University of Colorado
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EXERCISE 4

BY

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All questions have been performed on Jetson Board

QUESTION 1

```
ubuntu@tegra-ubuntu:~$ lsusb
Bus 002 Device 011: ID 046d:0802 Logitech, Inc. Webcam C200
Bus 002 Device 008: ID 0461:4d51 Primax Electronics, Ltd 0Y357C PMX-MMOCZUL (B) [Dell Laser Mouse]
Bus 002 Device 007: ID 413c:2113 Dell Computer Corp.
Bus 002 Device 006: ID 214b:7000
Bus 002 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
Bus 001 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
Bus 003 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
ubuntu@tegra-ubuntu:~$ lsusb | grep C200
Bus 002 Device 011: ID 046d:0802 Logitech, Inc. Webcam C200
ubuntu@tegra-ubuntu:~$
```

The “lsusb” command is first run in order to display the USB buses in the system and the various devices connected to these buses. The “lsusb | grep C200” command is executed to confirm that the camera is connected.

```
ubuntu@tegra-ubuntu:~$ dmesg | grep video
[    0.534697] Linux video capture interface: v2.00
[    4.230610] usbcore: registered new interface driver uvcvideo
ubuntu@tegra-ubuntu:~$ dmesg | grep video
[    0.534697] Linux video capture interface: v2.00
[    4.230610] usbcore: registered new interface driver uvcvideo
[   69.008966] uvcvideo: Found UVC 1.00 device <unnamed> (046d:0802)
ubuntu@tegra-ubuntu:~$ dmesg | grep video
[    0.534697] Linux video capture interface: v2.00
[    4.230610] usbcore: registered new interface driver uvcvideo
[   69.008966] uvcvideo: Found UVC 1.00 device <unnamed> (046d:0802)
ubuntu@tegra-ubuntu:~$
```

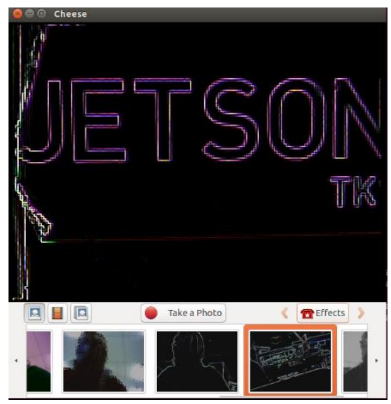
The “dmesg | grep video” command is executed in order to ensure that the USB device i.e. the camera was found.

QUESTION 2

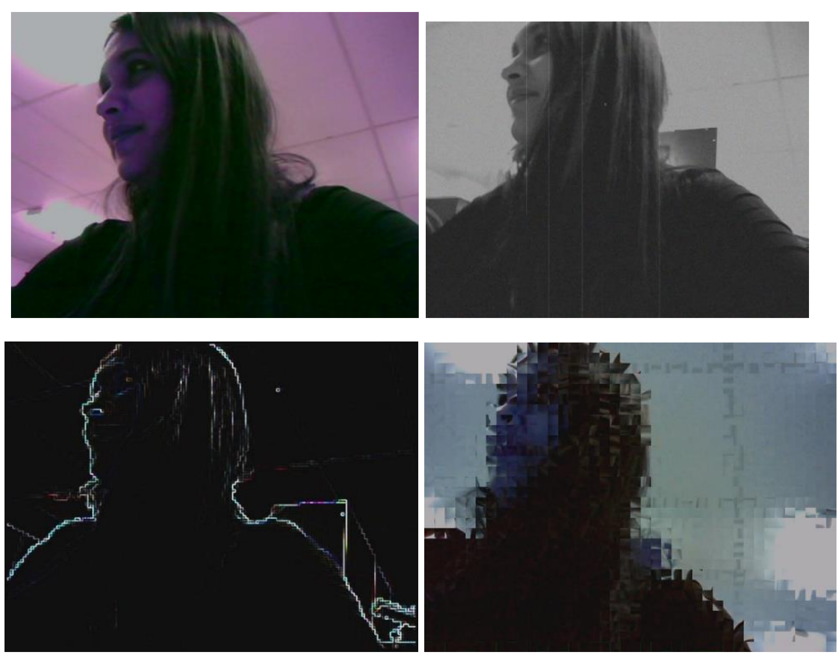
The Cheese Tool is installed and used as shown below:

```
ubuntu@tegra-ubuntu:~$ cheese

(cheese:12055): cheese-WARNING **: Internal data flow problem.: gstbasesink.c(3264): gst_base_sink_chain_unlocked (): /GstCameraBin:camerabin/GstWrapperCameraBinSrc:camera_source/GstBin:video_filter_bin/Cl
utterGstAutoVideoSink:cluttergstautovideosink0/ClutterGstVideoSink:cluttergstautovideosink0-actual-sink-clutter:
Received buffer without a new-segment. Assuming timestamps start from 0.

NvEglHandle: Unfreed handle of upon egl deinit: type=1 refcnt=1
NvEglHandle: Unfreed handle of upon egl deinit: type=2 refcnt=1
NvEglHandle: Unfreed handle of upon egl deinit: type=2 refcnt=1
ubuntu@tegra-ubuntu:~$ cheese
NvEglHandle: Unfreed handle of upon egl deinit: type=2 refcnt=1
NvEglHandle: Unfreed handle of upon egl deinit: type=1 refcnt=1
NvEglHandle: Unfreed handle of upon egl deinit: type=2 refcnt=1
ubuntu@tegra-ubuntu:~$ cheese

(cheese:12109): cheese-WARNING **: Internal data flow problem.: gstbasesink.c(3264): gst_base_sink_chain_unlocked (): /GstCameraBin:camerabin/GstWrapperCameraBinSrc:camera_source/GstBin:video_filter_bin/Cl
utterGstAutoVideoSink:cluttergstautovideosink0/ClutterGstVideoSink:cluttergstautovideosink0-actual-sink-clutter:
Received buffer without a new-segment. Assuming timestamps start from 0.


(cheese:12109): GVFS-RemoteVolumeMonitor-WARNING **: remote volume monitor with dbus name org.gtk.Private.UDisks2VolumeMonitor is not supported
NvEglHandle: Unfreed handle of upon egl deinit: type=2 refcnt=1
NvEglHandle: Unfreed handle of upon egl deinit: type=1 refcnt=1
NvEglHandle: Unfreed handle of upon egl deinit: type=2 refcnt=1
ubuntu@tegra-ubuntu:~$
```

Screenshot of capture using Cheese Tool:



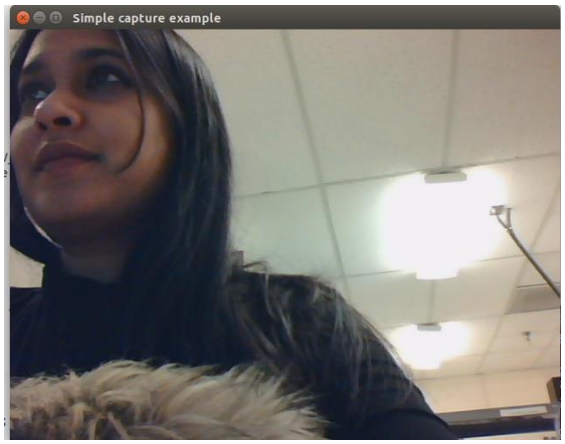
The various effects using the Cheese Tool:



QUESTION 3

Simpler Capture

```
ubuntu@tegra-ubuntu:~/Downloads/excercise 4/simpler-capture$ make
g++ -O0 -g   -c capture.cpp
g++  -O0 -g   -o capture capture.o `pkg-config --libs opencv` -L/usr/lib -lopencv_core -lopencv_flann -lopencv_video
ubuntu@tegra-ubuntu:~/Downloads/excercise 4/simpler-capture$ ls
capture  capture.cpp  capture.o  Makefile
ubuntu@tegra-ubuntu:~/Downloads/excercise 4/simpler-capture$ ./capture
```



This code is used for continuous streaming of picture using an infinite loop in which the image frame is captured, and it is checked if it is NULL which would result in break. cvNamedWindow API is used to create a window called Simple capture example and cvShowImage API is used to display the image in this named window. ESC key can be used to terminate the program.

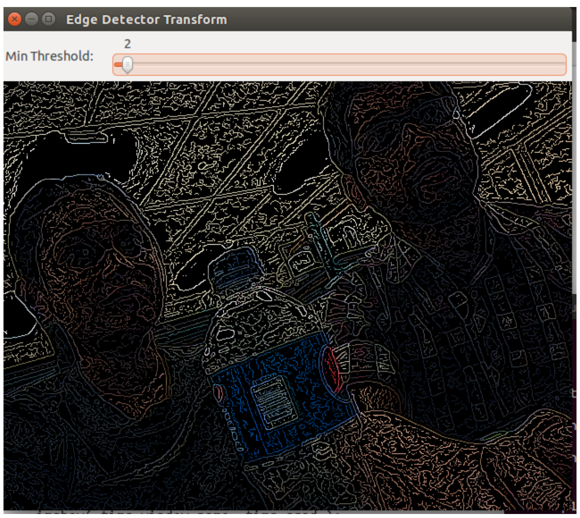
Simple Capture 2

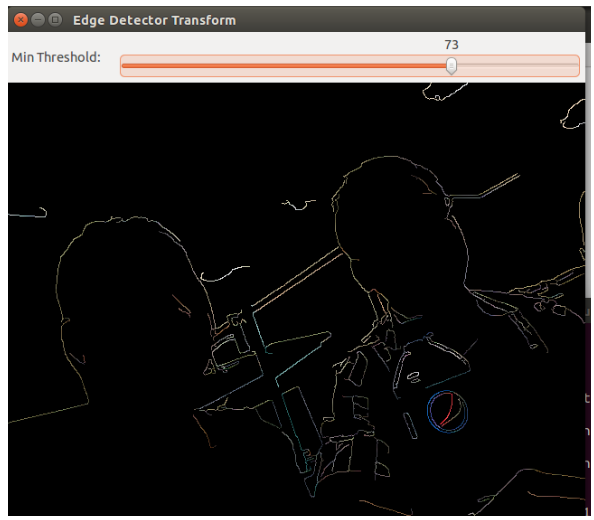
```
ubuntu@tegra-ubuntu:~/Downloads/excercise 4/simpler-capture-2$ make all
g++ -O0 -g   -c capture.cpp
g++  -O0 -g   -o capture capture.o `pkg-config --libs opencv` -L/usr/lib -lopencv_core -lopencv_flann -lopencv_video
ubuntu@tegra-ubuntu:~/Downloads/excercise 4/simpler-capture-2$ ls
capture  capture.cpp  capture.cpp~  capture.o  Makefile
ubuntu@tegra-ubuntu:~/Downloads/excercise 4/simpler-capture-2$ ./capture
```

