

Part 2: Report Deliverables

1. Provide a copy of your
 1. Original image
 2. Resized, greyscale image
 3. OpenCV DCT result
 4. Naive DCT result
 5. 1D DCT result
2. Use the `time` command to report how long each of the OpenCV, Naive, and 1D approaches take to execute (remember to remove the image display / keypress wait!).

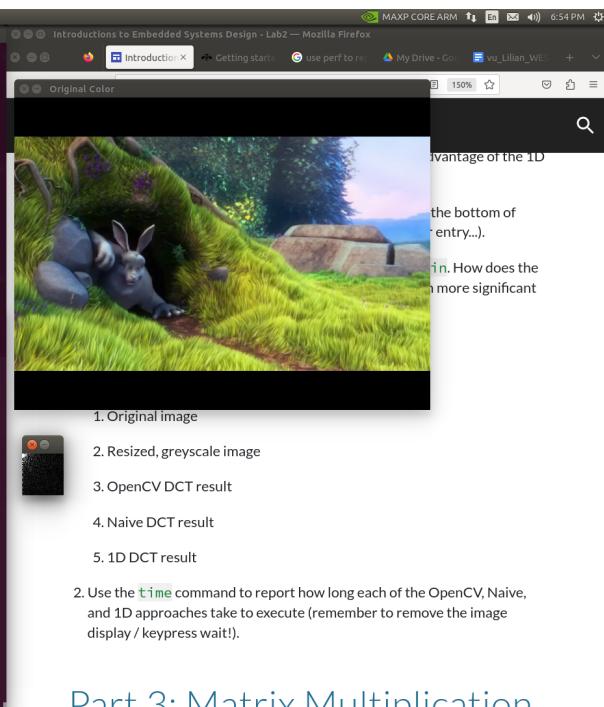
OpenCV DCT Time: Too long

Custom Naive DCT Time: 1329943s

Optimized 1D DCT Time: 117857s

OpenCV DCT Output

```
Original Color
[...]
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct
 2d_dct_2d_dct_regular.zip dct lab_pynq_basics README.md
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct/
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ cd dct/
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
 Gtk-Message: 10:51:48.167: Failed to load module "canberra-gtk-module"
 Built-in Native
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
 Gtk-Message: 10:51:51.513: Failed to load module "canberra-gtk-module"
 Built-in Native
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ Part 4: Report Deliverables
 bash: Part: command not found
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ For each algorithm (Native and Separable with an
 al threshold), report the execution time. For each algorithm (Native and Separable with an
 count cache misses, and L1 cache.
 bash: syntax error near unexpected token `('
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ Extra Credit: Report on at least 2 addition
 al metrics from perf. Explain what these metrics measure and why they are the same/different for each
 algorithm.
 bash: Extra: command not found
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ For the Separable, MM, and BMM implementations,
 experiment with various sizes. No need to do so for the Native implementation as it will take a signif-
 icant amount of time.
 bash: ./dct: command not found
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ You may need to change the FRAME_NUMBER to
 see a noticeable difference in some of the optimizations. Feel free to experiment.^C
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
 Gtk-Message: 10:53:00.237: Failed to load module "canberra-gtk-module"
 Built-in Native
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ vlm src/
 lab_dct.cxx main.cxx
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ vlm src/main.cxx
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ build_dct displayImages.lpybn image.tif include Makefile src
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
 Gtk-Message: 10:53:00.237: Failed to load module "canberra-gtk-module"
 Built-in Native
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
 Gtk-Message: 10:53:12.920: Failed to load module "canberra-gtk-module"
 Built-in Native
 ^C
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ vlm src/main.cxx
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ make
 g++ -O1 -finclude_next -Isrc/main.cxx -Isrc/build/main.o
 g++ -O1 -finclude_next -Isrc/main.cxx -Isrc/build/main.o
 -lopencv_imgcodecs -lopencv_videoio
 wes-237@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
 Gtk-Message: 10:54:20.800: Failed to load module "canberra-gtk-module"
 Open CV DCT
```



