signal Processing
Everything Mobile, Everything Interactive, Everything Clear

Communications

Augmented Reality
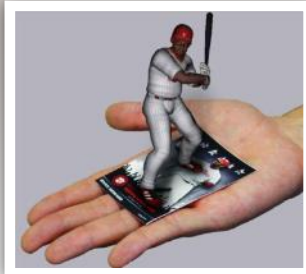
High Definition Audio

Object Recognition

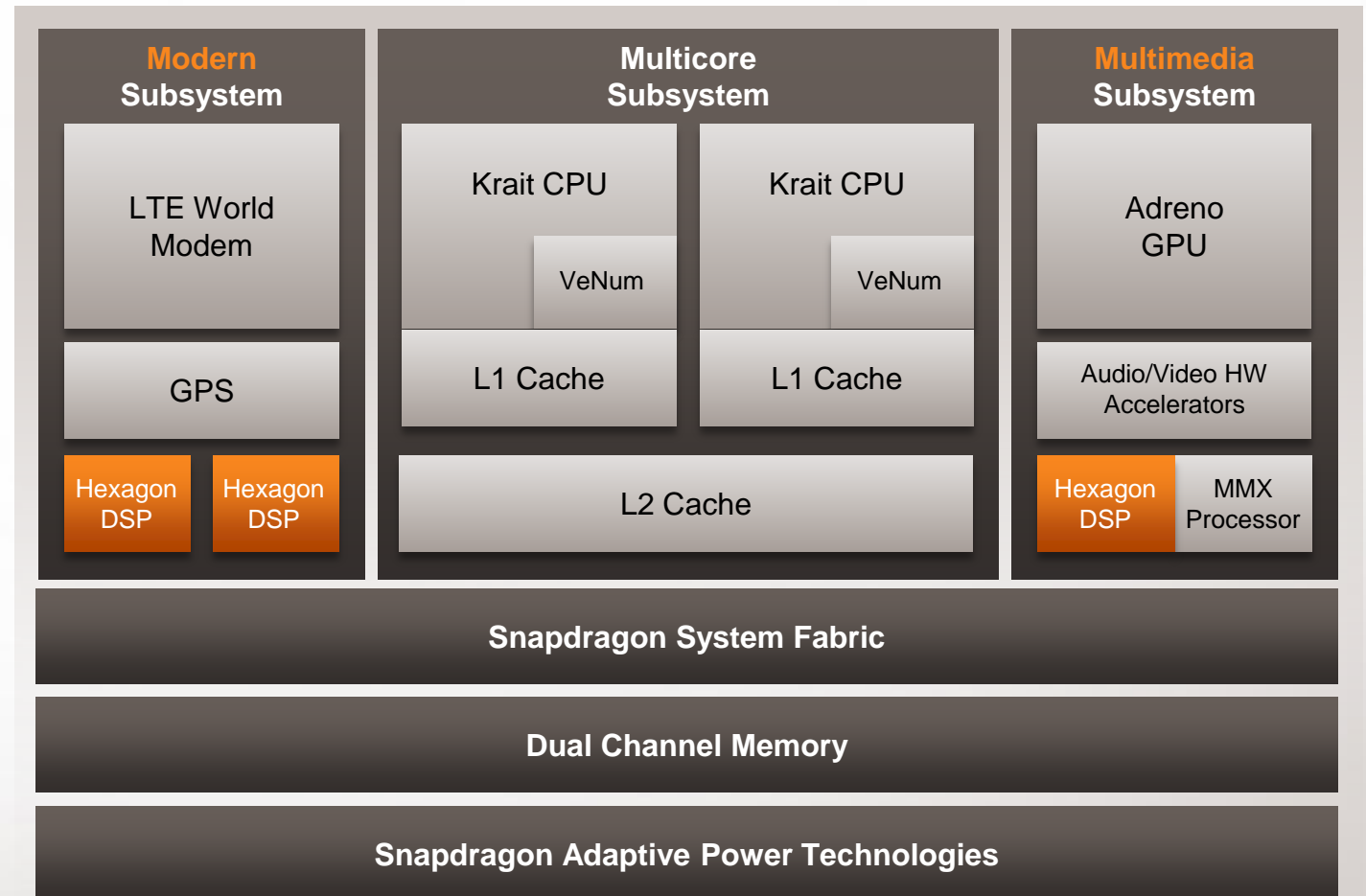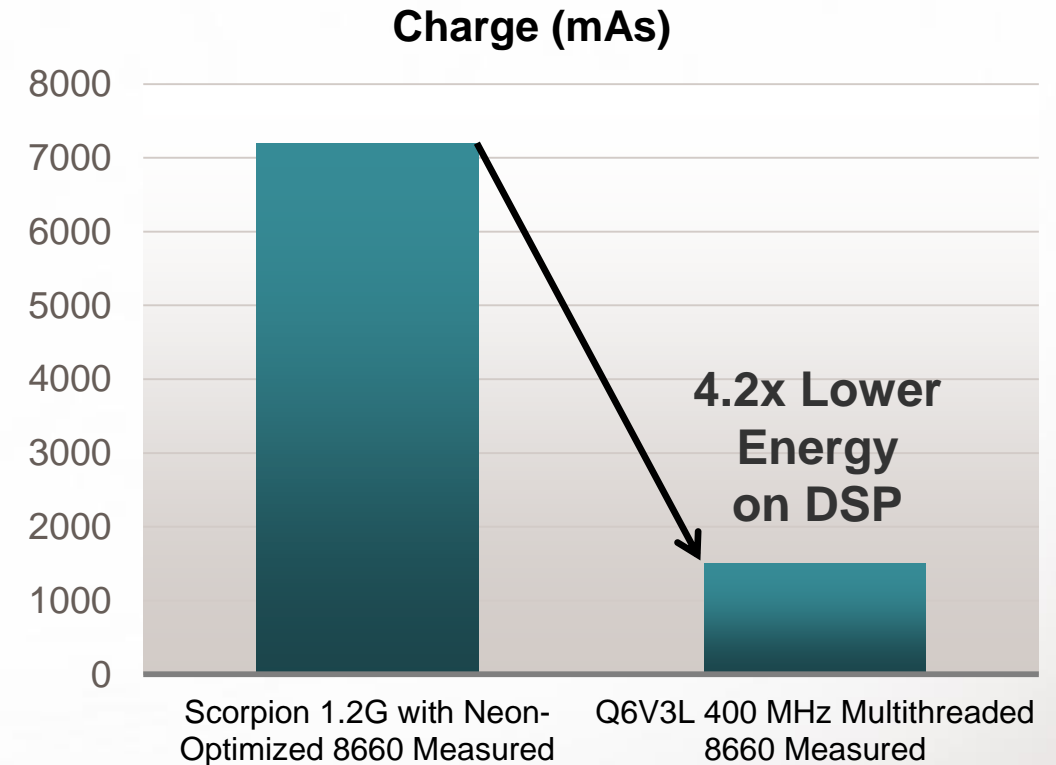**Gestures**