This code is used for continuous streaming of picture using an infinite loop in which the image frame is captured, and it is checked if it is NULL which would result in break. cvNamedWindow API is used to create a window called Simpler capture 2 Example and cvShowImage API is used to display the image in this named window. cvSetCaptureProperty API is used to set the width and height of the image frames. ESC key can be used to terminate the program.

QUESTION 4

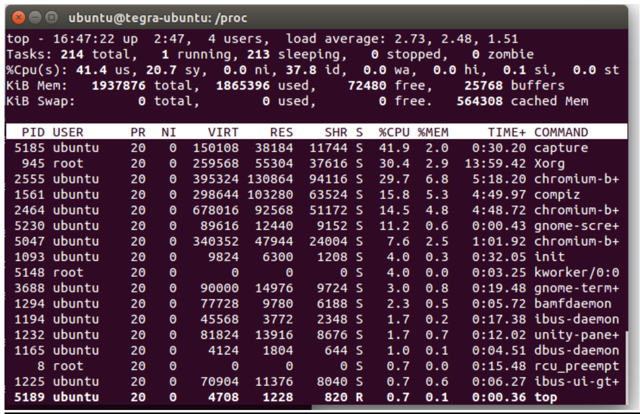
Canny Interactive





This code is used to apply canny transform on images which is basically an edge detection transform. createTrackbar API is used to create a trackbar to set the low threshold for the implementation of the canny algorithm. mat_frame is an object of Mat class which is initialised with captured image frame. cvtColor API to convert the image to grey scale from RGB. Noise reduction is done using blur API with a filter of kernel size of 3X3. Canny API is used to return the edge detected canny mask. It takes lowthreshold and highthreshold as argument where highthreshold is coded as 3 times the lowthreshold value. If the variation in the gradient is higher than the highthreshold, then it is detected as a boundary of an edge and if it is between the lowthreshold and the high threshold, then it is dectected as a continuation of an edge and if it is lower than the low threshold, then it is ignored. Scalar::all(0) is used to fill the image with zeros. copyTo function returns the original image masked using canny mask. imshow function is used to display the resutant image. The program will terminate when the user presses q.

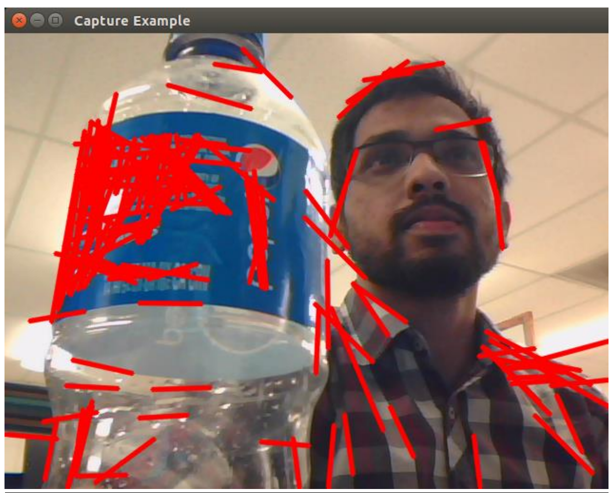
CPU Loading


ubuntu@tegra-ubuntu: /proc

```
top - 16:47:22 up  2:47,  4 users,  load average: 2.73, 2.48, 1.51
Tasks: 214 total,   1 running, 213 sleeping,   0 stopped,   0 zombie
%Cpu(s): 41.4 us, 20.7 sy,  0.0 ni, 37.8 id,  0.0 wa,  0.0 hi,  0.1 si,  0.0 st
KiB Mem:   1937876 total,  1865396 used,    72480 free,    25768 buffers
KiB Swap:        0 total,        0 used,        0 free.   564308 cached Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
 5185 ubuntu    20   0  150108  38184  11744 S  41.9  2.0   0:30.20 capture
  945 root      20   0  259568  55304  37616 S  30.4  2.9  13:59.42 Xorg
 2555 ubuntu    20   0  395324 130864  94116 S  29.7  6.8   5:18.20 chromium-b+
 1561 ubuntu    20   0  298644 103280  63524 S  15.8  5.3   4:49.97 compiz
 2464 ubuntu    20   0  678016  92568  51172 S  14.5  4.8   4:48.72 chromium-b+
 5230 ubuntu    20   0   89616  12440   9152 S  11.2  0.6   0:00.43 gnome-scre+
 5047 ubuntu    20   0  340352  47944  24004 S   7.6  2.5   1:01.92 chromium-b+
 1093 ubuntu    20   0    9824   6300   1208 S   4.0  0.3   0:32.05 init
 5148 root      20   0       0      0      0 S   4.0  0.0   0:03.25 kworker/0:0
 3688 ubuntu    20   0   90000  14976   9724 S   3.0  0.8   0:19.48 gnome-term+
 1294 ubuntu    20   0   77728   9780   6188 S   2.3  0.5   0:05.72 bamfdaemon
 1194 ubuntu    20   0   45568   3772   2348 S   1.7  0.2   0:17.38 ibus-daemon
 1232 ubuntu    20   0   81824  13916   8676 S   1.7  0.7   0:12.02 unity-pane+
 1165 ubuntu    20   0    4124   1804    644 S   1.0  0.1   0:04.51 dbus-daemon
    8 root      20   0       0      0      0 S   0.7  0.0   0:15.48 rcu_preempt
 1225 ubuntu    20   0   70904  11376   8040 S   0.7  0.6   0:06.27 ibus-ui-gt+
 5189 ubuntu    20   0    4708   1228    820 R   0.7  0.1   0:00.36 top
```

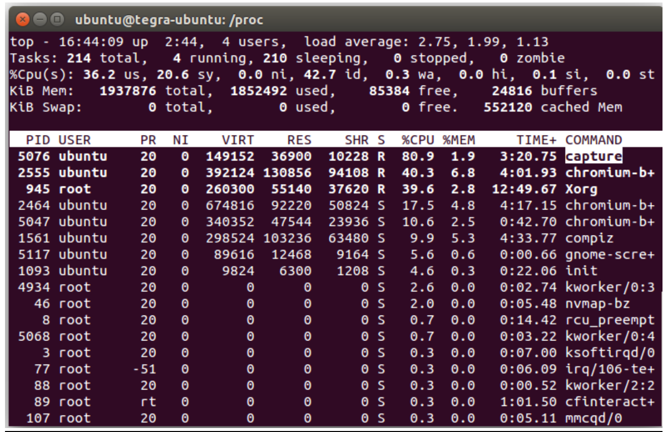
On running the top command, we can see that CPU Loading is 41.9%.

Hough Interactive



This code is used to apply hough transform on images which is basically a straight line detection transform. mat_frame is an object of Mat class which is initialised with captured image frame. The canny transform is applied to detect the edges of this image. lines is a variable of vector type which stores the 4 intergers for the lines that are detected in the image. HoughLinesP function returns the endpoints of the detected lines. Line function is used draw the lines on the original image i.e. mat_frame. cvShowImage is used to display the resultant image. The program will terminate when the user presses ESC.

CPU Loading



```
ubuntu@tegra-ubuntu: /proc
top - 16:44:09 up  2:44,  4 users,  load average: 2.75, 1.99, 1.13
Tasks: 214 total,   4 running, 210 sleeping,   0 stopped,   0 zombie
%Cpu(s): 36.2 us, 20.6 sy,  0.0 ni, 42.7 id,  0.3 wa,  0.0 hi,  0.1 si,  0.0 st
KiB Mem:   1937876 total,  1852492 used,    85384 free,    24816 buffers
KiB Swap:        0 total,        0 used,        0 free.   552120 cached Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
 5076 ubuntu    20   0  149152  36900  10228 R  80.9  1.9   3:20.75 capture
 2555 ubuntu    20   0  392124 130856  94108 R  40.3  6.8   4:01.93 chromium-b+
  945 root      20   0  260300  55140  37620 R  39.6  2.8  12:49.67 Xorg
 2464 ubuntu    20   0  674816  92220  50824 S  17.5  4.8   4:17.15 chromium-b+
 5047 ubuntu    20   0  340352  47544  23936 S  10.6  2.5   0:42.70 chromium-b+
 1561 ubuntu    20   0  298524 103236  63480 S   9.9  5.3   4:33.77 compiz
 5117 ubuntu    20   0   89616  12468   9164 S   5.6  0.6   0:00.66 gnome-scre+
 1093 ubuntu    20   0    9824   6300   1208 S   4.6  0.3   0:22.06 init
 4934 root      20   0       0      0      0 S   2.6  0.0   0:02.74 kworker/0:3
   46 root      20   0       0      0      0 S   2.0  0.0   0:05.48 nvmap-bz
    8 root      20   0       0      0      0 S   0.7  0.0   0:14.42 rcu_preempt
 5068 root      20   0       0      0      0 S   0.7  0.0   0:03.22 kworker/0:4
    3 root      20   0       0      0      0 S   0.3  0.0   0:07.00 ksoftirqd/0
   77 root     -51   0       0      0      0 S   0.3  0.0   0:06.09 irq/106-te+
   88 root      20   0       0      0      0 S   0.3  0.0   0:00.52 kworker/2:2
   89 root      rt   0       0      0      0 S   0.3  0.0   1:01.50 cfinteract+
  107 root      20   0       0      0      0 S   0.3  0.0   0:05.11 mmcqd/0
```

On running the top command, we can see that CPU Loading is 80.9%.