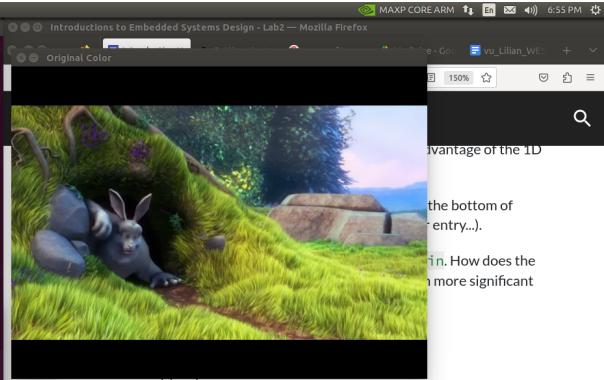
Part 3: Matrix Multiplication

Custom Naive DCT Output

It took 1329943s

Built-in Native
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct
Gtk-Message: 18:52:11.515: Failed to load module "canberra-gtk-module"
Built-in Native
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts Part 4: Report Deliverables
 bash: Part: command not found
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts For each algorithm (Naive and Separable with an d without LUTs; Matrix Multiplication, Block Matrix Multiplication), use perf to report on the cycle count, cache misses, and L1 cache.
 bash: syntax error near unexpected token `(' wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts Extra Credit: Report on at least 2 addition metrics from perf. Explain what these metrics measure and why they are the same/different for each algorithm.
 bash: Extra: command not found
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts For the Separable, MM, and BMM implementations, experiment with various sizes. No need to do so for the Native implementation as it will take a significant amount of time.
 bash: For: command not found
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts You may need to change the FRAME_NUMBER to see a noticeable difference in some of the optimizations. Feel free to experiment.%c
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts %c
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts %c
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts ./dct 1
 Gtk-Message: 18:52:23.337: Failed to load module "canberra-gtk-module"
 Built-in Native
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts vim src/
 lib/main.cxx lib/main.CXX
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts vim src/main.cxx
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts ls
 build dict displayingImages.ipynb image.tif include Makefile src
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts ./dct 1
 Gtk-Message: 18:53:00.733: Failed to load module "canberra-gtk-module"
 Built-in Native
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts ./dct 1
 Gtk-Message: 18:53:12.926: Failed to load module "canberra-gtk-module"
 Built-in Native
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts vim src/main.cxx
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts make
 g++ -O1 -Iinclude/c src/main.cxx -o build/main.o
 g++ -O1 -Iinclude/build/main/o build/lab/dct.o -o dct -lopencv_core -lopencv_highgui -lopencv_imgproc
 -lopencv_imagedecode -lopencv_videoeo
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts ./dct 1
 Gtk-Message: 18:54:20.806: Failed to load module "canberra-gtk-module"
 Open CV DCT

^C
 wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dcts ./dct 2
 Gtk-Message: 18:54:55.853: Failed to load module "canberra-gtk-module"
 CUSTOM NAME
 It took 1329943s



1. Original image
 2. Resized, greyscale image
 3. OpenCV DCT result
 4. Naive DCT result
 5. 1D DCT result

2. Use the `time` command to report how long each of the OpenCV, Naive, and 1D approaches take to execute (remember to remove the image display / keypress wait!).

