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HDR Tone-Mapping

PARALLEL ARCHITECTURE AND DISTRIBUTED PROGRAMMING PROJECT REPORT

Submitted by

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in partial fulfillment for the requirement of 7th Semester Parallel Architecture and Distributed Programming(18CS73)

Under the guidance of

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Academic Year 2021-22

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

RV COLLEGE OF ENGINEERING®, BENGALURU-59
(Autonomous Institution Affiliated to VTU, Belagavi)

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

DECLARATION

We, Atreya Bain and Chirag Bapat, students of eighth semester B.E., department of CSE, RV College of Engineering, Bengaluru, hereby declare that the minor project titled **'HDR Tone-Mapping'** has been carried out by us and submitted in partial fulfilment for the award of degree of Bachelor of Engineering in Computer Science and Engineering during the year 2021-22.

Further we declare that the content of the report has not been submitted previously by anybody for the award of any degree or diploma to any other university.

We also declare that any Intellectual Property Rights generated out of this project carried out at RVCE will be the property of RV College of Engineering, Bengaluru and we will be one of the authors of the same.

Place: Bengaluru
Date:

Name **Signature**

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CERTIFICATE

Certified that the project work titled 'HDR Tone-Mapping' is carried out by Atreya Bain(1RV18CS030), Chirag Bapat(1RV18CS048), who are bonafide students of RV College of Engineering®, Bengaluru, in partial fulfillment of the curriculum requirement of 7$^{\text{th}}$ Semester Parallel Architecture and Distributed Programming during the academic year **2021-22**. It is certified that all corrections/suggestions indicated for the internal Assessment have been incorporated in the report deposited in the departmental library. The report has been approved as it satisfies the academic requirements in all respect as prescribed by the institution.

Signature of faculty in-charge

Head of the Department
Dept. of CSE, RVCE

External Examination

Name of Examiners **Signature with date**

1.

2.

Acknowledgement

Any achievement, be it scholastic or otherwise does not depend solely on the individual efforts but on the guidance, encouragement and cooperation of intellectuals, elders and friends. A number of personalities, in their own capacities have helped me in carrying out this project work and, I would like to take this opportunity to thank them all.

I deeply express my sincere gratitude to my guide **Dr. Minal Moharir**, Associate Professor, Department of Computer Science and Engineering, RVCE, Bengaluru, for his able guidance, regular source of encouragement and assistance throughout this project.

I would like to thank **Dr. Ramakanth Kumar P**, Head of Department, Computer Science and Engineering, R.V.C.E, Bengaluru, for his valuable suggestions and expert advice.

First and foremost I would like to thank **Dr. Subramanya K. N**, Principal, R.V.C.E, Bengaluru, for his moral support towards completing my project work.

I thank my Parents, and all the Faculty members of Department of Computer Science and Engineering for their constant support and encouragement.

Last, but not the least, I would like to thank my peers and friends who provided me with valuable suggestions to improve my project.

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1 Introduction

High dynamic range (HDR) is a dynamic range higher than usual, synonyms are wide dynamic range, extended dynamic range, expanded dynamic range. The term is also the name of some of the technologies or techniques allowing to achieve high dynamic range images, videos, or audio. The dynamic range of an image is the range of luminosity between the brightest area and the darkest area of that image.

Modern movies have often been filmed with cameras featuring a higher dynamic range, and legacy movies can be converted even if manual intervention would be needed for some frames (as when black-and-white films are converted to color). Also, special effects, especially those that mix real and synthetic footage, require both HDR shooting and rendering. HDR video is also needed in applications that demand high accuracy for capturing temporal aspects of changes in the scene. This is important in monitoring of some industrial processes such as welding, in predictive driver assistance systems in automotive industry, in surveillance video systems, and other applications.

Tone-Mapping is a technique used in image processing and computer graphics to map one set of colors to another to approximate the appearance of high-dynamic-range images in a medium that has a more limited dynamic range. HDR images, contain high precision image data, and is represented by 32 bit or 64 bit floating point RGB values. To display such images, the numbers need to be scaled into the traditional 8-bit/10-bit RGB representation so that a standard monitor may display it on the screen. There are two methods of mapping-

- Linearly scale - Bright parts of the image will make the image mostly dark and unviewable.
- Tonemap - Scale the brightness so that the image is still viewable.

Hence, the best way of preserving brightness and viewability of the data is to process it via a tonemapping algorithm, and convert it into a standard dynamic range content, that can be easily displayed by traditional monitors.

1.1 Problem Statement

Implement HDR Tone-Mapping to display HDR images, using the Luminance remapping technique on a GPU using CUDA.

1.2 CUDA

CUDA (Compute Unified Device Architecture) is a parallel computing platform and programming model created by NVIDIA and implemented by the graphics processing units (GPUs) that they produce.

- The CUDA platform is accessible to software developers through CUDA accelerated libraries, compiler directives and extensions to industry-standard programming languages, including C, C++ and Fortran.
- CUDA gives developers access to the virtual instruction set and memory of the parallel computational elements in CUDA GPUs. Unlike CPUs, however, GPUs have a parallel throughput architecture that emphasizes executing many concurrent threads slowly, rather than executing a single thread very quickly.
- This approach of solving general-purpose problems on GPUs is known as GPGPU (General Purpose Graphics Processing Unit)

Parallel computing presents with its own shortcomings. GPGPU presents itself with some of these challenges:

- No recursive functions
- Limited CPU$<->$GPU bandwidth (Has to pass through PCI Bus
- CUDA is a proprietary Nvidia product
- Applications which depend upon previous computed data cannot be implemented trivially on CUDA.

