Unleashing the benefits of GPU Computing with ARM Mali

– Practical applications and use-cases –

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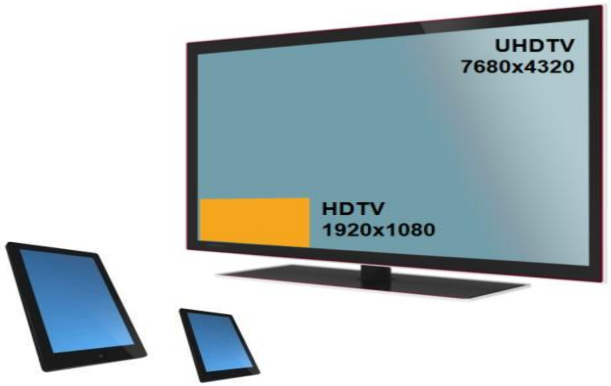
Today's Computational Challenges

- Trends
  - Growing display sizes and resolutions, richer content, novel applications
  - Continual users' expectation for improved experience
  - Increasing computational power requirements
- Limitations
  - Restricted energy and thermal budgets
  - In mobile, processing power greatly outgrowing battery capacity
  - Traditional scaling solutions not sustainable
- Necessity
  - Increase computational efficiency of processing platforms
  - Leverage on heterogeneous and parallel computing
  - Utilize the right processor for the task



Efficient Heterogeneous Computing

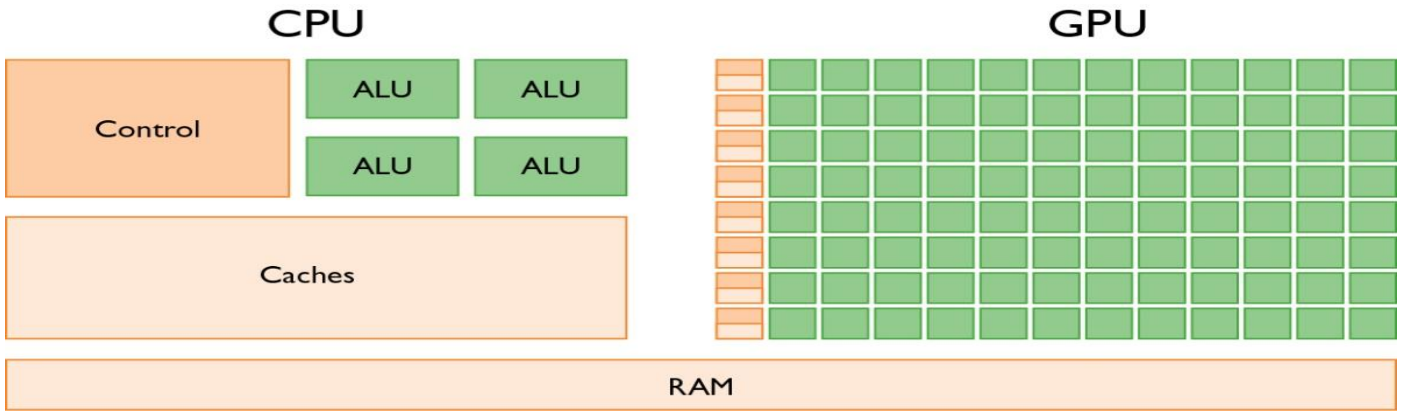
- Parallel compute is established in processor design
  - Microarchitecture and instruction sets
  - Multicore
  - Multiprocessor and System-on-Chip
- Different codes/algorithms suit different approaches
  - Fine-grained, coarse-grained, and embarrassing parallelism
  - Data parallelism, Task parallelism
  - Multi-threading, Multi-programming, SIMD
- Modern SoCs also feature GPU capable of accelerating non-graphical tasks

The Right Processor for the Task

Operating System
Most application processing

Programmable through C-like languages and APIs

Cost effective, efficient, great floating point performance



GPU can be used as computational accelerators or companion processor

2D/3D graphics
Advanced Image Processing
Accelerate/Complement ISP functionality
Offload video codec blocks
Accelerate physics computation

Benefits of GPU Compute

- Acceleration of embarrassing parallel workloads
- Better load-balance across system resources through the use of compute APIs designed for concurrency
- Increased system-level energy efficiency using the best processor for the job
- Free up CPU resource by offloading to GPU
- Enable offload of traditional hardware accelerated functions
- Portability and programmability