Sensor Processing

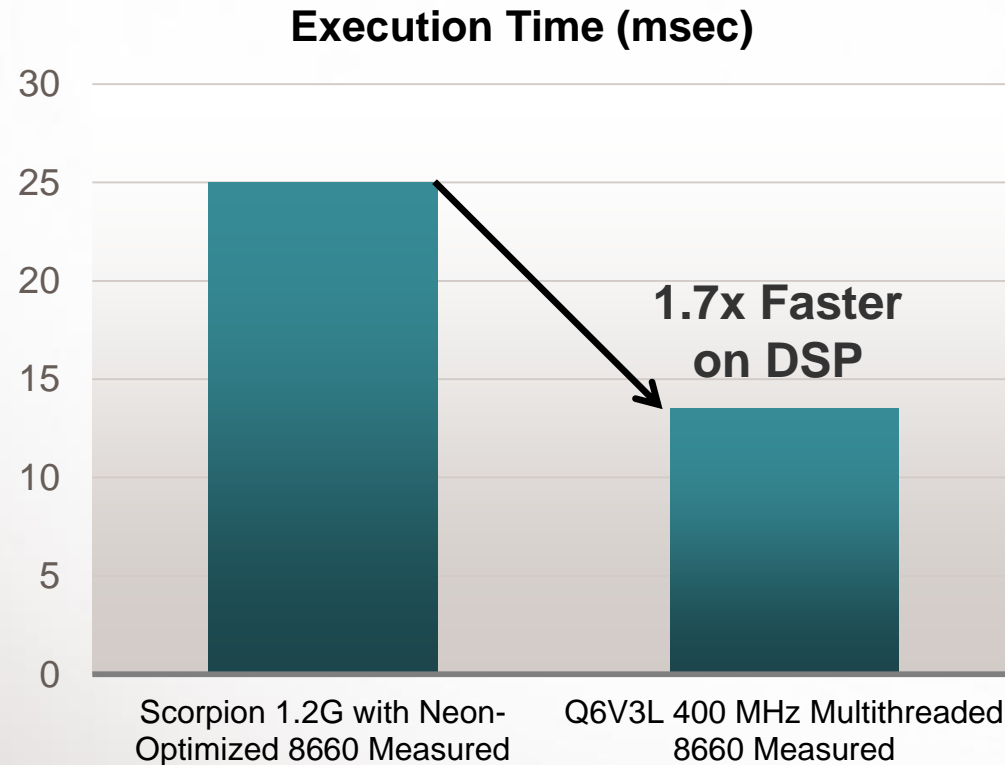**Image Processing**

Qualcomm Hexagon™ DSP

Robust Capability + Superior Power Efficiency

- **Optimal mix of DSP and CPU functions**
  - Adding control flow and scalar math to classic DSP functionality
  - Compiler-friendly ISA for robust tools (efficient C/C++ code)

- **Efficient and low power performance of tasks**
  - Communications
  - Audio playback
  - Audio effects
  - Noise cancellation
  - HD voice
  - Video functions
  - 2D to 3D auto-convert
  - Augmented reality processing

Snapdragon™ S4: MSM8960 Block Diagram

Augmented Reality Feature Detector

Execution Time (msec)

Charge (mAs)

1.7x Faster on DSP

4.2x Lower Energy on DSP

Scorpion 1.2G with Neon-Optimized 8660 Measured | Q6V3L 400 MHz Multithreaded 8660 Measured

- Used Fluid 8660 with Blur platform build 1.2
  - Kernel version 2.6.35.11-perf mharidev@blur-sys-srv4 #1
  - Build number msm8660_surf-eng 2.3.3 GINGERBREAD mharidev.22ms_33ms_CCCVCS_06_24_11
- Power measured with QEPM

Camera Imaging

DSP in Mobile Imaging

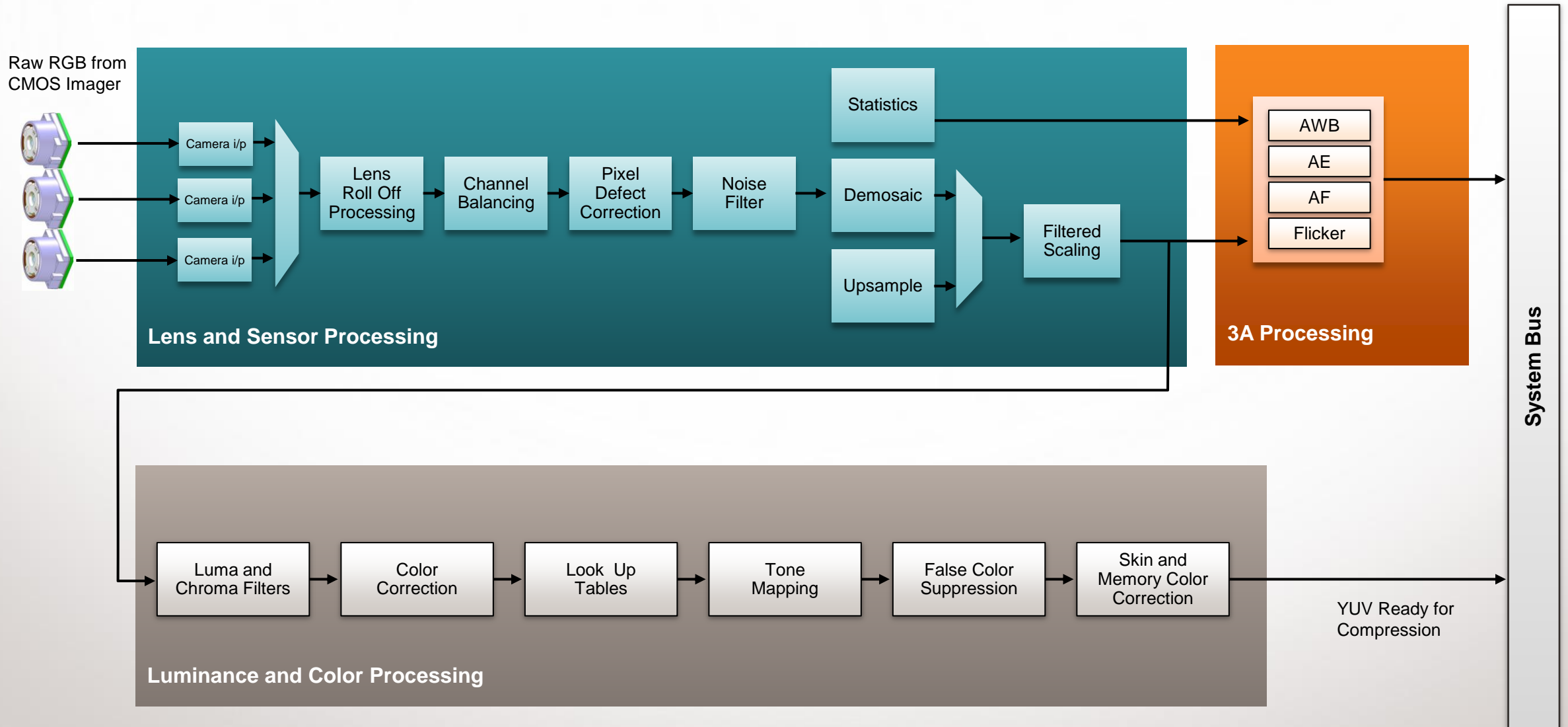| Capture	Today: Process/Edit	Tomorrow: Computational Camera
▪ Signal processing to convert CMOS Imager raw bayer RGB to YUV ▪ Mostly executed in dedicated logic for fast shot-shot throughput and low-power	▪ Variety of noise reduction algorithms ▪ Post processing/ editing ▪ New imaging codecs coming (i.e. JPEG XR) ▪ High dynamic range ▪ CV primitives	▪ Multiple cameras ▪ Array of Cameras ▪ Closer coupling of ISP and GPU