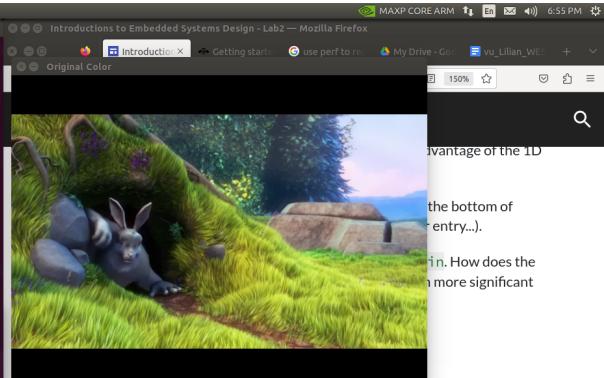
Part 3: Matrix Multiplication

Optimized 1D DCT Output

Original Color

```
bash: Part: command not found
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$          For each algorithm (Naive and Separable with an
d without LU), Matrix Multiplication, Block Matrix Multiplication), use perf to report on the cycle
count, cache misses, and L1 cache.
bash: syntax error near unexpected token `('
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$          Extra Credit: Report on at least 2 additional
perf metrics from perf. Explain what these metrics measure and why they are the same/different for each
algorithm.
bash: Extra: command not found
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$          For the Separable, MM, and BMM implementations,
experiment with various rows. No need to do so for the Native implementation as it will take a signifi-
cant amount of time.
bash: For: command not found
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$          You may need to change the FRAME_NUMBER to
see the noticeable difference in some of the optimizations. Feel free to experiment.^C
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$ ^C
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$ ^C
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
Gtk-Message: 18:52:23.337: Failed to load module "canberra-gtk-module"
Built-in Native
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$ vim src/
Ubuntu:~$ vim src/main.cxx
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$ vim src/main.cxx
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$ ls
build dict displayimages.ipynb image.tif include Makefile src
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
Gtk-Message: 18:53:00.233: Failed to load module "canberra-gtk-module"
Built-in Native
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
Gtk-Message: 18:53:12.926: Failed to load module "canberra-gtk-module"
Built-in Native
^C
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$ vim src/main.cxx
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$ make
0++ -O1 -Iinclude <src/main.cxx> -o build/main.o
g++ -O1 -Iinclude build/main.o build/lab_dct.o -o dct -lopencv_core -lopencv_highgui -lopencv_imgproc
-lopencv_imgcodecs -lopencv_videoio
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 1
Gtk-Message: 18:54:20.800: Failed to load module "canberra-gtk-module"
Open CV DCT

^C
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 2
Gtk-Message: 18:54:53.853: Failed to load module "canberra-gtk-module"
Ubuntu:~$ Custom Name
It took 1329943s
^C
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/dct$ ./dct 3
Gtk-Message: 18:55:20.701: Failed to load module "canberra-gtk-module"
It took 117857s
```



1. Original image
 2. Resized, greyscale image
 3. OpenCV DCT result
 4. Naive DCT result
 5. 1D DCT result

2. Use the `time` command to report how long each of the OpenCV, Naive, and 1D approaches take to execute (remember to remove the image display / `keypress wait()`)

Part 3: Matrix Multiplication

Part 3: Report Deliverables (Performance)

Compare the performance of your function to library implementation.

Use any benchmarks covered from WES237A (please mention PMU) to clearly describe in what ways each function is better than the others.

I used the gray image Mat array and used openCV to compare with my matrix multiplication function.

I used #ifdef REG inside /include/main.h to indicate that I am doing a regular Matrix multiplication and not a DCT.

Ideal_matmult = gray*gray;

Lilian_mat = lilian_matmult(gray);

```
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/2d_dct$ perf stat -e cycles,cache-misses,L1-dcache-loads,L1-dcache-stores ./2d_dct
WES237B lab 2
-----CUSTOM STUDENT DCT-----
W/ REG...
RMSE: 0.0001
Execute time: 1.25349
-----MATRIX MULTIPLICATION-----
W/ REGULAR...
MATMULT RMSE: 0.0000
Execute time: 0.00122356
Gtk-Message: 18:28:08.020: Failed to load module "canberra-gtk-module"
-----CUSTOM STUDENT DCT-----
W/ REG...
RMSE: 0.0001
Execute time: 1.33703
-----MATRIX MULTIPLICATION-----
W/ REGULAR...
MATMULT RMSE: 0.0000
Execute time: 0.00103946
-----CUSTOM STUDENT DCT-----
W/ REG...
RMSE: 0.0001
Execute time: 1.26283
-----MATRIX MULTIPLICATION-----
W/ REGULAR...
MATMULT RMSE: 0.0000
Execute time: 0.00110765
-----CUSTOM STUDENT DCT-----
W/ REG...
RMSE: 0.0001
Execute time: 1.27425
-----MATRIX MULTIPLICATION-----
W/ REGULAR...
MATMULT RMSE: 0.0000
Execute time: 0.00140481
-----CUSTOM STUDENT DCT-----
W/ REG...
RMSE: 0.0001
Execute time: 1.25386
-----MATRIX MULTIPLICATION-----
W/ REGULAR...
MATMULT RMSE: 0.0000
Execute time: 0.00103716
-----NVIDIA VPL Demos-----  
Performance counter stats for './2d_dct':  
13,237,998,656      cycles  
    7,451,936      cache-misses  
    7,451,936      L1-dcache-load-misses      #      0.21% of all L1-dcache hits  
  3,585,059,575      L1-dcache-loads  
  3,585,059,575      L1-dcache-stores  
  
       6.815016123 seconds time elapsed
```