Example GPU Compute Use Cases

Mobile

- Computational photography
- Moving and still image real-time stabilization
- Information extraction: object detection, classification and tracking
- Imaging: correction, improvement, consolidation
- Content and context understanding
- ISP pre- and post-processing
- Augmented reality
- Physics in games
- HEVC

DTV/STB

- 2D to 3D conversion
- Super resolution
- Video pre- and post-processing
- Camera based gesture UIs
- Trans-coding
- Information extraction and superimposition

Automotive

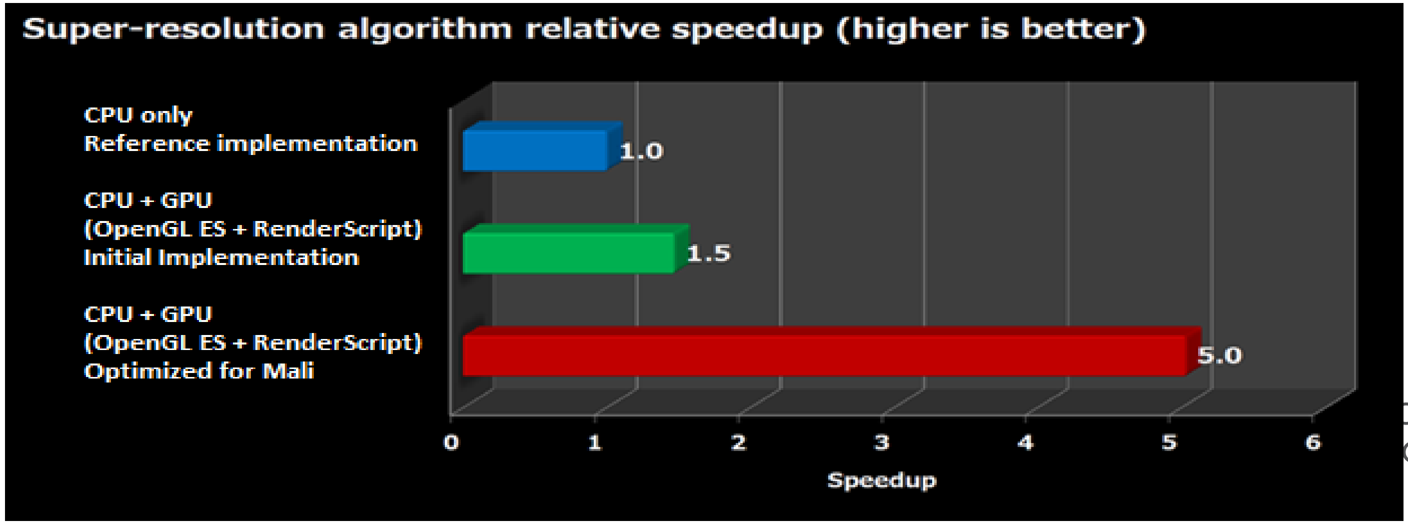
- Lane detection
- Smart head-light
- Road sign recognition
- Night vision
- Object classification
- Pedestrian, vehicle and collision detection
- Vehicle detection
- Dynamic cruise control

100s GFLOPs of efficient processing power: improve existing use-cases, enable next generation use-cases