Image Signal Processor (Capture): Key DSP-Intensive Blocks

Raw RGB from CMOS Imager

Lens and Sensor Processing

Camera i/p → Camera i/p → Camera i/p → Lens Roll Off Processing → Channel Balancing → Pixel Defect Correction → Noise Filter → Demosaic / Upsample → Filtered Scaling

Statistics

3A Processing
- AWB
- AE
- AF
- Flicker

Luminance and Color Processing

Luma and Chroma Filters → Color Correction → Look Up Tables → Tone Mapping → False Color Suppression → Skin and Memory Color Correction

YUV Ready for Compression

System Bus

Today: DSP Image Processing Applications
Powerful DSP for Image Processing and Editing

Supporting User and OEM Preferences for Different Noise Reduction Algorithms	**Computer Vision Libraries**	**Image Codec Flexibility High Dynamic Range**

Noise Reduction Off   Noise Reduction On

Add Image Blur

HDR Photography

webp   **JPEG XR**

Tomorrow: Computational Camera

Image Processing with Heterogeneous Cores: GPU, DSP, CPU via OpenCL, OpenGL APIs

OpenGL

OpenCL

Camera Special Effects (FX)—
Render Photos as Individual Textures
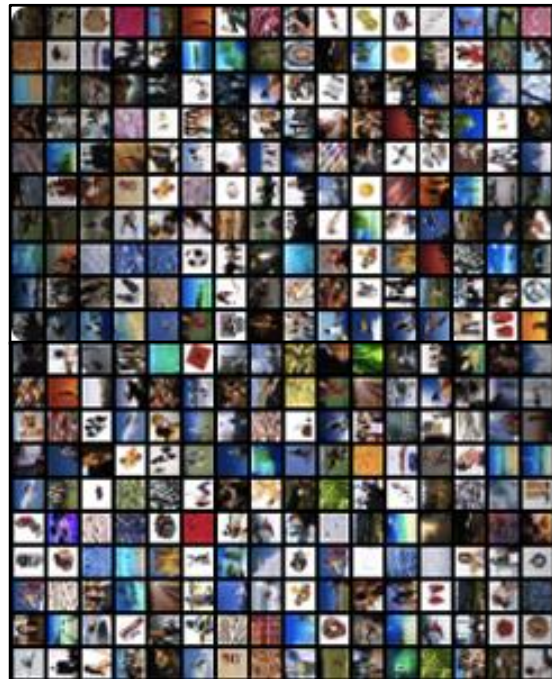
Computational Camera/
Multi-Camera Array Processing

Gestures

Gesture Control Use Cases

No-Look (<1 ft)	Touch-Free (<1 ft)	Lean Back (< 5ft)	Full Body (> 5 ft)
▪ Smartphone ▪ Embedded Car	▪ Smartphone/Tablet ▪ Embedded Car	▪ Tablet ▪ Embedded Car	▪ Set Top Box ▪ Embedded TV