Pulling it all together, and some Quality Assurance

You should have 4 algorithms (Naive, Separable (in-lab / Part 2 optimization), Matrix Multiplication, and Block Matrix Multiplication).

All 4 algorithms must have RMSE lower than 0.001.

All 4 algorithms must be able to choose to use LUT for DCT coefficients and scaling. Command-line arguments or simply `#ifdefs` are fine.

Part 4: Report Deliverables

1. For each algorithm (Naive and Separable with and without LUTs; Matrix Multiplication, Block Matrix Multiplication), use `perf` to report on the cycle count, cache misses, and L1 cache.
 - Extra Credit: Report on at least 2 additional metrics from `perf`. Explain what these metrics measure and why they are the same/different for each algorithm.
2. For the Separable, MM, and BMM implementations, experiment with various sizes. No need to do so for the Naive implementation as it will take a significant amount of time.
 - You may need to change the `FRAME_NUMBER` to see a noticeable difference in some of the optimizations. Feel free to experiment.

To set the settings for the different modes for LUT or without, Block Matrix multiplication or not, regular matrix multiplication and regular DCT or not, modify the main.h:

```

//< main.h > @ Home - Pictures < / >
// Lab2
// Recent:
// Created by Alireza on 7/6/16.
// Copyright © 2016 Alireza. All rights reserved.
// Desktop
#ifndef main_h
#define main_h
#include <iostream>
#include <stdio.h>
#ifdef _WIN32
#include <Windows.h>
#else
#include <unistd.h>
#endif
#include <opencv2/opencv.hpp>
#include <opencv2/core/core.hpp>
#include <opencv2/highgui/highgui.hpp>
#include <opencv2/imgproc/imgproc.hpp>

#include <math.h>

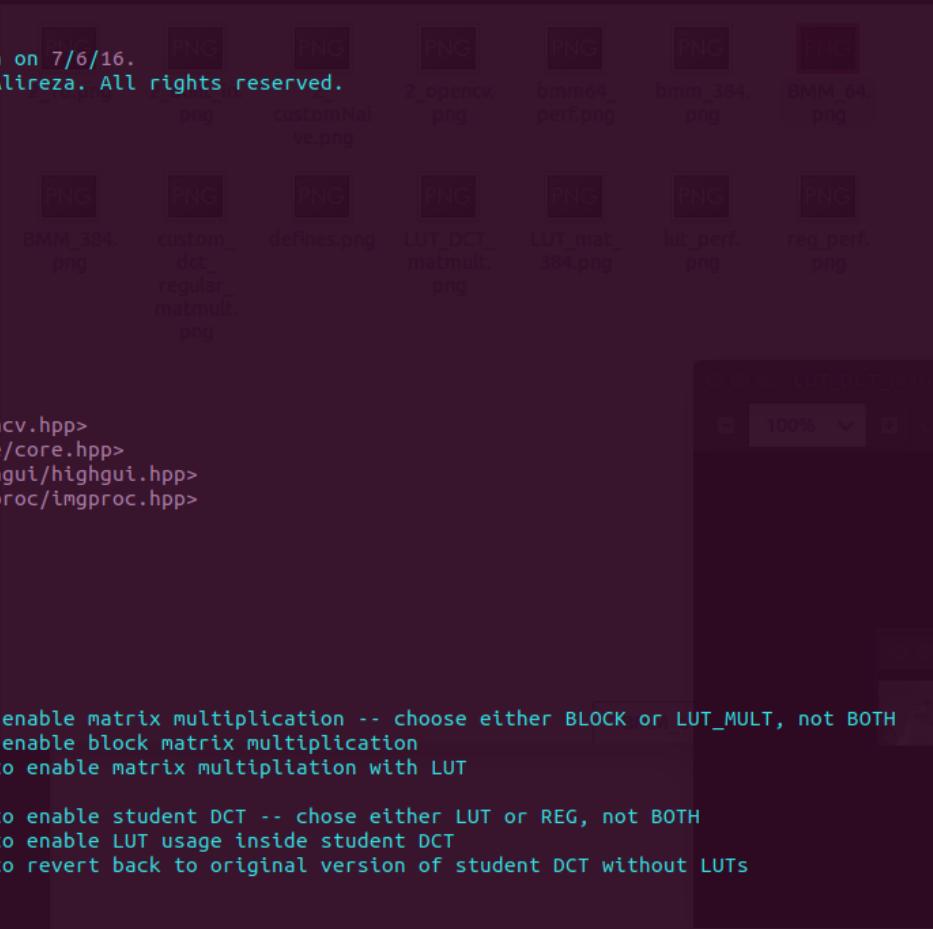
using namespace cv;

#define WIDTH 64
#define HEIGHT 64

#define MATMULT //to enable matrix multiplication -- choose either BLOCK or LUT_MULT, not BOTH
#define BLOCK //to enable block matrix multiplication
//#define LUT_MULT //to enable matrix multiplication with LUT

#define CUST_DCT //to enable student DCT -- chose either LUT or REG, not BOTH
//#define LUT_C //to enable LUT usage inside student DCT
//#define REG //to revert back to original version of student DCT without LUTs

/* student DCT */
Mat student_dct(Mat input);
void initDCT(int WIDTH, int HEIGHT);
Mat mat_mult(Mat input1, Mat input2);
Mat block_mat_mult(Mat input1, Mat input2);
Mat lillian_matmult(Mat input);
#endif /* main_h */
~
```