The Mali Ecosystem

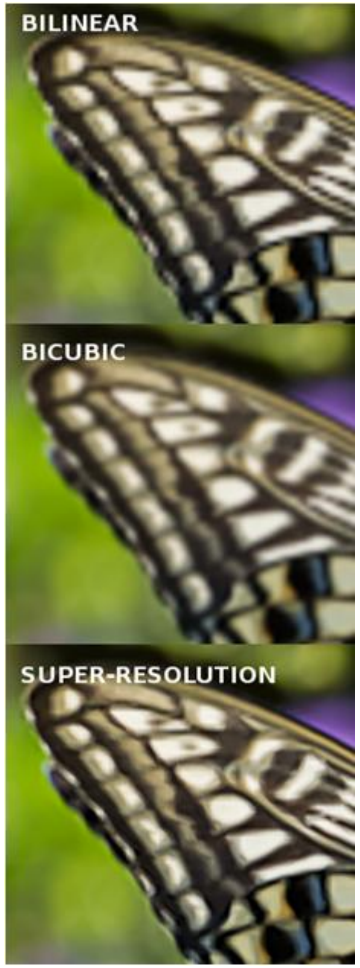
Super-Resolution

- Super-resolution techniques aim to increase resolution of imaging systems
  - Synthesis' proprietary algorithm delivers sharper and artefact-free edge interpolation
  - Implemented in OpenGL® ES and RenderScript for ARM Mali™-T600 family
  - Demonstrated publically on Google Nexus 10 (ARM Mali-T604 GPU) since MWC 13



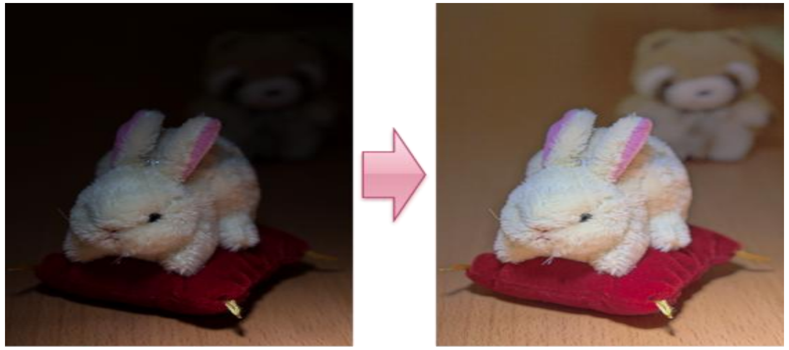
SYNTHESIS

OURCE: SYNTHESIS
ORPORATION



High Dynamic Range Imaging

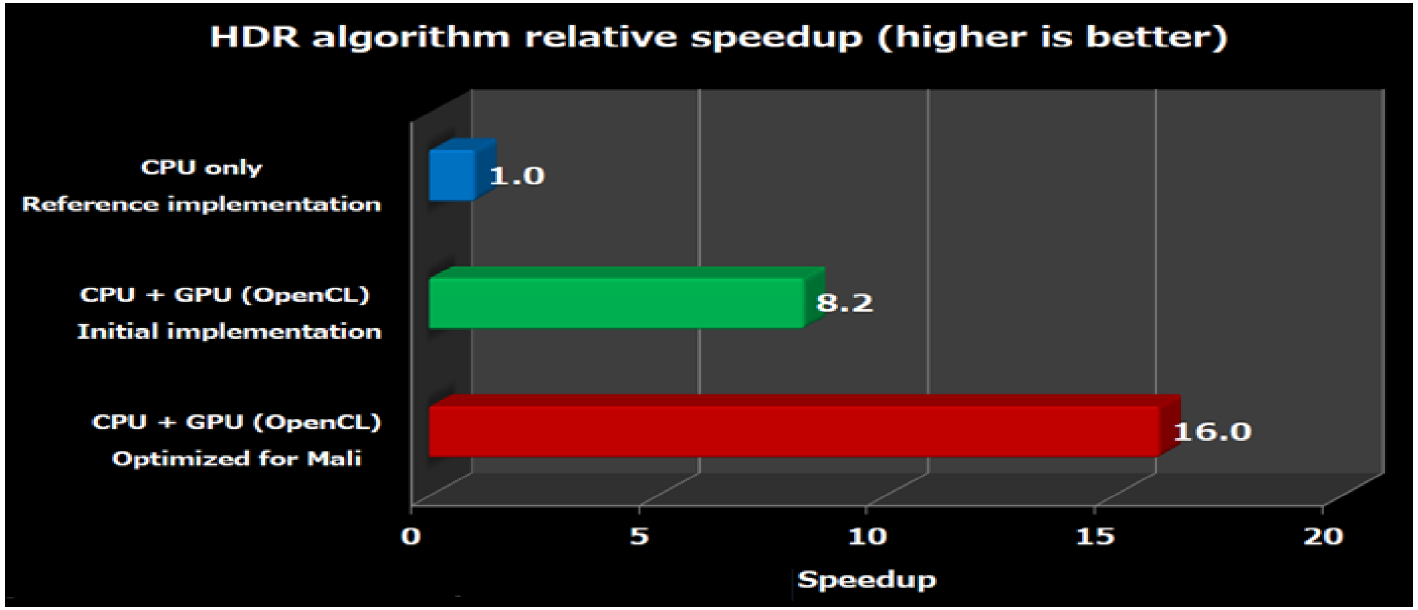
- Adaptive luminance/dynamic range enhancement algorithm
  - Increases the visible dynamic range of an image by adaptively enhancing the darkest areas
  - Unlike traditional gamma/tone-curve editing, only selected areas are computed, avoiding over-saturation
  - Optimized for ARM Mali-T600 family using OpenCL, demonstrated on InSignal Arndale Linux



