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Performance of HDR video in Mobile Devices

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Abstract

High Dynamic Range (HDR) video brings a new viewing experience, allowing users to see much more detail and colours compared to traditional video. Although it is already possible to watch HDR videos on computers, it was not possible to do this on mobile devices mainly due to their lower performance. The idea that the computational power of mobile devices is limited is outdated as nowadays these devices incorporate powerful processors that are comparable to many existing computers.

In this paper we investigate the performance of an HDR video player on two different mobile devices. Results show that there are currently mobile devices that are capable of displaying HDR video at over 20 frames per second.

Categories and Subject Descriptors (according to ACM CCS): I.3.4 [Graphics Utilities] - Application packages

1. Introduction

The real world presents a wide range of luminance levels where night scenes can have luminance values in the order of 10^{-4} cd/m^2 or less and daylight scenes can reach 10^6 cd/m^2. Nowadays, most of the digital images and video content is only able to capture a fraction of the visual information visible to the human eye and thus the scene cannot be reproduced in the future generation of display devices with the desirable colour quality [Man06]. The real problem is not in the resolution but the colour gamut and dynamic range (contrast) that those images that today's video formats can store. The dynamic range is defined as the ratio between the brightest and the darkest value that can be recorded simultaneously [Tre06].

High dynamic range (HDR) techniques were developed to enable the capture of the visual information of real scenes comparable to the visual information that the human eye can see. Advances in this area have led to systems that are able to capture real scenes with a large dynamic range. These systems can capture HDR scenes by combining multiple photographic exposures, as described by Debevec [DM97] and Xiao [XDCW02], or use improved, or multiple sensors that allow the capture of HDR information with a single exposure.

Since the very beginning of HDR imaging there has been the need to display these images in conventional LDR display devices. To achieve this it is necessary to reduce the range of values to a displayable range, whose process is designated as tone reproduction or tone mapping [KAR06]. Many tone mappers have been proposed over the years and each exhibits l different characteristics that result in different tone mapped images, for example, some are more sensitive to contrast others to detail or even colour.

Regarding the display of HDR images on mobile devices, it is already possible to capture and display HDR images (mainly photographs), and some studies have been made to identify what tone mappers perform better on these devices [UMM*10]. However the ability to capture and display HDR video within these devices only recently has become a possibility.

In this paper we present an evaluation of a mobile HDR video player. For this evaluation eleven tone mappers were implemented and ten HDR videos were used on two different mobile devices.

This paper is structured as follows: first related work in the area of HDR visualization in mobile devices is presented, then the design of the experimental approaches, the test description, the player characteristics and the parameters evaluated is described. Finally, the results of the experiment are shown and discussed, followed by some conclusions and suggestions for future work.

2. Background

This section will be composed with two parts: first we will make a brief explanation about all the TMOs used in this experiment; then we will present a brief description about modern mobile devices, and a more detailed description about the devices used in the experiment.

2.1 Tone mapping

For the experiments, two TMOs were considered and that have been termed "Auto Tone-mapping" and "Exposure". The "Auto Tone-mapping" mode is based on a logarithmic equation that takes in consideration the pixel values and multiplies it by the logarithmic mean luminance value. The "Exposure" is based on a simplified version of the Photographic Tone Reproduction for Digital Images [RSSF02]. The simplification we make allows us to dynamically configuring the factor coefficient in order to let the user "navigate" through the dynamic range, adjusting the exposure as he pleases on a scale of -10 to 10. False Colour gives a quick idea of the lighting within a scene distribution by graduating it on a luminance scale and representing it in different colours [EL13].

The Drago TMO, is an adaptive logarithmic TMO that simulates the human response to light, by doing a logarithmic compression of luminance values, and through an adaptive variance of logarithmic bases of 2 and 10 it provides a good preservation of details and contrast [DMAC03]. The method firstly scales the scene luminance to brightness luminance to find a scale factor and then interpolates the luminance to obtain significant compression levels while preserving details and contrast. In order to compensate for nonlinearities, a gamma correction is applied as a last step.

Tumblin & Rushmeier's TMO is based on Steven and Steven's work on brightness and takes in account the characteristics of the HVS. This TMO uses a sensation-preserving converter to reproduce the brightness and produce plausible outcomes [TR93].

