Advances of Media Technology in Modern Computing

Dr. Hong Jiang, Intel Fellow
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• History
• Heterogeneous Computing Architecture
• Video Codec
• Video Processing
• Perceptual Computing Initiatives
• Summary
Contents

• History
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Two decades ...
MPEG2:
- Block motion comp
- Block DCT

AVC/H.264:
- More complex block coding
- Loop filter & CABAC

HEVC/H.265:
- More complex block coding
- More complex loop filter

Two decades ... Video Coding

1993

2003

2013

2X coding efficiency every 10 years
Two decades ... Video Coding

MPEG2:
• Standard Definition (SD)
• DVD, Broadcast

AVC/H.264:
• High Definition (HD=6xSD)
• Blu-ray, Internet Streaming

HEVC/H.265 (promises):
• Ultra HD (4K = 24xSD)
• Cellular Wireless Streaming

1993  2003  2013

Complexity compounded by ↑ Resolution & ↓ Power
From Big Screen to Mobile

• HD media becomes ubiquitous
  – Optical media led the digital conversion (2006: Blu-ray)
  – Internet streaming is catching up (2009: 720p, 2012: 1080p)
  – All devices are HD capable (2008: DTV/PC, 2010: Smart Phone)
• Beyond HD – 4K Video is coming (2-3 years to reach consumers)

1.1B users

100h/min uploads

Today, video file >50% internet traffic In 2016, sum of all video >86% traffic

HD is ubiquitous & We Are Not Done Yet
Two decades ... Personal Computing

Intel® Pentium™:
• Performance spiral
• MMX/SSE extensions
  (Desktop PC Era)

Intel® Centrino™:
• Low power
• Wi-Fi
  (Mobile Computing Era)

Haswell (4th Gen Intel® Core™):
• Breakthrough battery life
• Leading Graphics/Media
  (Ultra mobility)

1993 2003 2013

Major transformation each decade
Two decades ... Personal Computing

Intel® Pentium™:
• 0.8 um process
• 3.1 millions transistors
(Desktop PC Era)

Intel® Centrino™:
• 0.13 um process
• 77 millions transistors
(Mobile Computing Era)

Haswell (4th Gen Intel® Core™):
• 22 nm process
• ~1.4 billions transistors
(Ultra Mobility)

1993  2003  2013

450x more transistors over 20 years!
Two decades ... Personal Computing

1993: Barely getting thumbnail video on PC

2003: Can play DVD; Limited quality.

2013: Multiple HD, 4K playback and encode; High quality HD video processing

Media Technology revolutionized
Contents

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Demands and Challenges

Higher Resolution

Higher Quality

Higher Intelligence

Lower Power
Two-Pronged Solutions

• Process Technology – Moore’s Law

• Architecture Innovation
Intel Tick/Tock Development Model

45nm Process Technology
- Nehalem
  - NEW Intel® Microarchitecture (Nehalem)

32nm Process Technology
- Westmere
  - (Nehalem)
- Sandy Bridge
  - NEW Intel Microarchitecture (Sandy Bridge)
- Ivy Bridge
  - (Sandy Bridge)

22nm Process Technology
- Haswell
  - NEW Intel Microarchitecture (Haswell)

Haswell CPU Family
- 22nm Process Technology

Haswell, 4th Generation Intel® Core™ Processors, builds upon innovations in the previous Core™ generations
Architecture Concept

• Trends: Higher capability in a lower power budget
• Power considerations drive a Fixed Function solution
• Flexibility considerations requires a Programmable solution

<table>
<thead>
<tr>
<th>EPI</th>
<th>Power Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 nJ</td>
<td>General purpose microprocessors (x86, ARM cores…)</td>
</tr>
<tr>
<td>1 nJ</td>
<td>Domain specific processors (GPU, DSP …)</td>
</tr>
<tr>
<td>0.1 nJ</td>
<td>ASIC, fixed function Blocks</td>
</tr>
<tr>
<td>0.01 nJ</td>
<td></td>
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</tbody>
</table>