Original image   After enhancement

SYNTHESIS

SOURCE: SYNTHESIS CORPORATION



Advanced Image Processing

- Image processing greatly accelerated through GPU Compute
  - RenderScript enables GPU Compute on Android
  - First supported with ARM Mali-T604 GPU
  - Mali GPU Compute proven to deliver major and consistent speed-up

Filter	Speed-up [1]
MotionBlur	3.5x
Cloud	4.2x
Labyrinth	3.8x
TitleReflection	7.3x
WhirlPinch	3.6x
Wave	7.0x
Bicubic	15.4x

[1] Acceleration compares RenderScript compiled on device (LLVM) on Dual-core ARM Cortex™-A15 CPU and ARM Mali-T604 GPU on a stock Google Nexus 10 device

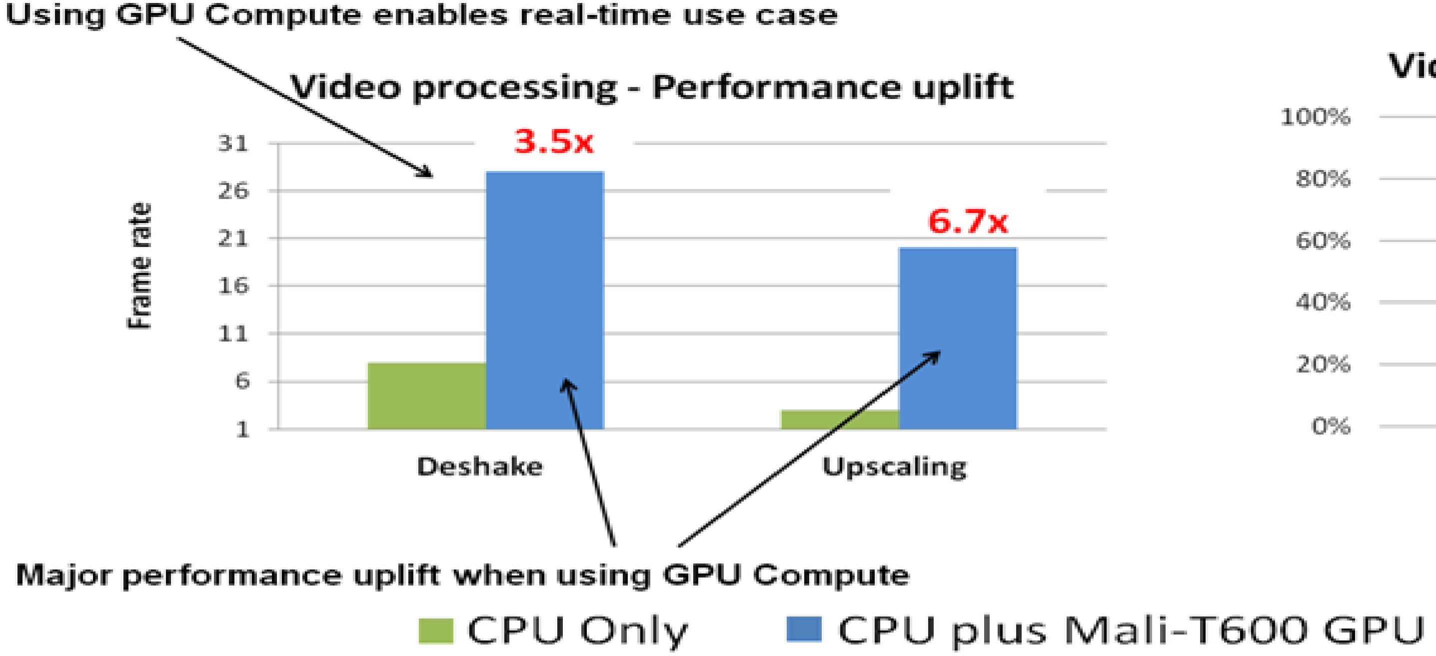
SOURCE: MULTICOREWARE INC.