- Driving
- Working Out
- Desktop
- Belt holster

- Mounted
- Desktop
- Driving

- Airplane
- Couch
- Lying in bed
- Kitchen
- Back Seat of Car

- Living Room

Gesture: DSP Enabling Strategies

Feature Detection	Motion Detection	Feature Tracking
Hand Pose Detection	Swipe Detection Optical Flow	Feature-Based Engagement Gesturing
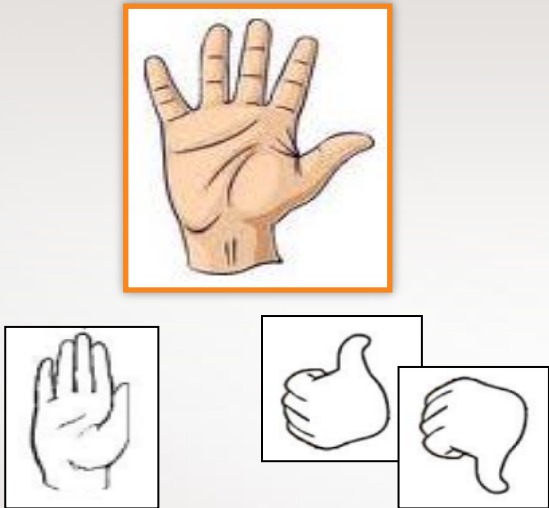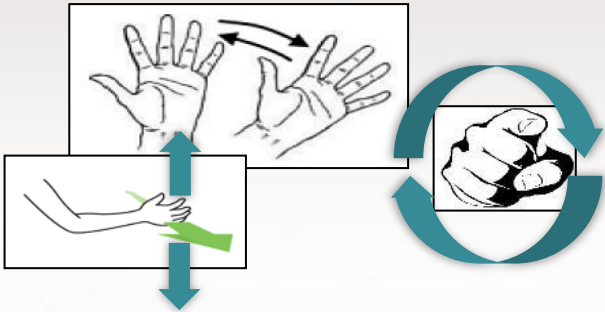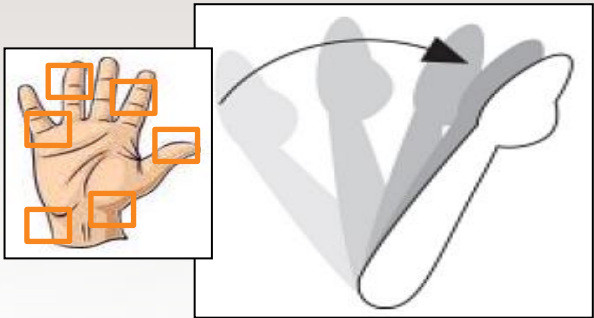
Face Tracking
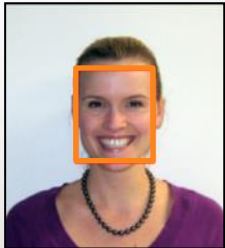
- Low-power always-on UI controls
- Low-latency gesture detection
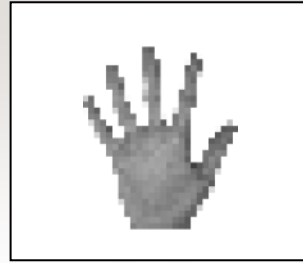- Offload high-level OS functions
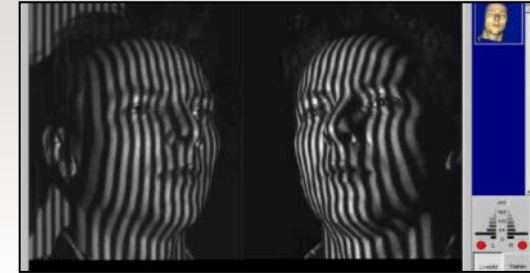
Gestures Technology
Suitable for DSP

Ultrasonics Processing

IR-Scanning
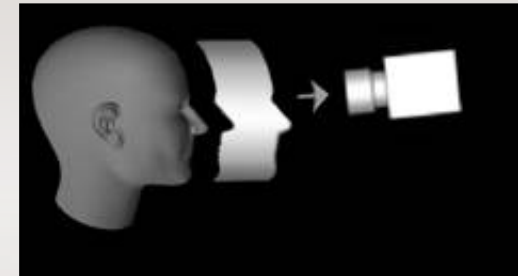

Coded/Structured Light
Depth Mapping

Stylus Based Gestures

Stereo Sparse Depth Mapping


Time-of-Flight
Depth Mapping

Sensors

Snapdragon™ Based Sensors Solution

- Sensor Core solution on chipsets includes both hardware and software components:
  - Dedicated Sensors Processor Subsystem (DSPS)
  - Sensors Services Framework

- Dedicated Sensors Processor Subsystem (Hardware)
  - Interfacing with various digital sensors
  - Hosting "low-power," "low timing jitter" sensor based applications
  - Interacting with other processors (modem, apps)
  - Managing I2C bus bandwidth

- Sensors Services Framework (Software)
  - Supports different sensors
    - Accelerometer, Compass, Ambient Light, Proximity, Gyro, Barometric Pressure, Fingerprint
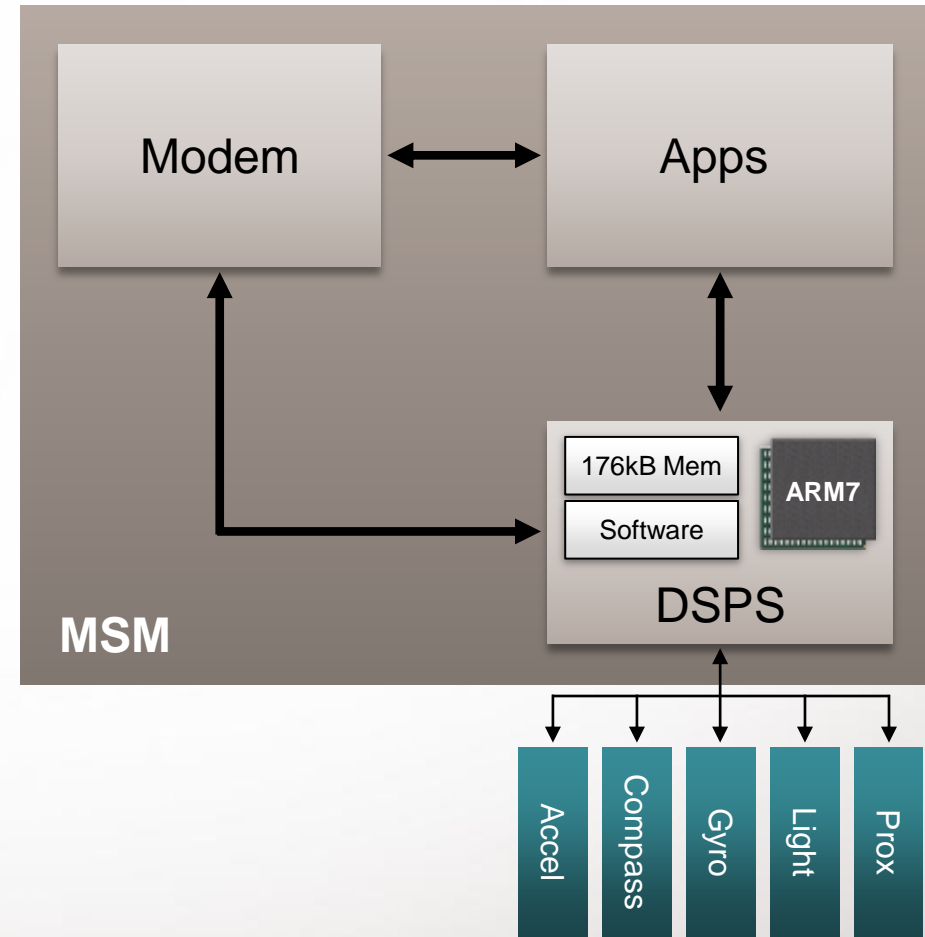
Sensor Based Features
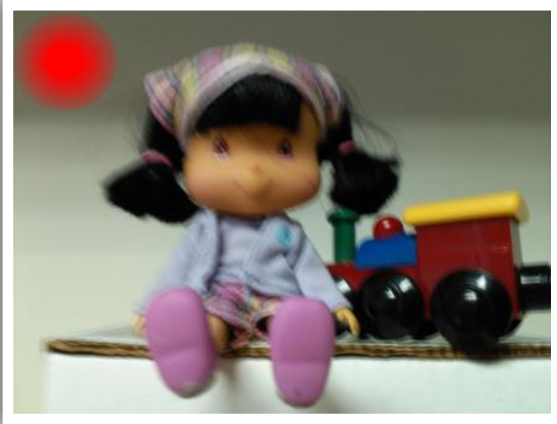
Shake Detection

- Detects blurriness caused by camera shake
  - Can be used to flag bad frames
  - Assist in picking the sharpest frame

Perspective Correction

- Cell phone cameras don't have perspective control; can correct distortion problem
  - Outdoor photos: slanted trees, telephone poles
  - Architectural photos: leaning buildings and structures
  - Indoor Photos: Tilted walls, skewed furniture

Electronic Image Stabilization (EIS)

DIS   **EIS**

- Image Stabilization
  - EIS: Relies on accelerometer and gyroscope to measure actual camera movement. Does not respond to movement of objects in the camera view.