QUESTION 5

Note: We have used a single program to calculate the average frame rate for each of the 3 interactive transformations and to check if the transformations meets its respective deadline.

By default, the program just checks and analyses if the transformations meet its respective deadlines.

To calculate just the average frame rate without checking for deadline, "#define CAL_FRAME_RATE" should be uncommented and "#define CHECK_DEADLINE" should be commented out.

The following transformations were used in this program:

- Canny Edge Detection
- Hough Transform
- Hough Elliptical Transform

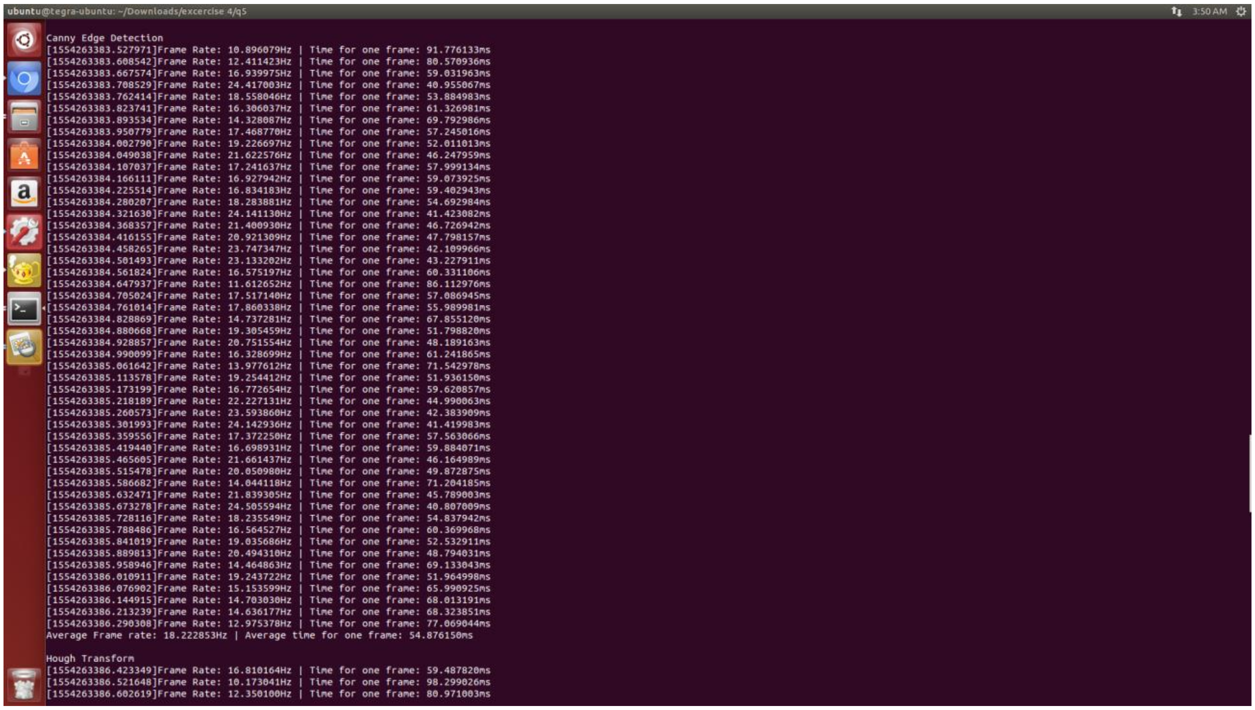
Calculating average frame rate

The transformation is carried out on 50 frames to calculate the average frame rate and therefore determine the deadline. Time taken between 2 consecutive frames is negated to determine time taken to run one frame. 1 is divided by this value to get the frames per second (fps). After 50 frames are obtained and processed on, the average frame rate is determined for each transformation.

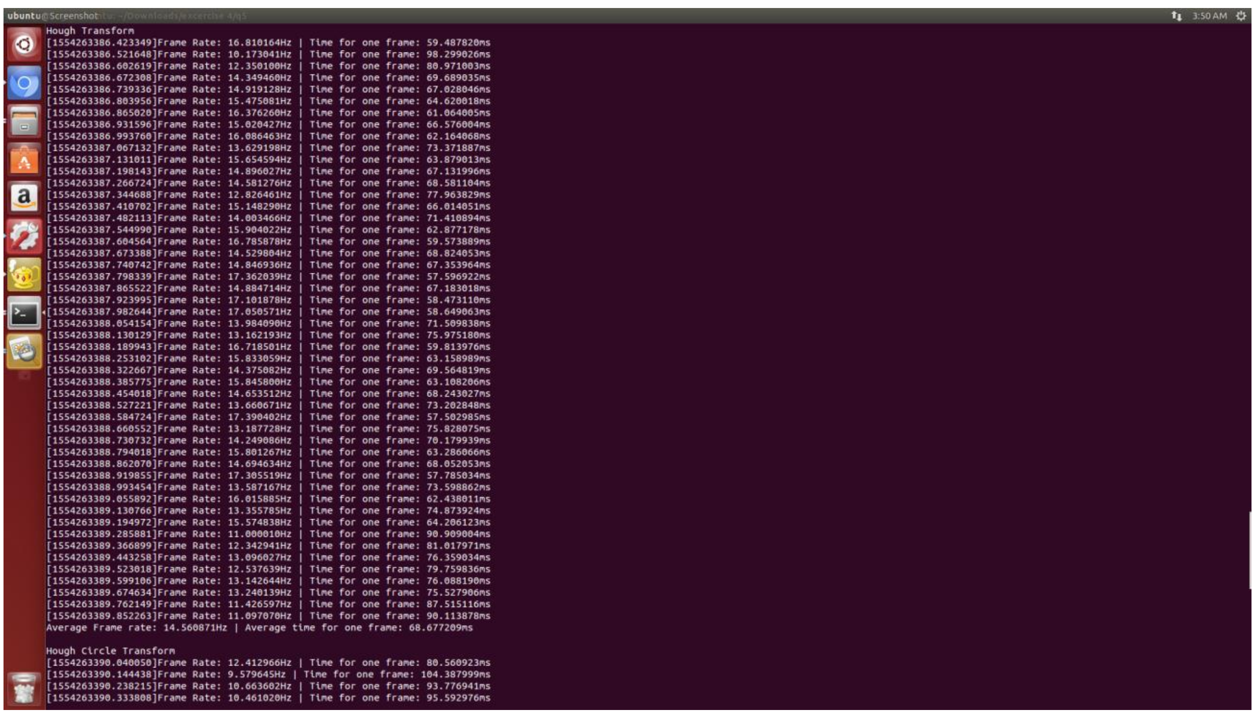
The following screenshots shows the average frame rate calculation for each resolution and for each of the transformations.