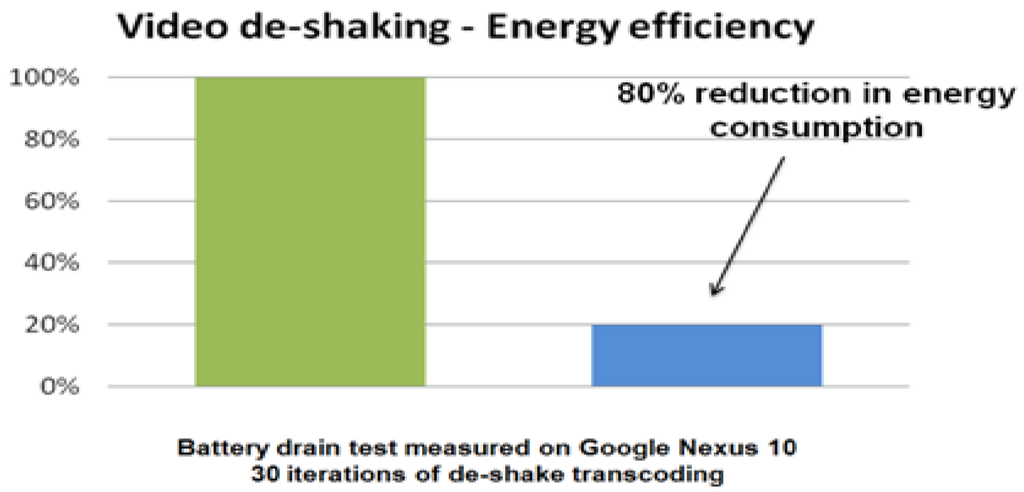
MULTICORE WARE

Video Pre and Post Processing

- GPU Compute improving video pre-/post-processing
  - MulticoreWare transcoding Android application
  - Video processing plug-ins written in RenderScript
  - Optimized for ARM Mali-T600 family, leveraging both CPU and GPU
  - Proven performance and power benefits, on a real device

MULTICORE WARE

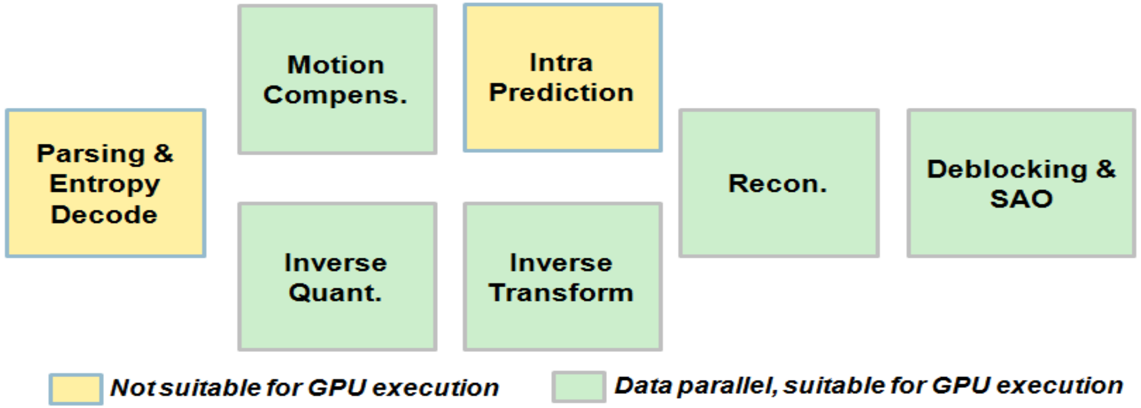




SOURCE: MULTICOREWARE INC.

Why GPU Compute for HEVC Decode?