Perf output of Gray:

Overall through perf, I can see how the block size in the cache can make a difference in the hits and misses as the data is being multiplied. The LUT implementation is fast but the block matrix multiplication was a lot faster by 1 second and the number of cycles until completion.

Regular DCT vs regular Matrix mult

```
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/2d_dct$ perf stat -e cycles,cache-misses,L1-dcache-loads,L1-dcache-stores ./2d_dct
WES237B lab 2
-----CUSTOM STUDENT DCT-----
W/ REG...
RMSE: 0.0001
Execute time: 1.25349
-----MATRIX MULTIPLICATION-----
W/ REGULAR...
MATMULT RMSE: 0.0000
Execute time: 0.00122356
Gtk-Message: 18:28:08.020: Failed to load module "canberra-gtk-module"
-----CUSTOM STUDENT DCT-----
W/ REG...
RMSE: 0.0001
Execute time: 1.33703
-----MATRIX MULTIPLICATION-----
W/ REGULAR...
MATMULT RMSE: 0.0000
Execute time: 0.00103946
-----CUSTOM STUDENT DCT-----
W/ REG...
RMSE: 0.0001
Execute time: 1.26283
-----MATRIX MULTIPLICATION-----
W/ REGULAR...
MATMULT RMSE: 0.0000
Execute time: 0.00110765
-----CUSTOM STUDENT DCT-----
W/ REG...
RMSE: 0.0001
Execute time: 1.27425
-----MATRIX MULTIPLICATION-----
W/ REGULAR...
MATMULT RMSE: 0.0000
Execute time: 0.00140481
-----CUSTOM STUDENT DCT-----
W/ REG...
RMSE: 0.0001
Execute time: 1.25386
-----MATRIX MULTIPLICATION-----
W/ REGULAR...
MATMULT RMSE: 0.0000
Execute time: 0.00103716
-----NVIDIA VPL Demos-----  

Performance counter stats for './2d_dct':
      13,237,998,656      cycles
          7,451,936      cache-misses
          7,451,936      L1-dcache-load-misses      #      0.21% of all L1-dcache hits
      3,585,059,575      L1-dcache-loads
      3,585,059,575      L1-dcache-stores