The model of visual adaptation for realistic image synthesis developed by Ferwerda et al. is based on psychophysical experiments and on the HVS characteristics. This TMO uses TVI functions and it "captures the changes in threshold visibility, colour appearance, visual acuity, and sensitivity over time that is caused by the visual system's adaptation mechanisms" [FPSG96]. The final result is achieved by a linear combination of photopic and scotopic vision to achieve the mesopic vision.

Ward's Global TMO finds the proportionality between the world luminance and the display luminance [WAR94]. For that, it uses maximum display luminance and the world adaptation and multiplies it by a scaling factor to obtain the display luminance value of a pixel. The operator, Filmic, is based on Haarm-Pieter Duiker's curve (Hable) and has been used in cinematic productions, such as Fantastic Four, or games, including Unleashed. The TMO measures the response curve and creates a function that approximately would match to the film curve.

Table 1. *2013 state of the art smartphones specifications*

			CPU		GPU		Display				
Brand	Model	RAM (GB)	Cores	Clock (GHz)	Cores	Speed (MHz)	Technology	Size	Pixel Arrangment	Resolution	PPI
Apple	iPhone 5	1	2	1.3	3	325	IPS LCD	4'	RGB	1136×640	326
Samsung	Galaxy S3	1	4	1.4	4	440	Super AMOLED HD	4.8'	PenTile	1280×720	306
Nokia	Lumia920	1	2	1.7	?	400	IPS LCD	4.5'	RGB	1280×768	332
Google	Nexus 4	2	4	1.7	?	?	IPS LCD	4.7'	RGB	1280×768	320
HTC	One X+	1	4	1.6	?	520	Super LCD 2	4.7'	RGB	1280×720	312

Table 2. *2013 state of art tablets specifications*

			CPU		GPU		Display			
Brand	Model	RAM (GB)	Cores	Clock (GHz)	Cores	Speed (MHz)	Techno-logy	Size	Resolu-tion	PPI
Apple	iPad 4	1	2	1.4	4	300	IPS LCD	9.7'	2048×1536	326
Samsung	Galaxy Tab 2	1	2	1	8	333	LCD	10.1'	1280×800	149
Asus	Transformer Pad Infinity	1	4	1.6	12	333	Super IPS+	10.1'	1920×1200	332
Google	Nexus 10	2	2	1.7	4	533	Super PLS	10'	2560x1600	300

Schlick's TMO is based on quantization technics and knowledge about human vision. It was designed to perform a simple and fast mapping to generate high realistic images through a non-uniform quantization process based on the lowest luminance levels of a display that can be perceived by the HVS [Sch94].

2.2. State of the Art Mobile devices

Mobile devices may be considered compact visual computing powerhouses [PCG*09]. Tables 1 and 2 present the main specifications of some state of the arte mobile devices: namely RAM, CPU, GPU and Displays.

3. Experiment

The main goal of this experiment was to evaluate the HDR video performance on Mobile devices. A prototype was thus implemented in iOS capable of playing HDR videos.

3.1 Videos Tested

Ten different videos were tested. Their characteristics can be seen in Table 3 and their thumbnails in Figure 1.

Figure 1 - *Thumbnails of each of the videos, from 1 to 10.*

Table 3 - *HDR videos tested.*

Video	Length (sec)	Resolution	Avg. Min. Lum.	Avg. Max. Lum.	Avg. Lum.	Encoded FPS
1	10	HD	$5.11e^{-11}$	3.2908	0.1247	30
2	24	HD	0.003443	0.83725	0.4228	30
3	15	HD	0.007253	80.7355	0.0974	30
4	45	HD	0.005266	0.57201	0.0632	30
5	8	HD	0	4.3457	0.1278	30
6	69	HD	0.005892	262.2425	0.2249	30
7	18	HD	0.001019	2.055	0.0483	30
8	30	HD	0.002419	31.69	0.0704	30
9	21	HD	0.004891	137.865	0.0891	30
10	9	FHD	0.001154	6.9655	0.4208	12

3.2 TMOs Tested

The tone mappers implemented in the viewer were: (1) Exposure, (2) False Colour, (3) Tone-mapped, (4) Drago, (5) Logarithmic, (6) Exponential, (7) Tumblim, Rushmeier, (8) Ferwerda, (9) Ward Global, (10) Filmic, (11) Schlick.