<u>640x480</u>

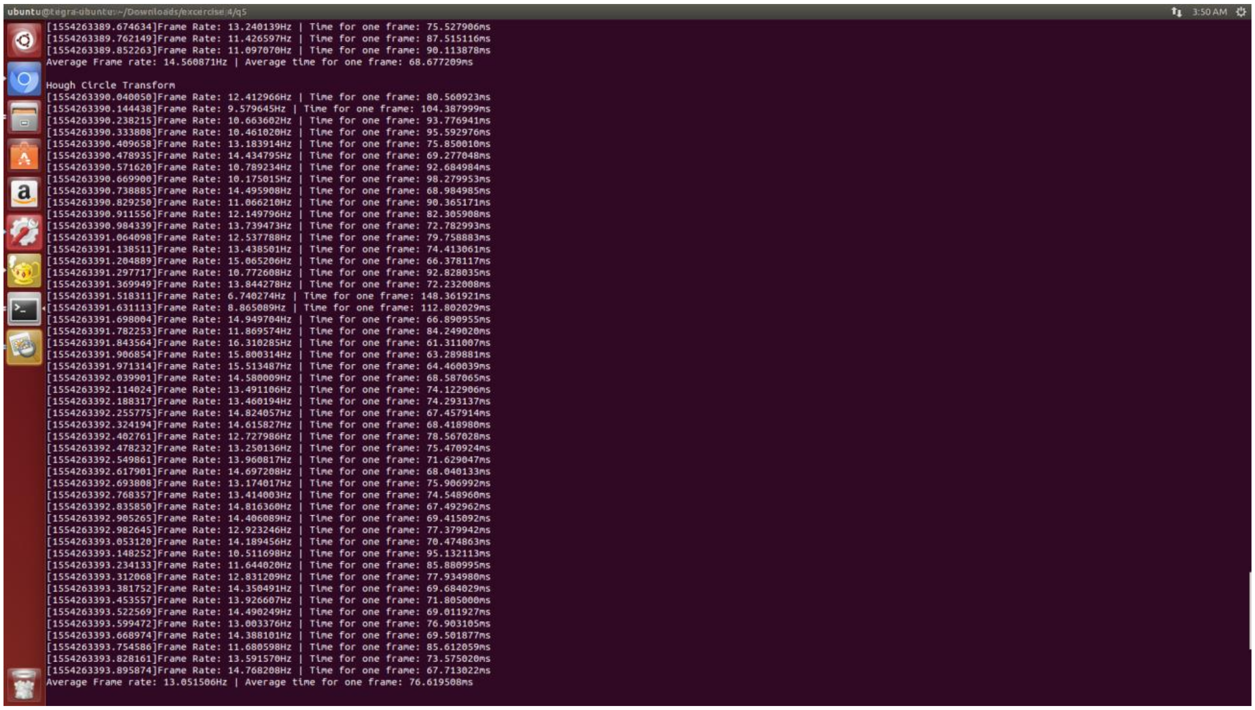
Canny Edge Detection



Hough Transform



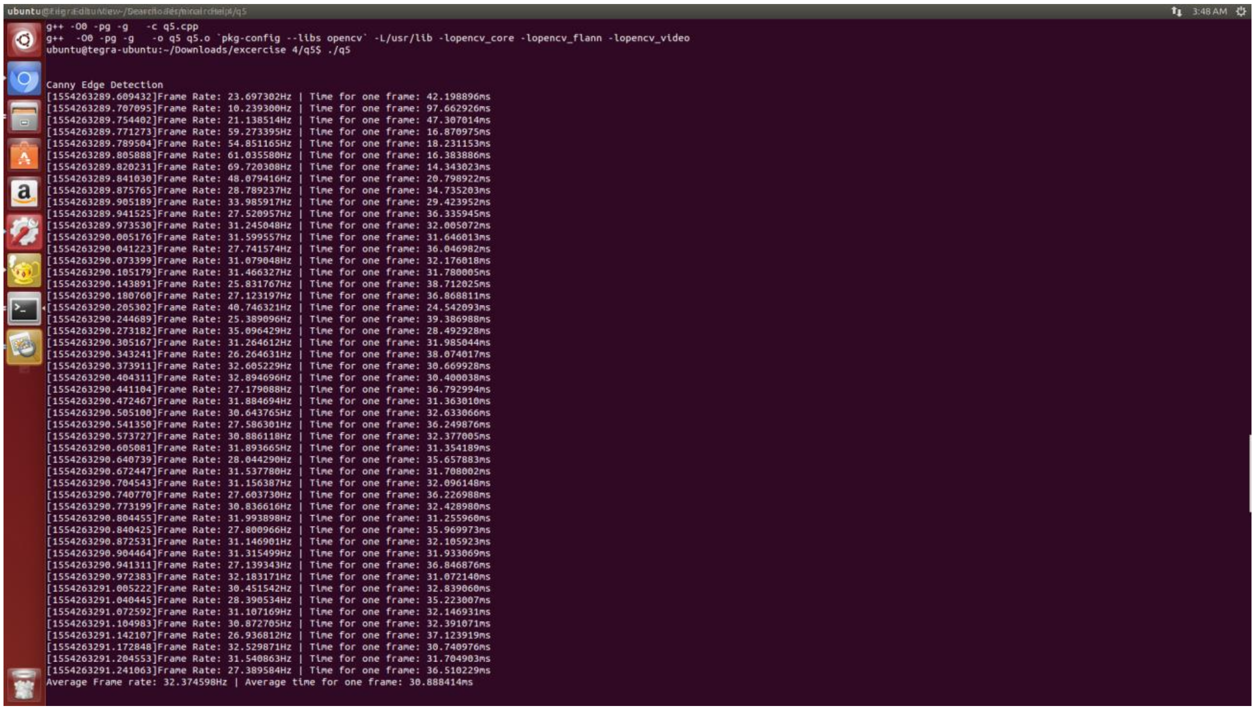
Hough Elliptical Transform



```
[1554263389.674634]Frame Rate: 13.240139Hz | Time for one frame: 75.527906ms
[1554263389.762149]Frame Rate: 11.426597Hz | Time for one frame: 87.515116ms
[1554263389.852263]Frame Rate: 11.097070Hz | Time for one frame: 90.113878ms
Average Frame rate: 14.560871Hz | Average time for one frame: 68.677209ms

Hough Circle Transform
[1554263390.040050]Frame Rate: 12.412966Hz | Time for one frame: 80.560923ms
[1554263390.144438]Frame Rate: 9.579645Hz | Time for one frame: 104.387999ms
[1554263390.238215]Frame Rate: 10.663602Hz | Time for one frame: 93.776941ms
[1554263390.333808]Frame Rate: 10.461020Hz | Time for one frame: 95.592976ms
[1554263390.409658]Frame Rate: 13.183914Hz | Time for one frame: 75.850010ms
[1554263390.478935]Frame Rate: 14.434795Hz | Time for one frame: 69.277048ms
[1554263390.571620]Frame Rate: 10.789234Hz | Time for one frame: 92.684984ms
[1554263390.669900]Frame Rate: 10.175015Hz | Time for one frame: 98.279953ms
[1554263390.738885]Frame Rate: 14.495908Hz | Time for one frame: 68.984985ms
[1554263390.829250]Frame Rate: 11.066210Hz | Time for one frame: 90.365171ms
[1554263390.911556]Frame Rate: 12.149796Hz | Time for one frame: 82.305908ms
[1554263390.984339]Frame Rate: 13.739473Hz | Time for one frame: 72.782993ms
[1554263391.064098]Frame Rate: 12.537788Hz | Time for one frame: 79.758883ms
[1554263391.138511]Frame Rate: 13.438501Hz | Time for one frame: 74.413061ms
[1554263391.204889]Frame Rate: 15.065206Hz | Time for one frame: 66.378117ms
[1554263391.297717]Frame Rate: 10.772608Hz | Time for one frame: 92.828035ms
[1554263391.369949]Frame Rate: 13.844278Hz | Time for one frame: 72.232008ms
[1554263391.518311]Frame Rate: 6.740274Hz | Time for one frame: 148.361921ms
[1554263391.631113]Frame Rate: 8.865089Hz | Time for one frame: 112.802029ms
[1554263391.698004]Frame Rate: 14.949704Hz | Time for one frame: 66.890955ms
[1554263391.782253]Frame Rate: 11.869574Hz | Time for one frame: 84.249020ms
[1554263391.843564]Frame Rate: 16.310285Hz | Time for one frame: 61.311007ms
[1554263391.906854]Frame Rate: 15.800314Hz | Time for one frame: 63.289881ms
[1554263391.971314]Frame Rate: 15.513487Hz | Time for one frame: 64.460039ms
[1554263392.039901]Frame Rate: 14.580009Hz | Time for one frame: 68.587065ms
[1554263392.114024]Frame Rate: 13.491106Hz | Time for one frame: 74.122906ms
[1554263392.188317]Frame Rate: 13.460194Hz | Time for one frame: 74.293137ms
[1554263392.255775]Frame Rate: 14.824057Hz | Time for one frame: 67.457914ms
[1554263392.324194]Frame Rate: 14.615827Hz | Time for one frame: 68.418980ms
[1554263392.402761]Frame Rate: 12.727986Hz | Time for one frame: 78.567028ms
[1554263392.478232]Frame Rate: 13.250136Hz | Time for one frame: 75.470924ms
[1554263392.549861]Frame Rate: 13.960817Hz | Time for one frame: 71.629047ms
[1554263392.617901]Frame Rate: 14.697208Hz | Time for one frame: 68.040133ms
[1554263392.693808]Frame Rate: 13.174017Hz | Time for one frame: 75.906992ms
[1554263392.768357]Frame Rate: 13.414003Hz | Time for one frame: 74.548960ms
[1554263392.835850]Frame Rate: 14.816360Hz | Time for one frame: 67.492962ms
[1554263392.905265]Frame Rate: 14.406089Hz | Time for one frame: 69.415092ms
[1554263392.982645]Frame Rate: 12.923246Hz | Time for one frame: 77.379942ms
[1554263393.053120]Frame Rate: 14.189456Hz | Time for one frame: 70.474863ms
[1554263393.148252]Frame Rate: 10.511698Hz | Time for one frame: 95.132113ms
[1554263393.234133]Frame Rate: 11.644020Hz | Time for one frame: 85.880995ms
[1554263393.312068]Frame Rate: 12.831209Hz | Time for one frame: 77.934980ms
[1554263393.381752]Frame Rate: 14.350491Hz | Time for one frame: 69.684029ms
[1554263393.453557]Frame Rate: 13.926607Hz | Time for one frame: 71.805000ms
[1554263393.522569]Frame Rate: 14.490249Hz | Time for one frame: 69.011927ms
[1554263393.599472]Frame Rate: 13.003376Hz | Time for one frame: 76.903105ms
[1554263393.668974]Frame Rate: 14.388101Hz | Time for one frame: 69.501877ms
[1554263393.754586]Frame Rate: 11.680598Hz | Time for one frame: 85.612059ms
[1554263393.828161]Frame Rate: 13.591570Hz | Time for one frame: 73.575020ms
[1554263393.895874]Frame Rate: 14.768208Hz | Time for one frame: 67.713022ms
Average Frame rate: 13.051506Hz | Average time for one frame: 76.619508ms
```