25

ISAGNav 2.0's Full Inertial Navigation System (Accel+Gyro) Filter
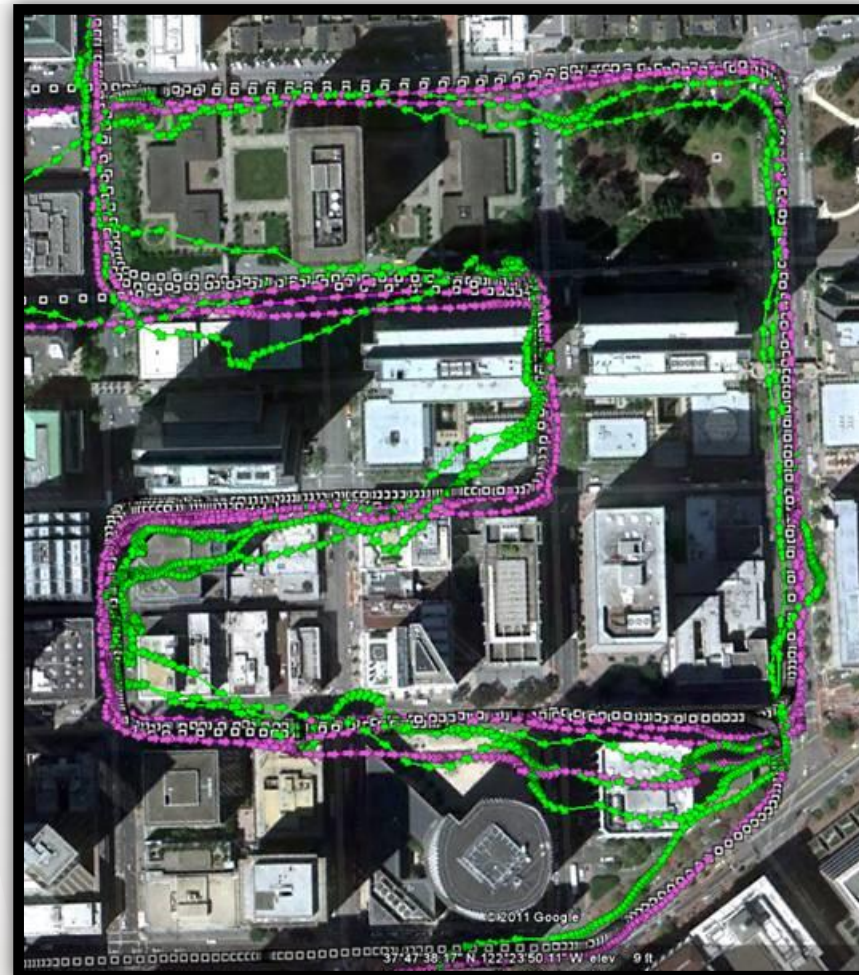
Performance Results

Positioning accuracy and track smoothness

Green: Existing GNSS performance (w/ ISAGNav 1.0)

Pink: ISAGNav 2.0 INS (Accel + Gyro) filter performance

White/Black squares: Truth

Dataset: SF downtown, collected 8/3/11, playback 10/6/11

Downtown Performance	Horiz. Error 68%ile (m)	Horiz. Error 95%ile (m)	Horiz. Error Max (m)
ISAGNav 1.0	26.6	71.7	150.4
ISAGNav 2.0	16.4	39.6	60.6

Video

Use Cases with Mobile Video

Entertain

- User generated content
- Produced, high value content

Share

- Project to large displays using wireless display
- Share with others using social media services

Create

- Record video
- Edit and/or post-process video

Communicate

- High quality, one to one or one to many video telephony
- Collaborate on tasks, projects

Today: Mobile Video Support on Qualcomm DSP

Support for specific video codecs on DSP

Value added video feature support such as 2D to 3D video conversion using DSP

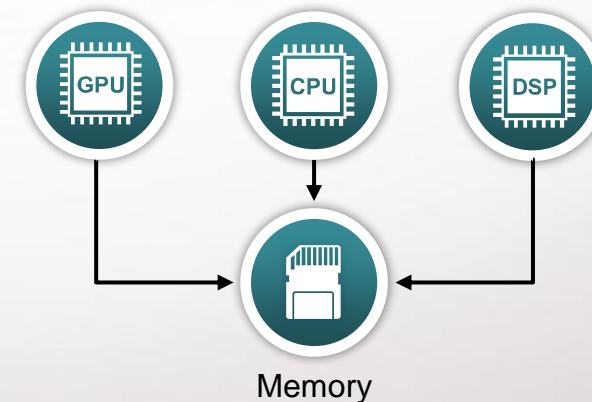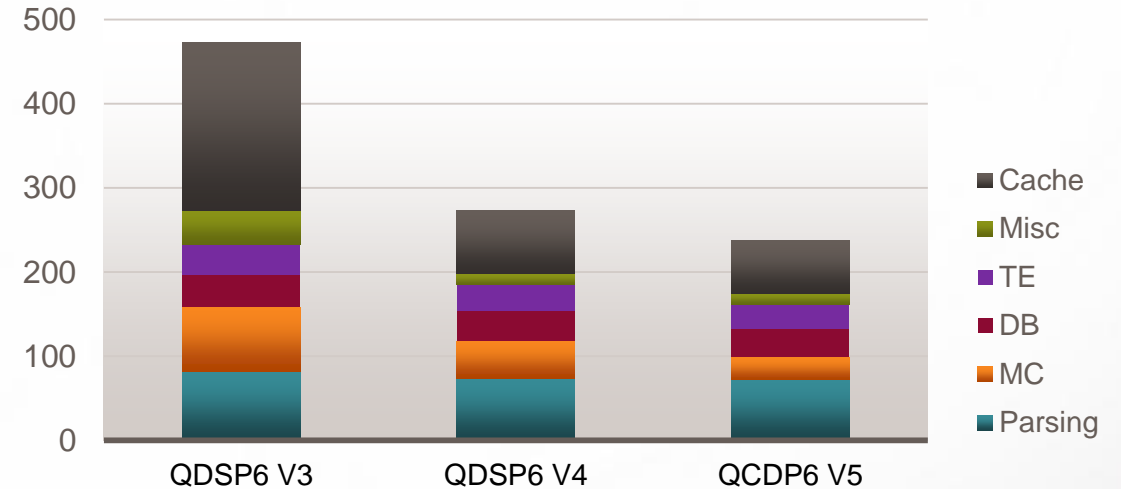Enhancing video or display post-processing with DSP