- Mass-market deployment of new codecs brings challenges
  - Early adoption of hardware codecs carries some risk
  - High performance software implementations become cardinal to the success of HEVC
- Combining CPU and GPU Compute enable most efficient HEVC decode
  - High resolution HEVC decoding on CPU-only creates high loading
  - GPUs are traditionally idle during video playback
  - GPU architecture suits acceleration of parallel codec blocks
  - Offloading computation to the GPU enables CPU to perform other tasks



"Mali GPUs are well suited for video acceleration with significant power/performance benefits"

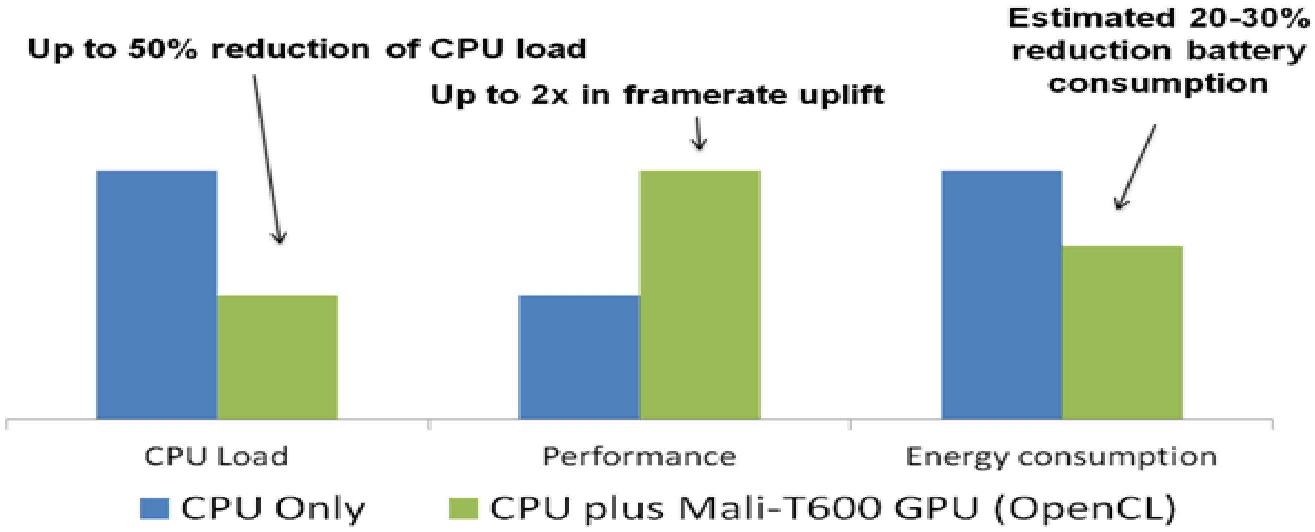
"Mali acceleration opens up the possibility of 1080p @ 60 fps and 4K x 2K @ 30 fps HEVC decode on mobile devices without dedicated HW"