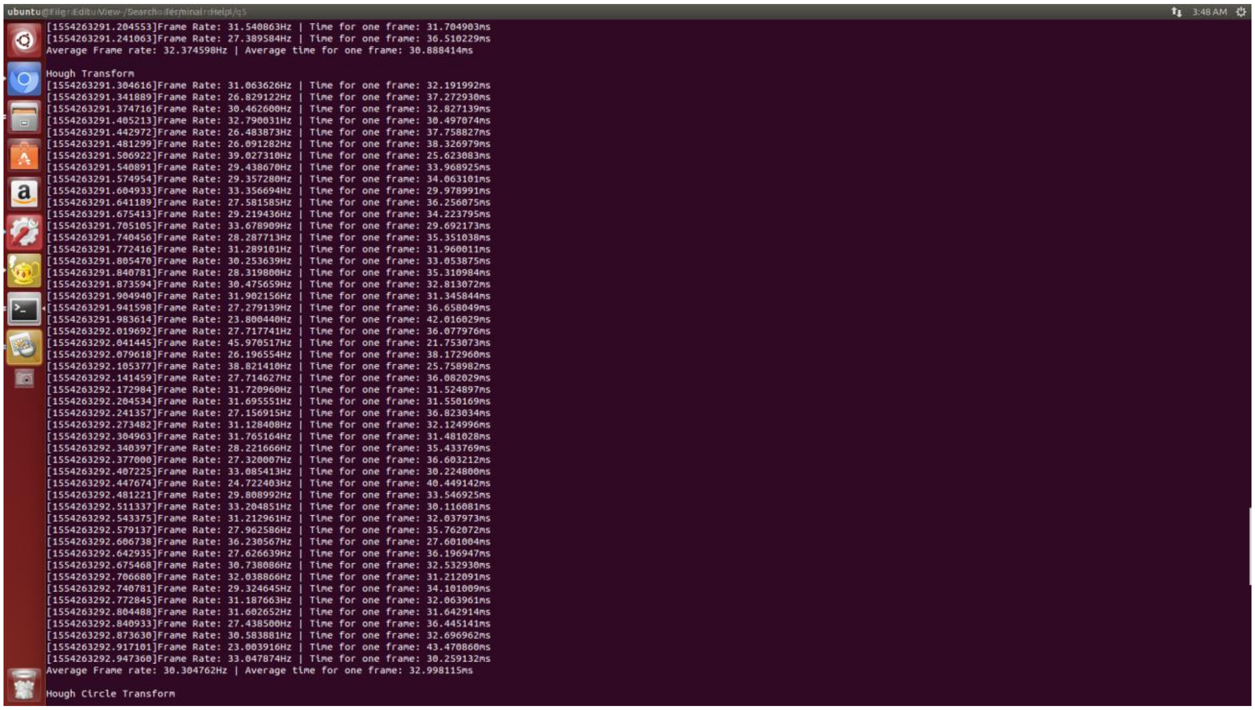
<u>160x120</u>

Canny Edge Detection

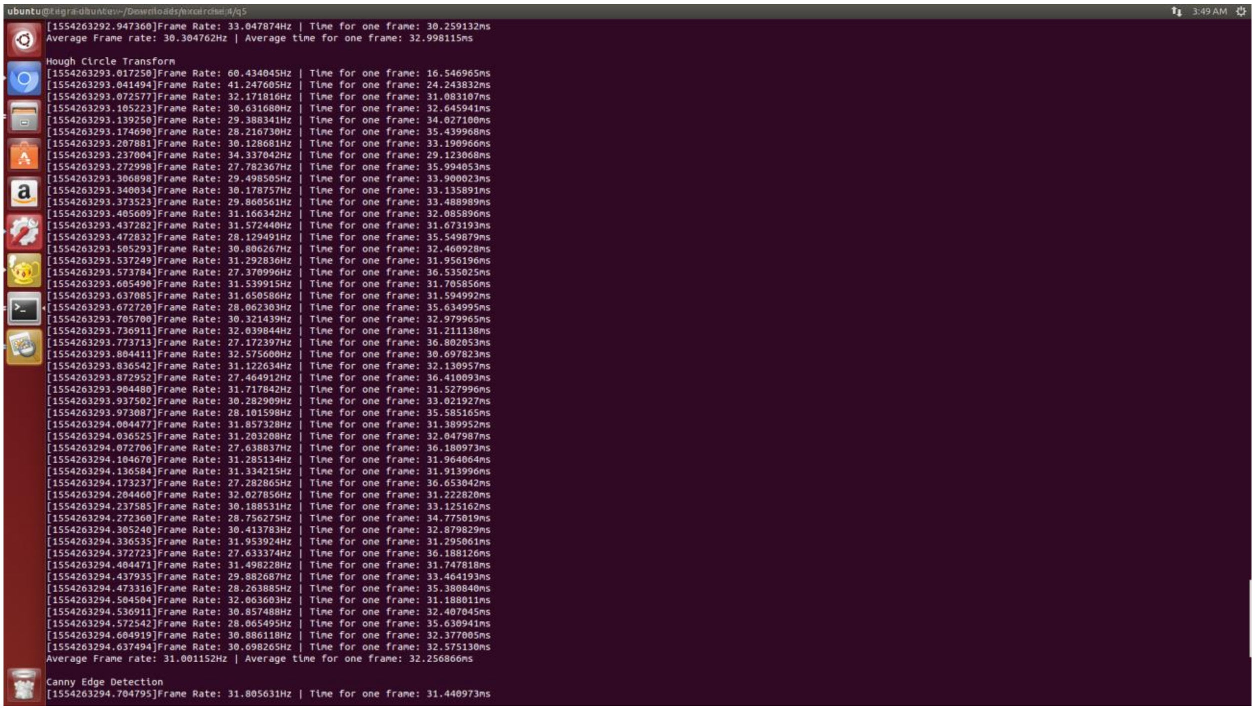


```
g++ -O0 -pg -g    -c q5.cpp
g++  -O0 -pg -g   -o q5 q5.o `pkg-config --libs opencv` -L/usr/lib -lopencv_core -lopencv_flann -lopencv_video
ubuntu@tegra-ubuntu:~/Downloads/excercise 4/q5$ ./q5


Canny Edge Detection
[1554263289.609432]Frame Rate: 23.697302Hz | Time for one frame: 42.198896ms
[1554263289.707095]Frame Rate: 10.239300Hz | Time for one frame: 97.662926ms
[1554263289.754402]Frame Rate: 21.138514Hz | Time for one frame: 47.307014ms
[1554263289.771273]Frame Rate: 59.273395Hz | Time for one frame: 16.870975ms
[1554263289.789504]Frame Rate: 54.851165Hz | Time for one frame: 18.231153ms
[1554263289.805888]Frame Rate: 61.035580Hz | Time for one frame: 16.383886ms
[1554263289.820231]Frame Rate: 69.720308Hz | Time for one frame: 14.343023ms
[1554263289.841030]Frame Rate: 48.079416Hz | Time for one frame: 20.798922ms
[1554263289.875765]Frame Rate: 28.789237Hz | Time for one frame: 34.735203ms
[1554263289.905189]Frame Rate: 33.985917Hz | Time for one frame: 29.423952ms
[1554263289.941525]Frame Rate: 27.520957Hz | Time for one frame: 36.335945ms
[1554263289.973530]Frame Rate: 31.245048Hz | Time for one frame: 32.005072ms
[1554263290.005176]Frame Rate: 31.599557Hz | Time for one frame: 31.646013ms
[1554263290.041223]Frame Rate: 27.741574Hz | Time for one frame: 36.046982ms
[1554263290.073399]Frame Rate: 31.079048Hz | Time for one frame: 32.176018ms
[1554263290.105179]Frame Rate: 31.466327Hz | Time for one frame: 31.780005ms
[1554263290.143891]Frame Rate: 25.831767Hz | Time for one frame: 38.712025ms
[1554263290.180760]Frame Rate: 27.123197Hz | Time for one frame: 36.868811ms
[1554263290.205302]Frame Rate: 40.746321Hz | Time for one frame: 24.542093ms
[1554263290.244689]Frame Rate: 25.389096Hz | Time for one frame: 39.386988ms
[1554263290.273182]Frame Rate: 35.096429Hz | Time for one frame: 28.492928ms
[1554263290.305167]Frame Rate: 31.264612Hz | Time for one frame: 31.985044ms
[1554263290.343241]Frame Rate: 26.264631Hz | Time for one frame: 38.074017ms
[1554263290.373911]Frame Rate: 32.605229Hz | Time for one frame: 30.669928ms
[1554263290.404311]Frame Rate: 32.894696Hz | Time for one frame: 30.400038ms
[1554263290.441104]Frame Rate: 27.179088Hz | Time for one frame: 36.792994ms
[1554263290.472467]Frame Rate: 31.884694Hz | Time for one frame: 31.363010ms
[1554263290.505100]Frame Rate: 30.643765Hz | Time for one frame: 32.633066ms
[1554263290.541350]Frame Rate: 27.586301Hz | Time for one frame: 36.249876ms
[1554263290.573727]Frame Rate: 30.886118Hz | Time for one frame: 32.377005ms
[1554263290.605081]Frame Rate: 31.893665Hz | Time for one frame: 31.354189ms
[1554263290.640739]Frame Rate: 28.044290Hz | Time for one frame: 35.657883ms
[1554263290.672447]Frame Rate: 31.537780Hz | Time for one frame: 31.708002ms
[1554263290.704543]Frame Rate: 31.156387Hz | Time for one frame: 32.096148ms
[1554263290.740770]Frame Rate: 27.603730Hz | Time for one frame: 36.226988ms
[1554263290.773199]Frame Rate: 30.836616Hz | Time for one frame: 32.428980ms
[1554263290.804455]Frame Rate: 31.993898Hz | Time for one frame: 31.255960ms
[1554263290.840425]Frame Rate: 27.800966Hz | Time for one frame: 35.969973ms
[1554263290.872531]Frame Rate: 31.146901Hz | Time for one frame: 32.105923ms
[1554263290.904464]Frame Rate: 31.315499Hz | Time for one frame: 31.933069ms
[1554263290.941311]Frame Rate: 27.139343Hz | Time for one frame: 36.846876ms
[1554263290.972383]Frame Rate: 32.183171Hz | Time for one frame: 31.072140ms
[1554263291.005222]Frame Rate: 30.451542Hz | Time for one frame: 32.839060ms
[1554263291.040445]Frame Rate: 28.390534Hz | Time for one frame: 35.223007ms
[1554263291.072592]Frame Rate: 31.107169Hz | Time for one frame: 32.146931ms
[1554263291.104983]Frame Rate: 30.872705Hz | Time for one frame: 32.391071ms
[1554263291.142107]Frame Rate: 26.936812Hz | Time for one frame: 37.123919ms
[1554263291.172848]Frame Rate: 32.529871Hz | Time for one frame: 30.740976ms
[1554263291.204553]Frame Rate: 31.540863Hz | Time for one frame: 31.704903ms
[1554263291.241063]Frame Rate: 27.389584Hz | Time for one frame: 36.510229ms
Average Frame rate: 32.374598Hz | Average time for one frame: 30.888414ms
```