Max Power Efficiency
Max Flexibility

EPI: Energy spent per Instruction in nJ
NEW EXPERIENCES

Media & Display

GPU Architecture Playbook for Media Computing

Phones & Tablets
Ultrabooks™
Laptops
Workstations & Servers

INNOVATIVE FORM FACTORS

Intel is building Media solutions with Great Power and Scalable Performance for Innovative Form Factors and New Experiences
Increasing Graphics Performance

Source: Intel. 3DMark06

Baseline

80x
70x
60x
50x
40x
30x
20x
10x

2006  2007  2008  2009  2010  2011  2012  2013

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Haswell: Processor Graphics Architecture

**Video Quality Engine**
- Video Processing
- Color Processing

**Multi-Format Codec:**
- Parallel engine
- High performance
- Video Decode and Encode

**Media Optimized Execution Units:**
- Zero overhead thread switching
- Native media ISA
- Vector/Matrix oriented operations

**Media Accelerators**
- Higher throughput & low power
- Retaining flexibility
Some GT3 sku’s come with an 128MB eDRAM, as cache shared with CPU

Significant generational EU count growth (Top line from 8, 16 to 40 EU’s)
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Intel® Quick Sync Video

Intel® Quick Sync Video is HW-based video codec capability:

• Break-through performance & quality ➔ new User Experiences
• Many more applications: Wireless Display, Game recording…
Haswell: Quick Sync Video Performance and Power

- 4x-12x real-time transcode at various quality modes
- 10-hour video playback time on latest Apple MacBook Air
- Multi-stream 4K decode
- > real-time 4K Encode

![HD Mosaic](image1.png) ![4K Mosaic](image2.png)

**Intel HD Graphics 4600**
AVC Transcode Performance and Power

<table>
<thead>
<tr>
<th></th>
<th>Intel QSV Disable</th>
<th>Intel QSV Enable</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power (W)</strong></td>
<td>24.74</td>
<td>48.4</td>
</tr>
<tr>
<td><strong>Speed (FPS)</strong></td>
<td>60</td>
<td>280</td>
</tr>
</tbody>
</table>

4.6x faster speed at 0.5x power over SW encoder
Deployment as Media Servers

Example:
- QuickFire Network 1U uServer contains 11 3rd Gen Intel® Core™ mobile processors
- Transcoding over 88 1080p30 HD streams per blade!
Video Encode: A Balanced Approach

<table>
<thead>
<tr>
<th>Encode Solutions</th>
<th>Performance</th>
<th>Power</th>
<th>Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPGPU</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Traditional Fix Function HW</td>
<td>High †</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Flexible Intel Quick Sync Video</td>
<td>High</td>
<td>Low</td>
<td>Balanced</td>
</tr>
</tbody>
</table>

† Subject to actual implementation

- Intel implements a flexible hardware design approach for encoding
  - Hybrid of fix function HW and programmable EU array.
  - Provides balance between performance, power and flexibility

Hybrid 2-Stage Video Encoder:

- “ENC”
  - Rate Control
  - Motion Estimation
  - Intra Prediction
  - Mode Decision

- Accelerated by HW VME

- “PAK” Full HW fix function pipeline
  - Motion Comp.
  - Intra Prediction
  - Forward Quant
  - Pixel Reconstruction
  - Entropy Coding
Encoder Parallelization and Scalability

- **Decoupled Encoding Operations**
  - ENC: Multi-threaded in wave front order macroblocks
  - PAK: Pipelined in raster order macroblocks

- **Multiple level of parallelization**
  - Decoding vs. Encoding
  - ENC and PAK
  - ENC: Multiple Macroblocks in Wave fronts
  - ENC/VME HW: Integer vs. Fractional Search
Intel Quick Sync Video – Multi-year Improvements

- Performance: Over 50% hardware CAGR for three generations
- Quality: Hardware features and algorithm improvements
- Usability: Fine grained quality vs. performance tradeoff control

Data is captured with internal test app over a big set of test clips.
• Frame 670 of Star Trek Into Darkness movie trailer transcoded in HandBrake QSV beta. Both set to VBR 2Mbps Best Quality setting under HandBrake High Profile preset
• Same encode quality on Intel 4th Gen Core Processor with HD 4200/4400/4600, Iris, and Iris Pro. Performance varies on different SKUs
Intel HD Graphics 4000 vs. Intel Iris Pro Graphics 5200

HD Graphics 4000

Iris Pro Graphics 5200

• Frame 670 of Star Trek Into Darkness movie trailer transcoded in HandBrake QSV beta. Both set to VBR 2Mbps Best Quality setting under HandBrake High Profile preset.
• Same encode quality on Intel 4th Gen Core Processor with HD 4200/4400/4600, Iris, and Iris Pro. Performance varies on different SKUs.