1.3 Why Parallelise

Tonemapping provides for the perfect opportunity for image processing. Such image processing tasks are repetitive, and can take advantage of GPU parallelism very effectively.

- Tone-mapping is done for images, where there are millions of pixels present.
- Processing HDR images and videos can become a repetitive and taxing job for the CPU, and this is best offloaded to the GPU.

The algorithm chosen here, involves luminance scaling, and presents a few regions of code that can be parallelized:

- Prefix sum scanning: Involves building a cdf of the image's color data. A popular parallel algorithm for this is the Hillis Steele's parallel scan algorithm.
- Applying the global tonemap operator: Global tonemap operators provide tonemapping via global image characteristics, which are not image region specific and hence can be easily paralellized.

2 Methodology

2.1 Basic principle

There are two ways to bring about tone-mapping:

1. Global operators: Non-linear functions based on the luminance and other global variables of the image.
2. Local operators: The parameters of the non-linear function change in each pixel, according to features extracted from the surrounding parameters. Those algorithms are more complicated; they can show artifacts, but they can (if used correctly) provide the best performance, since human vision is mainly sensitive to local contrast.

A good way to begin with is by using the Luminance model:

- The YC_bC_r color space is a popular color space used in TVs, as it splits out a luminance component (the black and white) and 2 color components.
  - Traditionally, the color TVs would use this as a way of displaying color, and the B&W TVs would simply display only the luminance component, saving on hardware and bandwidth costs.
- The Y component can be scaled here accordingly to change the brightness of that region of the image.

Here is the general description of the procedure:

1. Convert the image the the YC_bC_r space.

$$\begin{bmatrix} Y' \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.2126 & 0.7152 & 0.0722 \\ -0.1146 & -0.3854 & 0.5 \\ 0.5 & -0.4542 & -0.0458 \end{bmatrix} \begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} \tag{1}$$

2. Construct a histogram of brightness values.

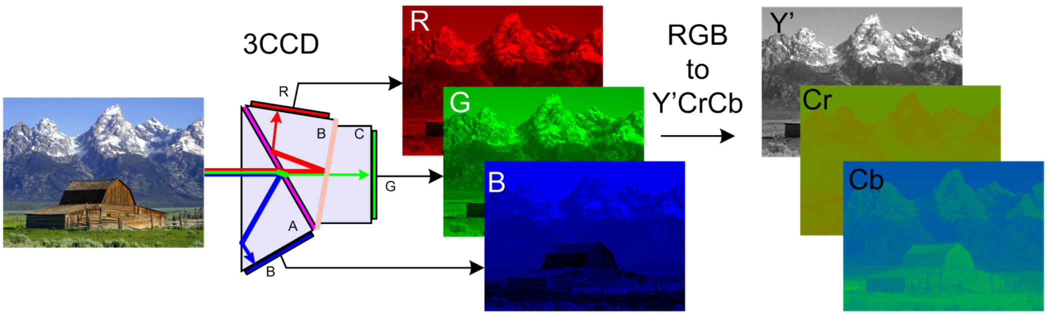


Figure 1: RGB to YC_bC_r

3. Construct a CDF from the histogram.

4. Normalize the CDF, scaling the values of luminance.

5. Taking the log of the luminance, scale it according to the histogram CDF generated.

6. Process and convert back to RGB model as required.

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} 1 & 0 & 1.5748 \\ 1 & -0.1873 & -0.4681 \\ 1 & 1.8556 & 0 \end{bmatrix} \begin{bmatrix} Y' \\ Cb \\ Cr \end{bmatrix} \tag{2}$$

3 Result and Analysis

3.1 Outputs

The parallel implementation that was created was verified against the serial implementation by diffing the images created. Some example outputs have been shown below, with the left hand side being the linear mapped images, and the right hand side being the parallel tonemapping implementation.

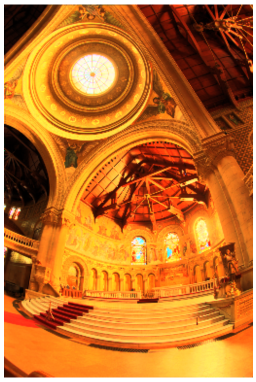
3.2 Analysis

- Prefix sum calculation is a bottleneck - This can be done efficiently with the Hillis Steele prefix calculation algorithm.

- Serial and parallel implementation can be proven to be similar - Use differences to measure.

- 8-10x improvements in performance over naive implementations.

(a) Input image



(b) Output image

Figure 2: Memorial HDR

(a) Input image

(b) Output image

Figure 3: Golden Gate HDR

3.2.1 Execution times

P	Serial	Parallel	Acceleration factor
GoldenGate	16.509000	1.228768	13.435409
Memorial	1.235000	0.200224	6.168092
Rec709(Flower)	3.198000	0.333056	9.601989
je_gray_park_4k	114.597000	10.039872	11.414189

Table 1: Execution times for various HDR images

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