```

6.815016123 seconds time elapsed

LUT DCT vs LUT Mat Mult

```
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/2d_dct$ perf stat -e cycles,cache-misses,L1-dcache-load-misses,L1-dcache-loads,L1-dcache-stores ./2d_dct
WES237B lab 2
-----CUSTOM STUDENT DCT-----
W/ LUT...
RMSE: 0.0001
Execute time: 0.0423323
-----MATRIX MULTIPLICATION-----
W/ LUT...
MATMULT RMSE: 0.0000
Execute time: 0.0015703
Gtk-Message: 19:18:58.775: Failed to load module "canberra-gtk-module"
-----CUSTOM STUDENT DCT-----
W/ LUT...
RMSE: 0.0001
Execute time: 0.042537
-----MATRIX MULTIPLICATION-----
W/ LUT...
MATMULT RMSE: 0.0000
Execute time: 0.00189158
-----CUSTOM STUDENT DCT-----
W/ LUT...
RMSE: 0.0001
Execute time: 0.0430745
-----MATRIX MULTIPLICATION-----
W/ LUT...
MATMULT RMSE: 0.0000
Execute time: 0.00181961
-----CUSTOM STUDENT DCT-----
W/ LUT...
RMSE: 0.0001
Execute time: 0.0428022
-----MATRIX MULTIPLICATION-----
W/ LUT...
MATMULT RMSE: 0.0000
Execute time: 0.00184051
-----CUSTOM STUDENT DCT-----
W/ LUT...
RMSE: 0.0001
Execute time: 0.043569
-----MATRIX MULTIPLICATION-----
W/ LUT...
MATMULT RMSE: 0.0000
Execute time: 0.00175532

Performance counter stats for './2d_dct':
      986,737,706      cycles
      8,001,384      cache-misses
      8,001,384      L1-dcache-load-misses    #    2.55% of all L1-dcache hits
     314,391,433      L1-dcache-loads
     314,391,433      L1-dcache-stores

      0.636721006 seconds time elapsed
```

LUT DCT vs Block Mat Mult 64

```
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/2d_dct$ perf stat -e cycles,cache-misses,L
misses,L1-dcache-loads,L1-dcache-stores ./2d_dct
WES237B lab 2
-----CUSTOM STUDENT DCT-----
W/ LUT...
RMSE: 0.0001
Execute time: 0.0438478
-----MATRIX MULTIPLICATION-----
W/ BLOCK...
MATMULT RMSE: 0.0000
Execute time: 0.00199603
Gtk-Message: 19:23:53.365: Failed to load module "canberra-gtk-module"
-----CUSTOM STUDENT DCT-----
W/ LUT...
RMSE: 0.0001
Execute time: 0.0578902
-----MATRIX MULTIPLICATION-----
W/ BLOCK...
MATMULT RMSE: 0.0000
Execute time: 0.00199516
-----CUSTOM STUDENT DCT-----
W/ LUT...
RMSE: 0.0001
Execute time: 0.0436568
-----MATRIX MULTIPLICATION-----
W/ BLOCK...
MATMULT RMSE: 0.0000
Execute time: 0.00196224
-----CUSTOM STUDENT DCT-----
W/ LUT...
RMSE: 0.0001
Execute time: 0.0426308
-----MATRIX MULTIPLICATION-----
W/ BLOCK...
MATMULT RMSE: 0.0000
Execute time: 0.00196592
-----CUSTOM STUDENT DCT-----
W/ LUT...
RMSE: 0.0001
Execute time: 0.0434375
-----MATRIX MULTIPLICATION-----
W/ BLOCK...
MATMULT RMSE: 0.0000
Execute time: 0.00208966

Performance counter stats for './2d_dct':
      980,995,277      cycles
      6,307,651      cache-misses
      6,307,651      L1-dcache-load-misses      #      2.00% of all L1-dcache hits
    315,088,003      L1-dcache-loads
    315,088,003      L1-dcache-stores

      0.658174737 seconds time elapsed
```