Source: Ittiam Systems

HEVC decode using OpenCL on Mali

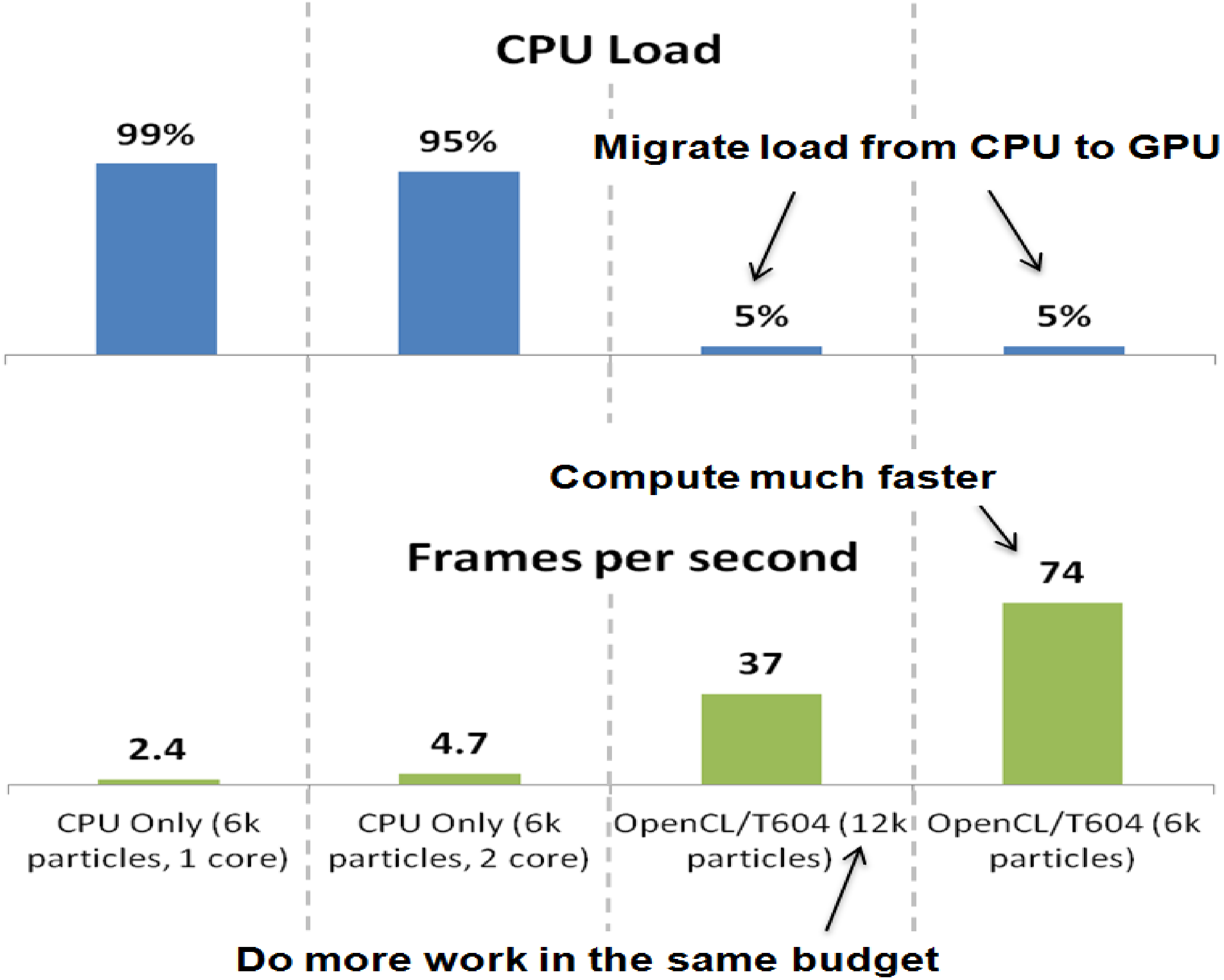
- ARM is collaborating with several codec vendors
  - Ensuring widest availability of HEVC across multiple ARM platforms
  - Enabling HEVC early, in software, through ARM NEON™ and GPU Compute
  - Multiple partners developing OpenCL-enabled HEVC codecs for Mali-T600

Ittiam SQUID DESIGN SYSTEMS Aricent PIXTREE PUX ArcSoft VisualOn



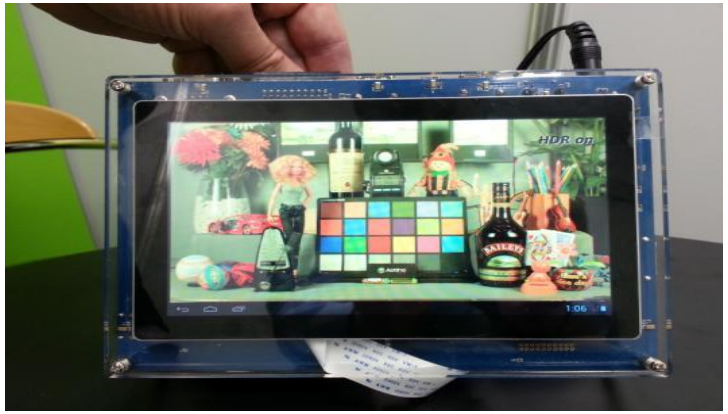
Physics (cloth simulation)

- In-house physics engine
- InSignal Arndale platform
- OpenCL/Linux on ARM Mali-T604