Each video was played five times using the same tone mapper and results are recorded so an average of the frames per second was gathered. The TMOs were applied in each frame separately before displaying.

3.3 Devices Tested

Two mobile devices were used: Apple iPhone 5 and Apple iPad 4. These devices were chosen because they were the newest devices released with iOS.

4. Results

In this section we present the results obtained in the two devices tested, it's showed the average FPS in both devices and the battery consumption of the experiment.

4.1 iPhone 5

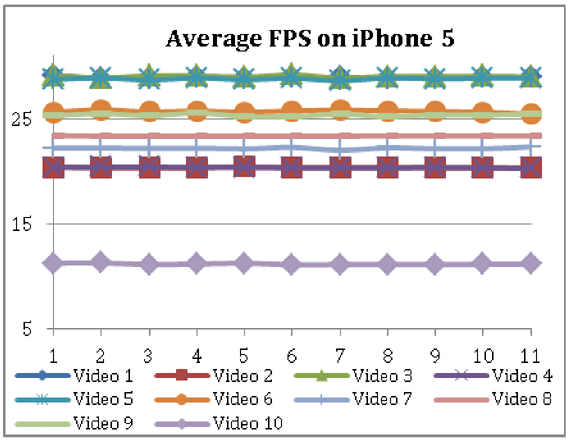

Figure 2 - *Average FPS achieved by every TMO for each video with iPhone 5.*

The iPhone used in this experience had the latest iOS version (iOS 6.1.2). The test lasted for four hours and forty-five minutes. The experiment started with 100% battery level and 20% was reached after around 3 hours of the test.

In figure 2 is shown the average of FPS that was obtained for each TMO/video. As one can see, the best performance is achieved with video 1, video 3, video 5 and video 10 where the average FPS is close to 30 FPS. For this test the best average FPS attained was with video 3 with Exponential TMO.

4.2 iPad 4

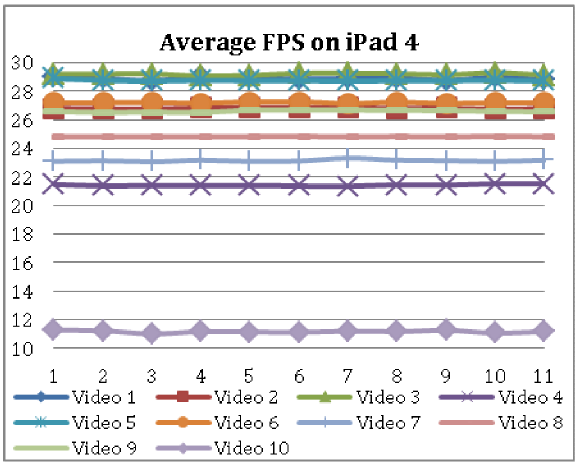

Figure 3 - *Average FPS achieved by every TMO for each video with iPad 4*

The OS system of iPad used was the latest iOS (6.1.1). Three hours and thirty minutes were required to complete the test with this device. The battery consumption this device was satisfactory, with the whole test only draining 50% of the battery level.

The best average FPS achieved was 29.31 with video 3 and Filmic TMO. The results are slightly better than the iPhone 5 results.

5. Conclusions

With this experiment we wanted to know if current smartphones and tablets had the capabilities of playing HDR content. From the results obtained we can see that the performance of the devices varies greatly depending on the content being played, however it is possible to achieve frame rates over 24 FPS. This is the PAL standard and thus one can say that is already possible to have HDR video playback on mobile devices.

From the state of the art devices presented in section 2 we can see that there are already some more powerful devices than the ones tested and thus we can expect these will probably be able to achieve even better results.

The similar results for different tone mappers for the same video is due to the fact every tone mapper is global, and thus only the complexity of the tone mapper affects the performance.

Future work will extend this study to evaluate other devices, for example, older devices such as iPad 2 and iPhone 4. In addition we will also implement a selection of local TMOs.

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