Hough Transform

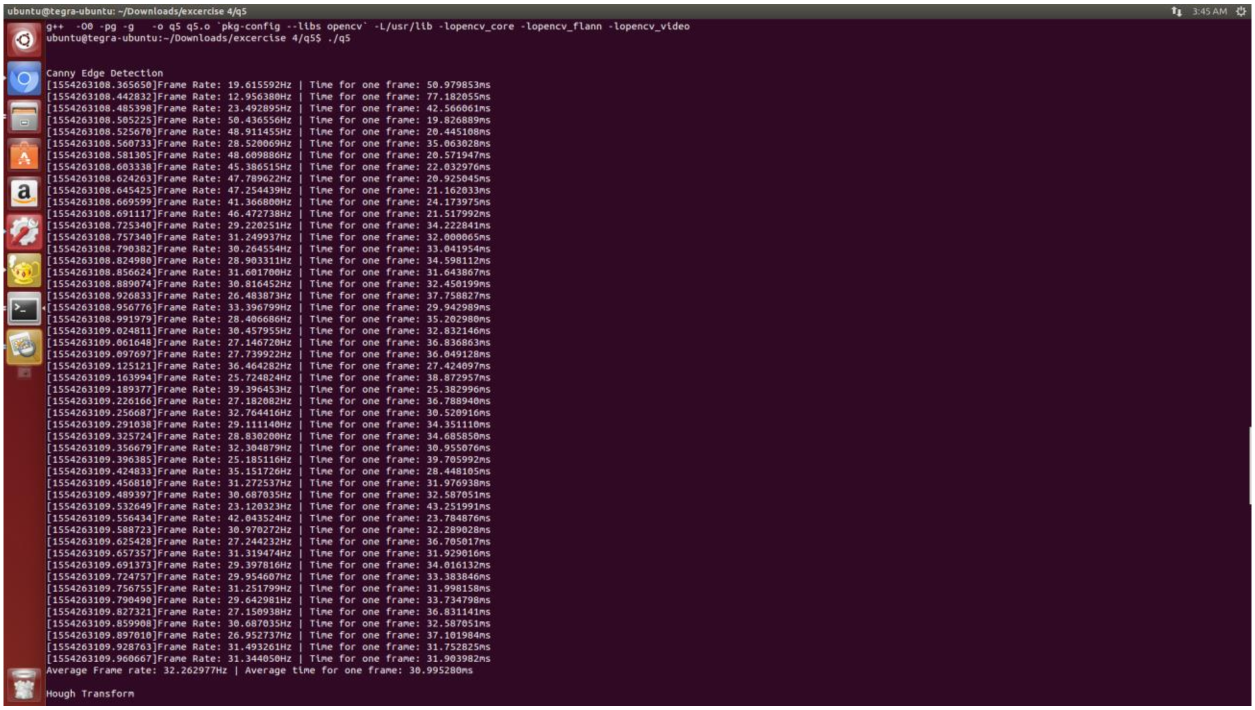


Hough Elliptical Transform

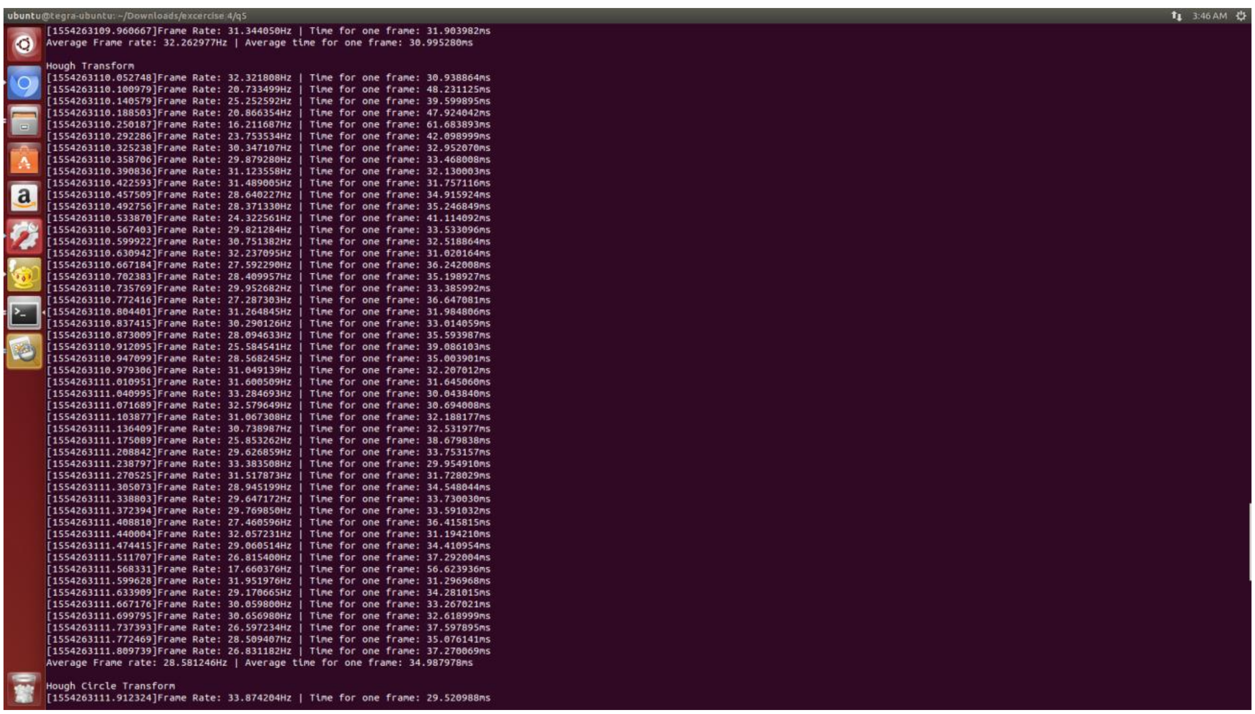


<u>320x240</u>

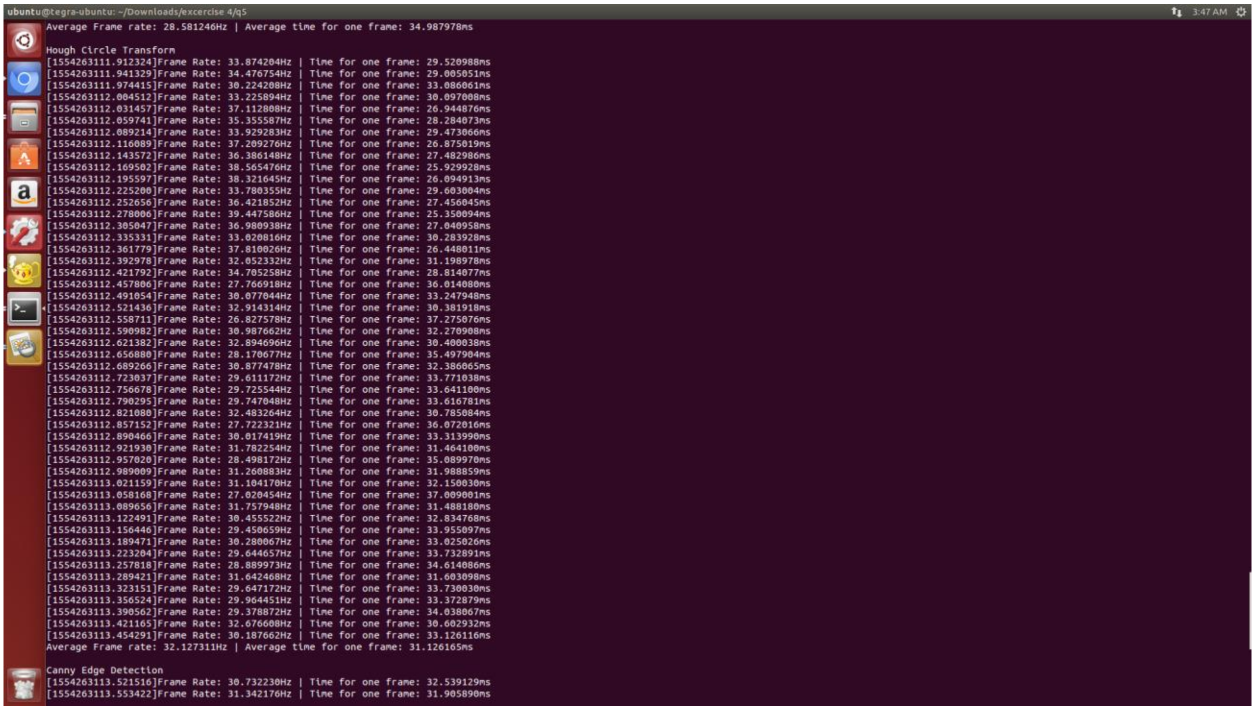
Canny Edge Detection



Hough Transform



Hough Elliptical Transform



```
ubuntu@tegra-ubuntu: ~/Downloads/excercise 4/q5
Average Frame rate: 28.581246Hz | Average time for one frame: 34.987978ms

Hough Circle Transform
[1554263111.912324]Frame Rate: 33.874204Hz | Time for one frame: 29.520988ms
[1554263111.941329]Frame Rate: 34.476754Hz | Time for one frame: 29.005051ms
[1554263111.974415]Frame Rate: 30.224208Hz | Time for one frame: 33.086061ms
[1554263112.004512]Frame Rate: 33.225894Hz | Time for one frame: 30.097008ms
[1554263112.031457]Frame Rate: 37.112808Hz | Time for one frame: 26.944876ms
[1554263112.059741]Frame Rate: 35.355587Hz | Time for one frame: 28.284073ms
[1554263112.089214]Frame Rate: 33.929283Hz | Time for one frame: 29.473066ms
[1554263112.116089]Frame Rate: 37.209276Hz | Time for one frame: 26.875019ms
[1554263112.143572]Frame Rate: 36.386148Hz | Time for one frame: 27.482986ms
[1554263112.169502]Frame Rate: 38.565476Hz | Time for one frame: 25.929928ms
[1554263112.195597]Frame Rate: 38.321645Hz | Time for one frame: 26.094913ms
[1554263112.225200]Frame Rate: 33.780355Hz | Time for one frame: 29.603004ms
[1554263112.252656]Frame Rate: 36.421852Hz | Time for one frame: 27.456045ms
[1554263112.278006]Frame Rate: 39.447586Hz | Time for one frame: 25.350094ms
[1554263112.305047]Frame Rate: 36.980938Hz | Time for one frame: 27.040958ms
[1554263112.335331]Frame Rate: 33.020816Hz | Time for one frame: 30.283928ms
[1554263112.361779]Frame Rate: 37.810026Hz | Time for one frame: 26.448011ms
[1554263112.392978]Frame Rate: 32.052332Hz | Time for one frame: 31.198978ms
[1554263112.421792]Frame Rate: 34.705258Hz | Time for one frame: 28.814077ms
[1554263112.457806]Frame Rate: 27.766918Hz | Time for one frame: 36.014080ms
[1554263112.491054]Frame Rate: 30.077044Hz | Time for one frame: 33.247948ms
[1554263112.521436]Frame Rate: 32.914314Hz | Time for one frame: 30.381918ms
[1554263112.558711]Frame Rate: 26.827578Hz | Time for one frame: 37.275076ms
[1554263112.590982]Frame Rate: 30.987662Hz | Time for one frame: 32.270908ms
[1554263112.621382]Frame Rate: 32.894696Hz | Time for one frame: 30.400038ms
[1554263112.656880]Frame Rate: 28.170677Hz | Time for one frame: 35.497904ms
[1554263112.689266]Frame Rate: 30.877478Hz | Time for one frame: 32.386065ms
[1554263112.723037]Frame Rate: 29.611172Hz | Time for one frame: 33.771038ms
[1554263112.756678]Frame Rate: 29.725544Hz | Time for one frame: 33.641100ms
[1554263112.790295]Frame Rate: 29.747048Hz | Time for one frame: 33.616781ms
[1554263112.821080]Frame Rate: 32.483264Hz | Time for one frame: 30.785084ms
[1554263112.857152]Frame Rate: 27.722321Hz | Time for one frame: 36.072016ms
[1554263112.890466]Frame Rate: 30.017419Hz | Time for one frame: 33.313990ms
[1554263112.921930]Frame Rate: 31.782254Hz | Time for one frame: 31.464100ms
[1554263112.957020]Frame Rate: 28.498172Hz | Time for one frame: 35.089970ms