Original   Enhanced

Future: Efficient DSP Architecture

- **More efficient DSP architecture for video processing**
  - Low inter-processing overhead
  - High multimedia signal processing performance
  - Lower power
  - Lower latency
  - More workload per Mhz/MIPS through new instructions and cache feature

- **System level partition for video tasks on heterogeneous architecture through OpenCL**
  - Bit stream decode on **DSP**
  - Pixel decode on **CPU**
  - Loop filter, motion estimation on **GPU**

MIPS Required for H.264 MP Decode FWVGA @ 30fps, 4 Mbps

Legend: Cache, Misc, TE, DB, MC, Parsing

X-axis: QDSP6 V3, QDSP6 V4, QCDP6 V5

GPU, CPU, DSP → Memory

Computer Vision
or **FastCV™**?

Computer Vision Use Cases

Augmented Reality

Gestures

Face Recognition

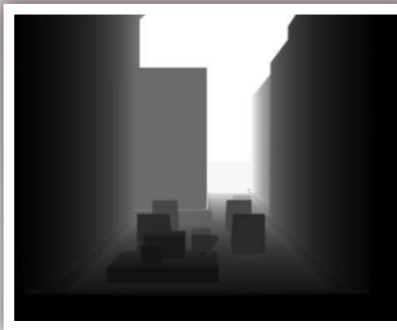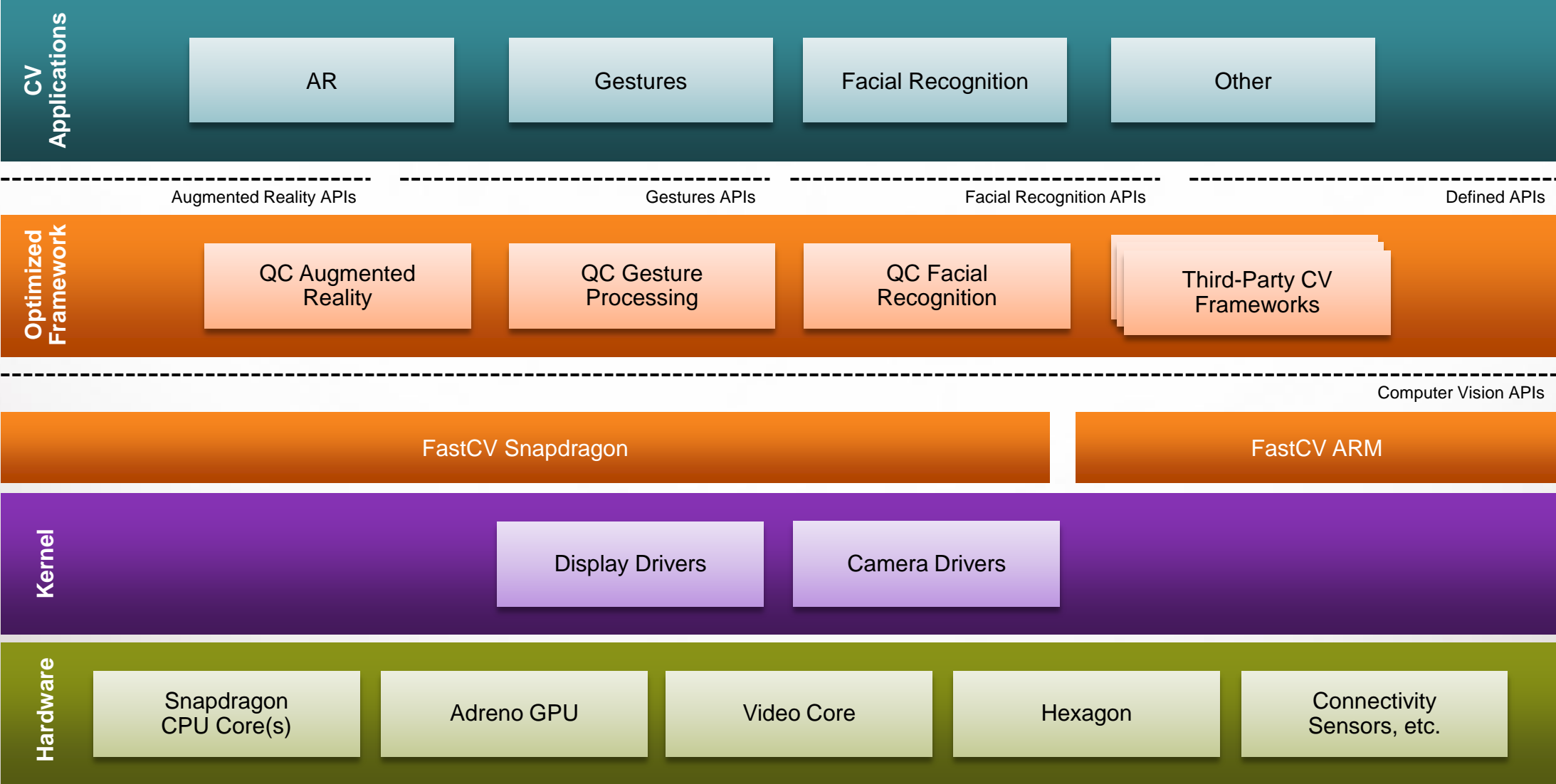Text Recognition

Depth Mapping

Image Stabilization

FastCV™ Overview

- FastCV is an API and library which enables Real-Time Computer Vision (CV) applications
- FastCV enables mobile devices to run CV applications efficiently
- FastCV allows developers to HW accelerate their CV application
- FastCV is analogous to OpenGL ES in the rendering domain
- FastCV is a clean modular library