Generational quality improvements
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Video Processing Pipe

- Migrated to a dedicated VP pipe **Video Quality Engine (VQE)**
- Extensive suite of functions for higher quality video at lower power

*In Media Sampler*
De-noise

- Spatial and Temporal De-noise Filter
  - Global noise level measurement
  - Content-adaptive spatiotemporal filtering of noise
  - Motion history-based blending of spatial and temporal filter results

- Block
Skin-tone Processing

- **Per-pixel Enhancement of Skin-tone Pixels**
  - Reproduce the natural skin colors on the display screen
  - Skin Tone Detection identifies pixels with skin-like colors with per-pixel indicator
  - Skin Tone Enhancement modifies the Saturation and Hue of the skin-tone pixels

- **Block**

  ![Skin-tone Definition](image)

  **Skin-tone Detection**

  ![Skin-tone Enhancement](image)

  **Skin-tone Indicator**
Contrast Enhancement

- **Automatic Contrast Enhancement**: Per-pixel mapping of luma to enhance contrast
  1. Histogram of luma Y pixel values is generated for the input video frame
  2. Piece-Wise Linear Function (PWLF) is generated from luma histogram
  3. Pixel values are modified according to the PWLF

- **Block Interface**
  - Input: YCbCr 444
  - Output: YCbCr 444 with modified Y
Saturation Enhancement

- **Per-Pixel Saturation Enhancement**
  - Utilize 6 basic colors as primaries/anchors (Red, Green, Blue, Magenta, Yellow, Cyan)
  - Adjust colorfulness (saturation) of pixels while maintaining their color (hue)

- **Block Interface**
  - Input: YCbCr 444
  - Output: YCbCr 444 with modified CbCr components

![Diagram showing color space with modified components](image)
Color Correction

• Display proper colors on display screen
  1. Inverse gamma correction via PWLF
  2. 3x3 matrix multiplication with input/output offset
  3. Forward gamma correction via PWLF

• Block Interface
  • Input: RGB
  • Output: RGB
Before

After (Color Correction)
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Towards
Natural, Intuitive and Immersive
Human-Computer Interactions

Now

Near Future

The Vision
Perceptual Computing
Adding “Human-like Senses” to the Computing Devices
Download the SDK and order the 3D Camera at intel.com/software/perceptual
Intel® Perceptual Computing SDK

Easily Implemented by Application Developers for:

- Games
- Entertainment
- Productivity
- Accessibility
- Immersive Teleconferencing
- Education
- Health
- Enterprises
- Retail
- Industrial

Download the SDK and order the 3D Camera at intel.com/software/perceptual
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Media Usage Outlook

Consumption
- Internet streaming video
- DVD/Blu-ray disc
- Stereoscopic 3D video

Creation
- Photo, video, audio encoding
- Video encode and transcoding
- User generated contents

Interaction
- Face & object detection
- Scene analysis
- Perceptual computation

Recognition
- Video and sensory inputs
- Gesture recognition
- Augmented reality

Synthesis

Image Effects

Playback
Quality

Transcode

Decode

Face

Recognition

Mining/
Analysis

Synthesis

Perception

Internet streaming video
DVD/Blu-ray disc
Stereoscopic 3D video

Gesture

Face & object detection
Scene analysis
Perceptual computation

Video and sensory inputs
Gesture recognition
Augmented reality
Concluding Remarks

• We are in the era of HD digital media

• Moore’s Law inspires Innovations

• Heterogeneous computing addresses the HD media demands

• Media continues to be an exciting fields for years to come