LUT Mat Mult vs Block Mat Mult 384

```
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/2d_dct$ perf stat -e cycles,cache-misses,L1-dcache-load
misses,L1-dcache-loads,L1-dcache-stores ./2d_dct 384
WES237B lab 2
-----MATRIX MULTIPLICATION-----
W/ LUT...
MATMULT RMSE: 0.0000
Execute time: 0.54035
Gtk-Message: 19:44:12.857: Failed to load module "canberra-gtk-module"
-----MATRIX MULTIPLICATION-----
W/ LUT...
MATMULT RMSE: 0.0000
Execute time: 0.586869
-----MATRIX MULTIPLICATION-----
W/ LUT...
MATMULT RMSE: 0.0000
Execute time: 0.526321
-----MATRIX MULTIPLICATION-----
W/ LUT...
MATMULT RMSE: 0.0000
Execute time: 0.564884
-----MATRIX MULTIPLICATION-----
W/ LUT...
MATMULT RMSE: 0.0000
Execute time: 0.549306

Performance counter stats for './2d_dct 384':

  6,223,774,332      cycles
      582,035,017    cache-misses
      582,035,017    L1-dcache-load-misses  #  42.61% of all L1-dcache hits
  1,366,067,721     L1-dcache-loads
  1,366,067,721     L1-dcache-stores

  3.228596125 seconds time elapsed
```

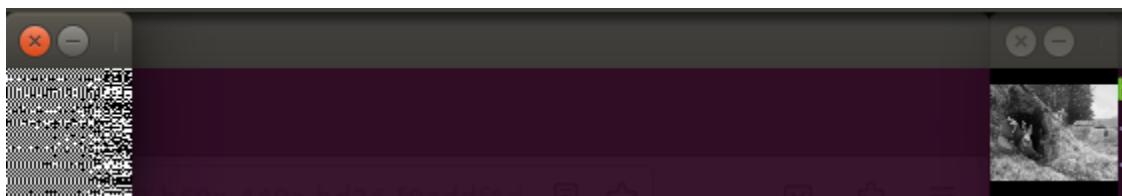
```
wes-237b@wes237b-tx2-3:~/wes237b_assignment2/2d_dct$ perf stat -e cycles,cache-misses,L1-dcache-load-misses,L1-dcache-loads,L1-dcache-stores ./2d_dct 384
WES237B lab 2
-----MATRIX MULTIPLICATION-----
W/ BLOCK...
MATMULT RMSE: 0.0000
Execute time: 0.341308
Gtk-Message: 19:45:34.240: Failed to load module "canberra-gtk-module"
-----MATRIX MULTIPLICATION-----
W/ BLOCK...
MATMULT RMSE: 0.0000
Execute time: 0.369383
-----MATRIX MULTIPLICATION-----
W/ BLOCK...
MATMULT RMSE: 0.0000
Execute time: 0.3592
-----MATRIX MULTIPLICATION-----
W/ BLOCK...
MATMULT RMSE: 0.0000
Execute time: 0.351826
-----MATRIX MULTIPLICATION-----
W/ BLOCK...
MATMULT RMSE: 0.0000
Execute time: 0.390184

Performance counter stats for './2d_dct 384':
      4,235,057,326      cycles
      311,191,500      cache-misses
      311,191,500      L1-dcache-load-misses    #  22.63% of all L1-dcache hits
      1,375,225,679      L1-dcache-loads
      1,375,225,679      L1-dcache-stores

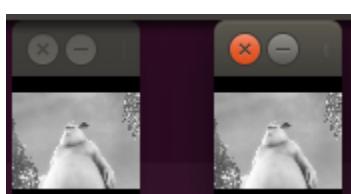
      2.265001657 seconds time elapsed
```

Output Pictures of Gray:

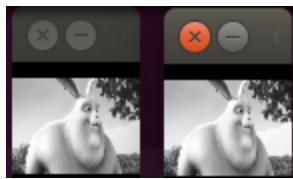
Regular DCT vs Regular Matrix Mult



LUT DCT vs LUT Mat Mult



LUT DCT vs Block Mat Mult 64



LUT DCT vs Block Mat Mult 384