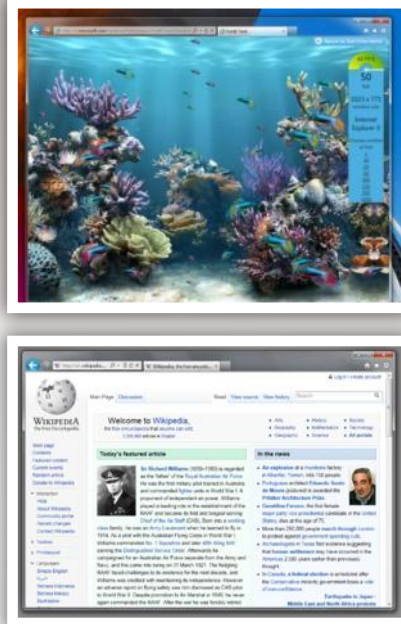| FastCV Value	Specifics
Smaller Scope	✓ APIs most widely used ✓ APIs most computationally intense ✓ APIs suitable for heterogeneous core optimization
Optimize for Embedded/Mobile	✓ More granular API ✓ Better power/performance

FastCV™ Architecture

CV Applications

| AR | Gestures | Facial Recognition | Other |

Augmented Reality APIs   Gestures APIs   Facial Recognition APIs   Defined APIs

Optimized Framework

| QC Augmented Reality | QC Gesture Processing | QC Facial Recognition | Third-Party CV Frameworks |

Computer Vision APIs

FastCV Snapdragon   FastCV ARM

Kernel

| Display Drivers | Camera Drivers |

Hardware

| Snapdragon CPU Core(s) | Adreno GPU | Video Core | Hexagon | Connectivity Sensors, etc. |

Graphics

Mobile Apps That Benefit from Graphics Acceleration
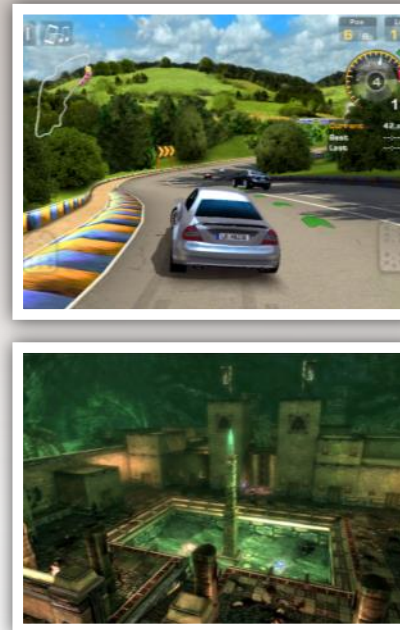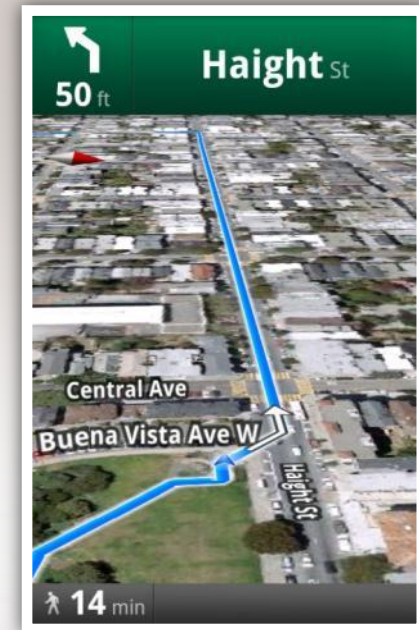

**User Interfaces**

Web Browsers

Games

Navigation

Qualcomm's Integrated Processing Strengths for Gaming

- **Superior visual experience**
  - Fully integrated Adreno GPU, Krait CPU
  - High bandwidth memory access
  - HD Video, Stereoscopic HD Display support

- **Integrated LTE multi-mode modem**
  - Fastest data rates on LTE
    - Can download most games over the air in less than 10 seconds
  - High performance multi-player network-based online gaming
    - LTE latency: 50ms–100ms
  - High quality voice during multiplayer gaming
    - LTE capable of simultaneous voice and data, using SVLTE (voice over 1x; data over LTE)

- **Gesture recognition, wireless display, integrated GPS, Wi-Fi, camera, DRM, etc.**
  - Complete integration of technologies critical for best connected gaming experience