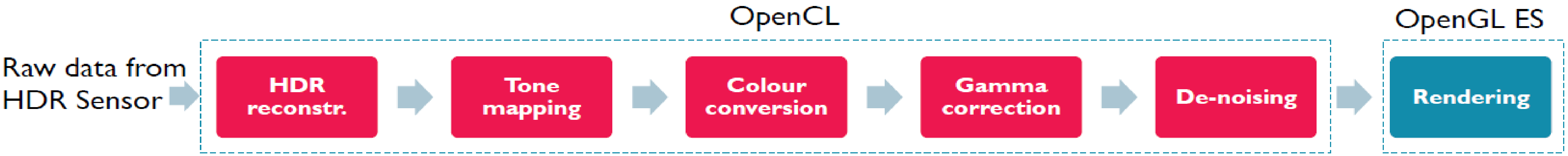


ISP Pipeline Offload to GPU (OpenCL)

- OpenCL API enables offload/acceleration on ARM Mali-T604 GPU
- Software solution gives more flexibility and enables algorithm modifications right up to consumer device release
- Sensor and camera module vendors can invest in optimized portable software libraries instead of hardware
- SoC implementers can reduce device costs by offloading ISP blocks to the GPU

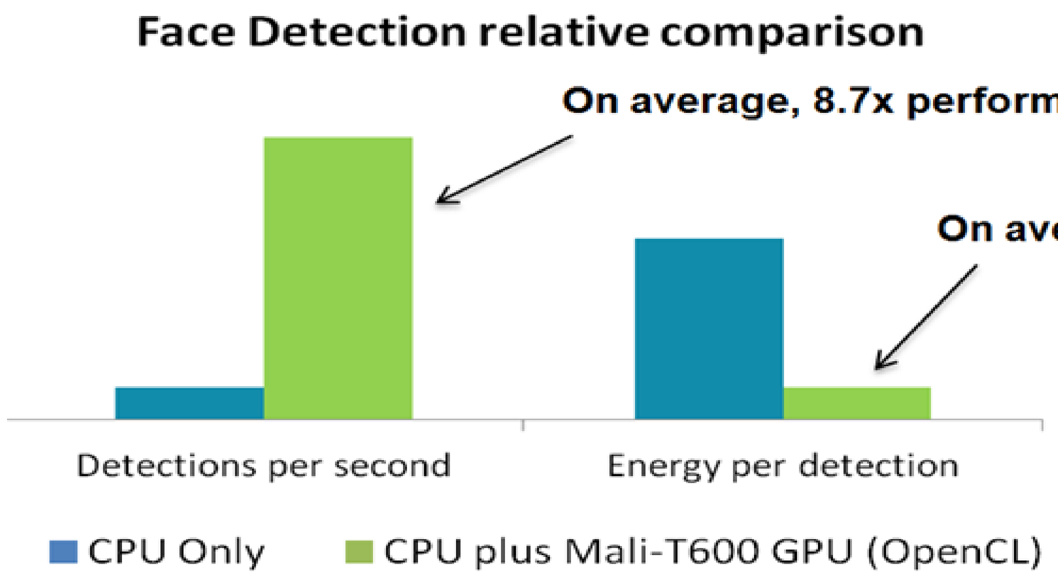


Entire ISP pipeline for HDR imaging demonstrated running on ARM Mali-T604 GPU (InSignal Arndale, Samsung Exynos 5 Duo) using OpenCL



Computer Vision Based Applications

- Computer Vision entails the acquisition, processing, analysis and understanding of sensor data (images), in order to derive information to enable decisions to be made
  - GPU Compute is particularly suited for the acceleration of Computer Vision
  - Face detection study demonstrated significant performance and energy benefits with ARM Mali-T604 GPU



Tested on an instrumented InSignal Arndale Community Board
Algorithm based on OpenCV Face Detection example
OpenCL kernels re-written and optimized for Mali-T604
Average results represented, permuting CPU and GPU operational frequencies

Conclusions

- Modern compute APIs enable efficient and portable heterogeneous computing
  - Use the best processor for the task
  - Balance workload across system resources
  - Offload heavy parallel computation to the GPU

- GPU Computing with ARM Mali-T600 GPUs is proven to deliver benefits for real world applications
  - Advanced imaging, computer vision, computational photography and media codecs
  - Improved performance and energy efficiency measured on consumer devices

- The Mali Ecosystem is making GPU Compute a reality today
  - Industry leaders take advantage of ARM Mali-T600 capabilities to innovate and deliver
  - Be one of them!