[1554263112.989009]Frame Rate: 31.260883Hz | Time for one frame: 31.988859ms
[1554263113.021159]Frame Rate: 31.104170Hz | Time for one frame: 32.150030ms
[1554263113.058168]Frame Rate: 27.020454Hz | Time for one frame: 37.009001ms
[1554263113.089656]Frame Rate: 31.757948Hz | Time for one frame: 31.488180ms
[1554263113.122491]Frame Rate: 30.455522Hz | Time for one frame: 32.834768ms
[1554263113.156446]Frame Rate: 29.450659Hz | Time for one frame: 33.955097ms
[1554263113.189471]Frame Rate: 30.280067Hz | Time for one frame: 33.025026ms
[1554263113.223204]Frame Rate: 29.644657Hz | Time for one frame: 33.732891ms
[1554263113.257818]Frame Rate: 28.889973Hz | Time for one frame: 34.614086ms
[1554263113.289421]Frame Rate: 31.642468Hz | Time for one frame: 31.603098ms
[1554263113.323151]Frame Rate: 29.647172Hz | Time for one frame: 33.730030ms
[1554263113.356524]Frame Rate: 29.964451Hz | Time for one frame: 33.372879ms
[1554263113.390562]Frame Rate: 29.378872Hz | Time for one frame: 34.038067ms
[1554263113.421165]Frame Rate: 32.676608Hz | Time for one frame: 30.602932ms
[1554263113.454291]Frame Rate: 30.187662Hz | Time for one frame: 33.126116ms
Average Frame rate: 32.127311Hz | Average time for one frame: 31.126165ms

Canny Edge Detection
[1554263113.521516]Frame Rate: 30.732230Hz | Time for one frame: 32.539129ms
[1554263113.553422]Frame Rate: 31.342176Hz | Time for one frame: 31.905890ms
```

According to our analysis and the above images, following are the average frame rates obtained:

	640x480	160x120	320x240
Canny Edge Detection	21 fps	31 fps	32 fps
Hough Transform	14 fps	31 fps	28 fps
Hough Elliptical Transform	13 fps	32 fps	32 fps

Following are the deadlines (with margin) used:

	640x480	160x120	320x240
Canny Edge Detection	63ms	47ms	46ms
Hough Transform	89ms	47ms	51ms
Hough Elliptical Transform	92ms	46ms	46ms

<u>Determining if transformation meets deadline</u>

SCHED_FIFO scheduling algorithm is utilized to execute this program.

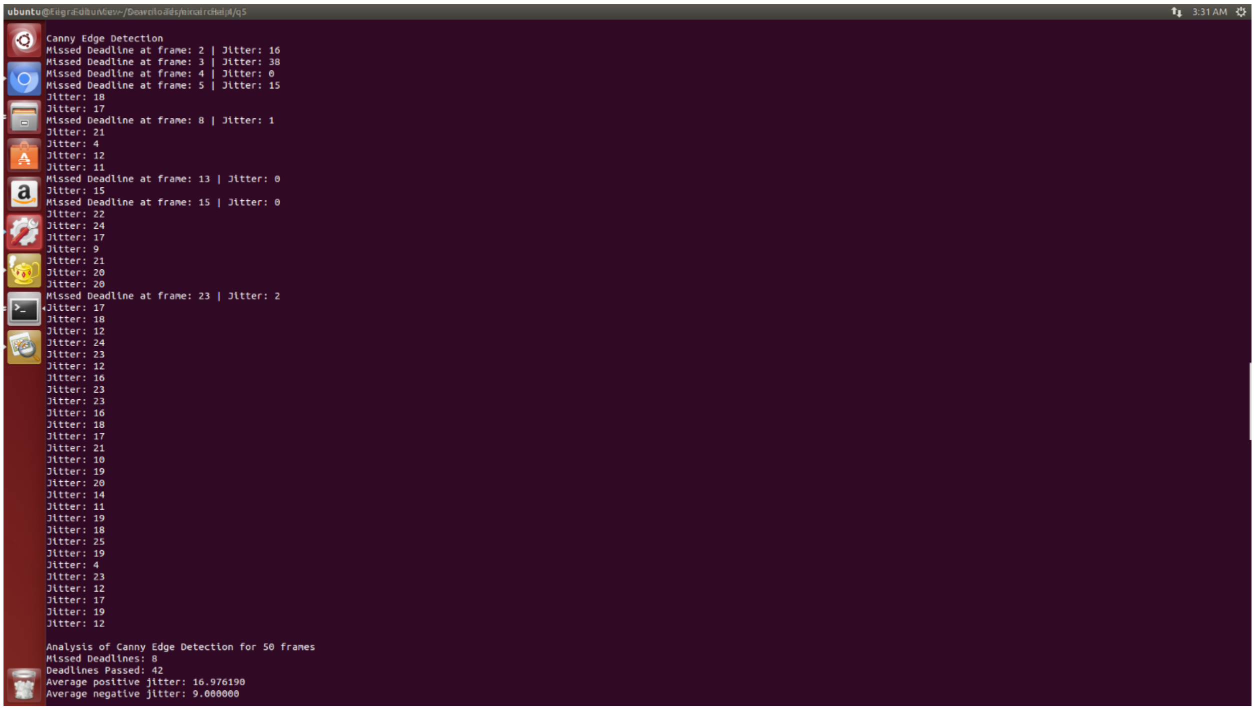
Using the above calculated deadlines, the time taken to carry out the transformation on each of the frame is checked with the deadline to determine if the deadline is missed or if the deadline is passed. If the deadline is passed, the positive jitter is printed. If the deadline is missed, a message is printed along with the frame number and the negative jitter. At the end of 50 frames, an analysis is printed, which prints the number of deadlines missed, the number of deadlines passed, the average positive jitter and average negative jitter. Once this is carried out for 50 frames for one transformation, the analysis for the 50 frames for other transformation is carried out. Therefore, 50 frames for each transformation is processed and analyzed sequentially in an infinite loop. Three Semaphores regulate this sequence of execution. Therefore, 50 frames of Canny Edge Detection are analyzed, then 50 frames of Hough Transform, then 50 frames of Hough Elliptical Transform, and so on infinitely. The semaphore also protects the camera object in each thread and ensures there is no contention among the 3 three threads.