ADRENO GPU	4G LTE Modem
DSP	Krait CPU(s)
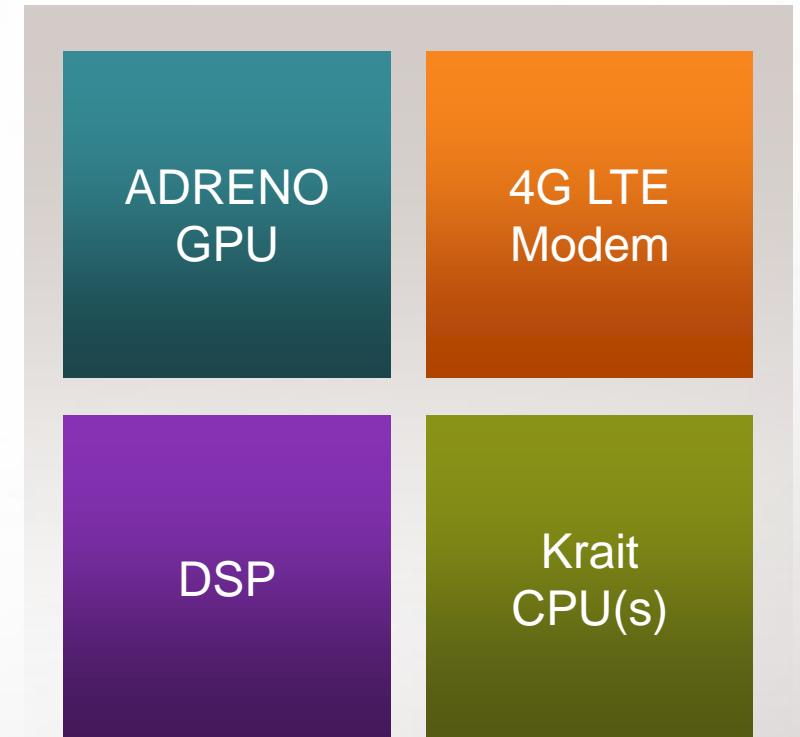
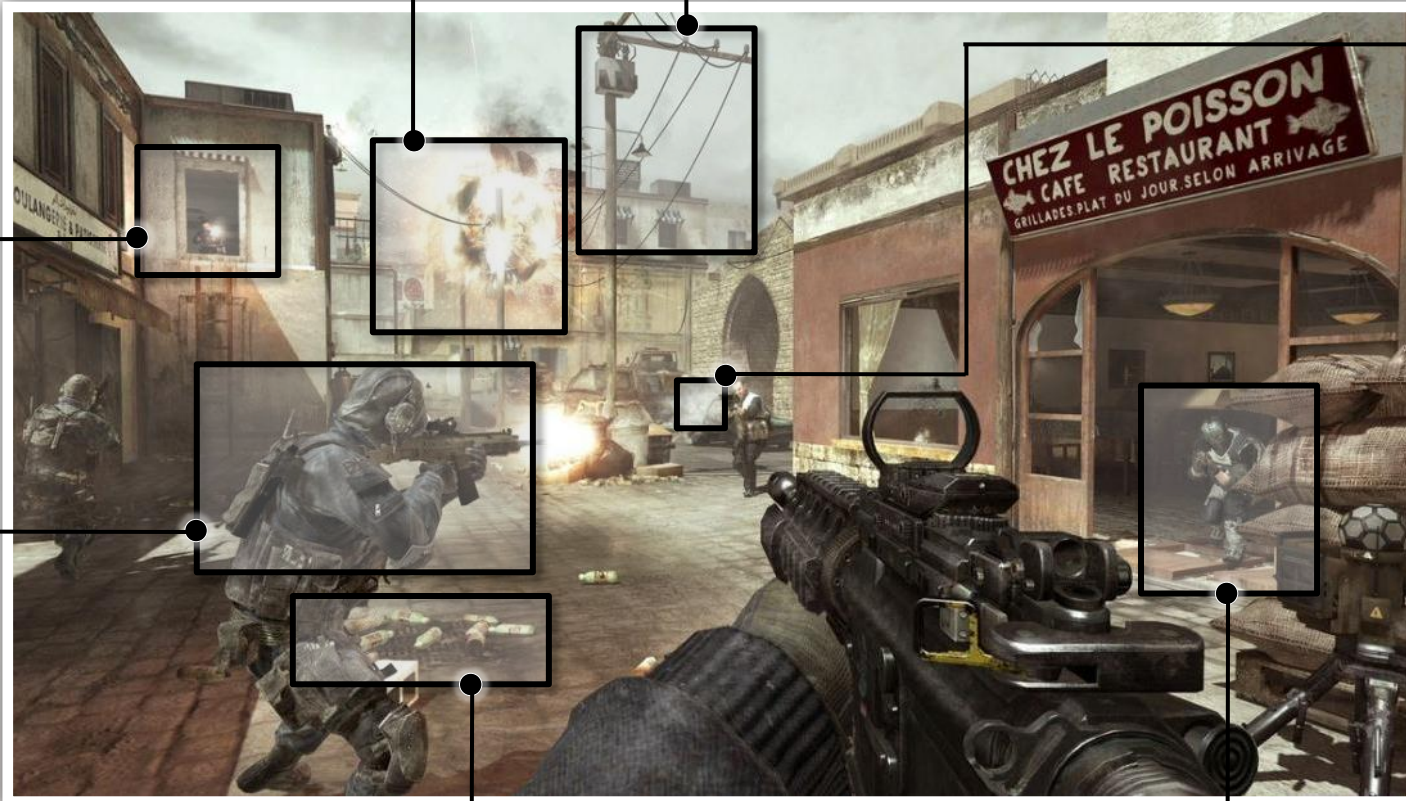# 8064: Quad Core CPU + Adreno 320 in Next-Gen Games

Particle Effects: Simulating and rendering thousands of particles interacting with the environment

"Rope Physics": Simulating power lines that sway in the wind, break when damaged, and interact with the player and world

Projectiles: Tracking bullets to identify not only if a bullet hits, but where on the body the hit occurred

Artificial Intelligence: Execution of enemy behaviors and CPU intensive path finding algorithms

**Vertex Skinning:** Transforming hundreds of thousands of vertices

Animation: Decompressing multiple animation streams, blending them together, and applying the resulting transforms to the character skeleton

Rigid Body Dynamics: Simulation of bottles interacting with the player, enemies, and the environment

Integration Brings Together Diverse Technologies into One Design
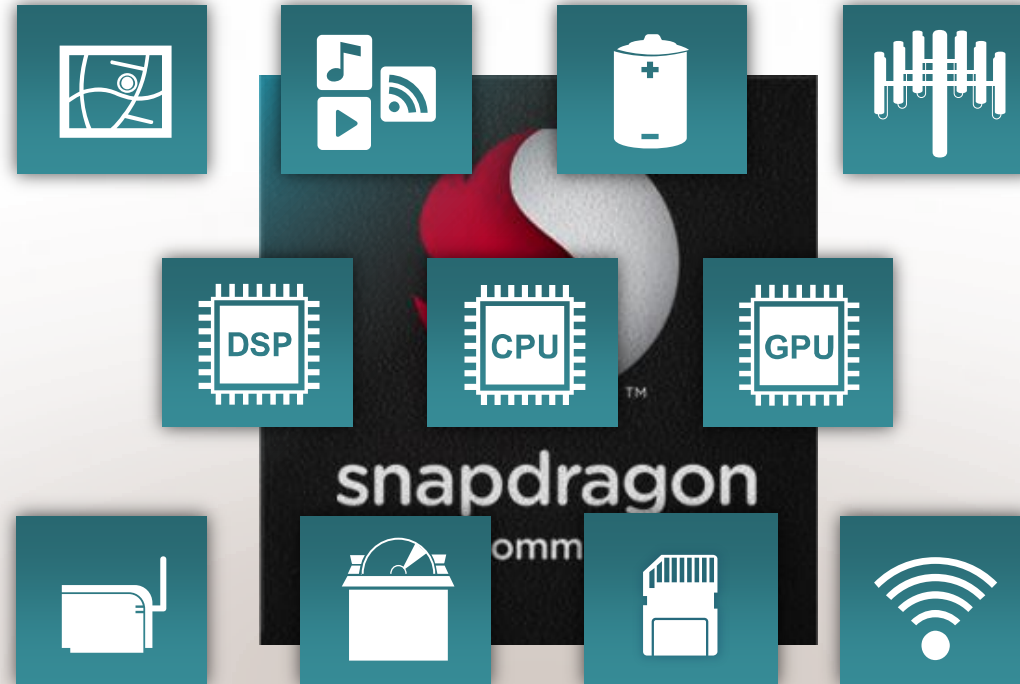
Snapdragon™: The All-In-One Mobile Chip

Standby

Messaging

Make a Call

Find Your Way

Surf the Web

Watch and Stream Movies

Gaming

POWER ||||||||||||||||||||||||||||||

Adapts to Deliver Unrivaled Mobile Experiences and Longer Battery Life

Note: Simulation for presentation purposes.

Conclusions

Thank You