Final predictable response jitter analysis

The final screenshots of the response analysis are attached below. The analysis of the 50 frames is at the bottom which displays the number of missed deadlines, number of passed deadlines, the average of positive jitter and the average of negative jitter.

640x480

Canny Edge Detection



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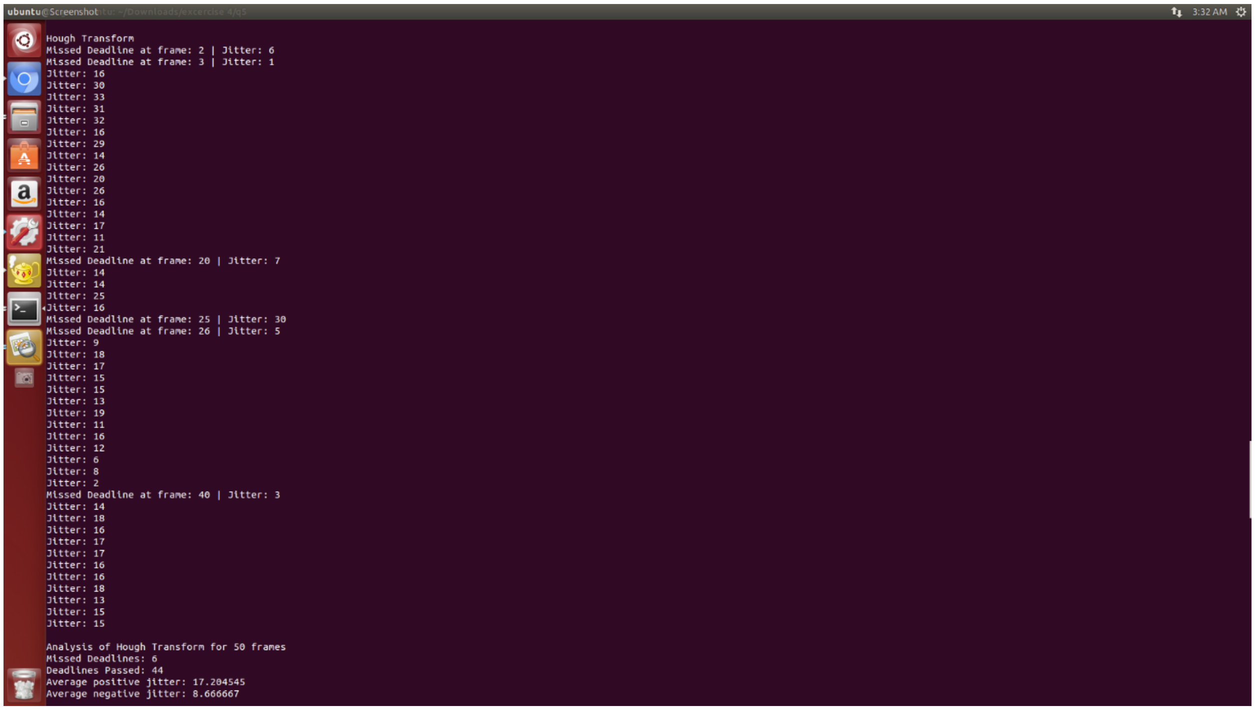
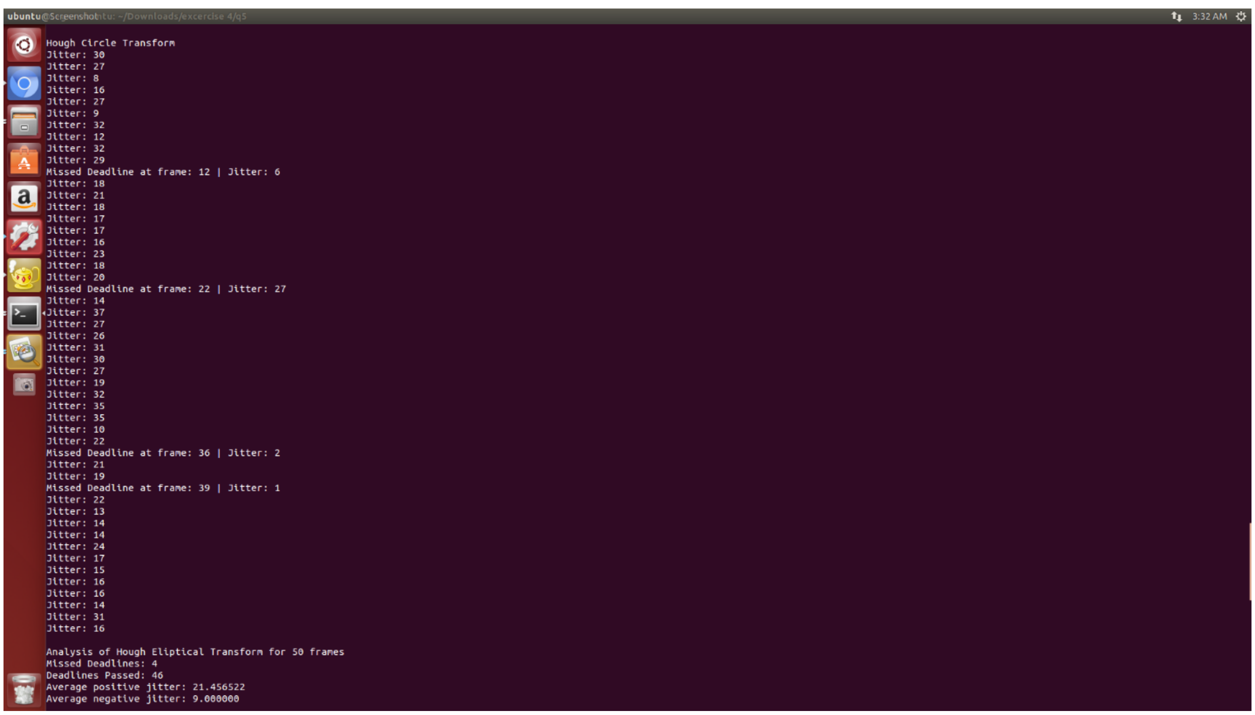
Boulder

Hough Transform

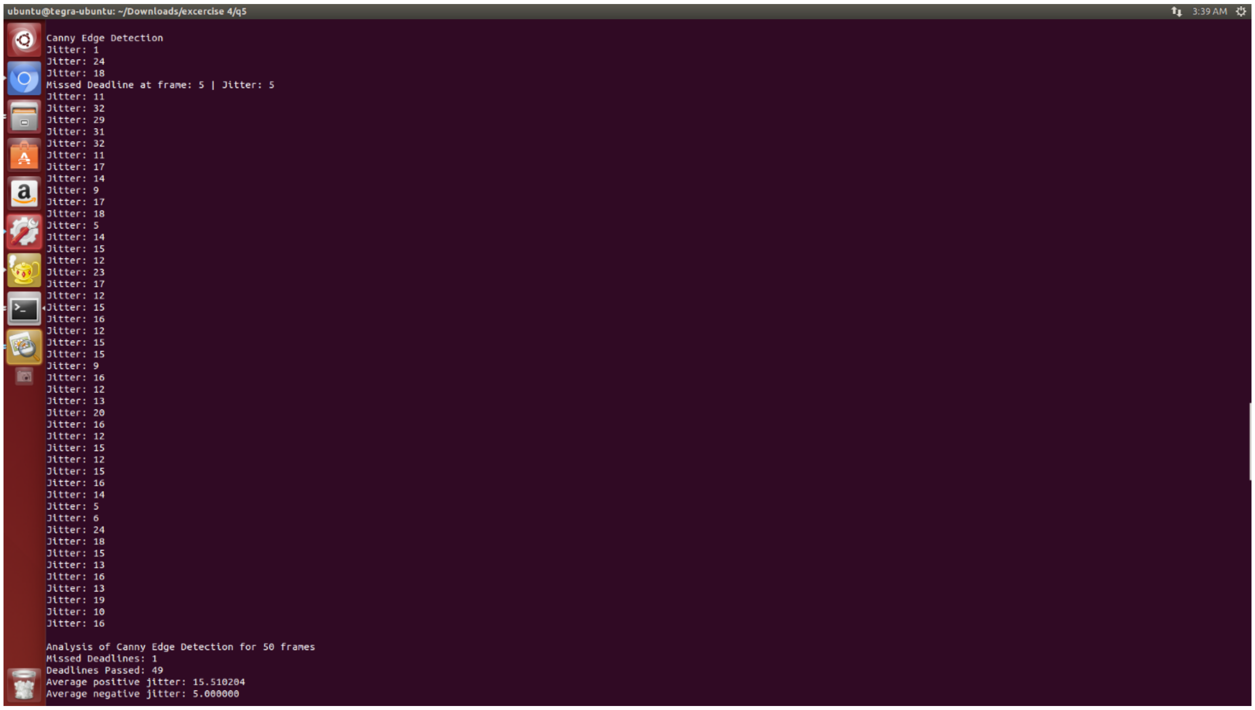


Hough Circle Transform



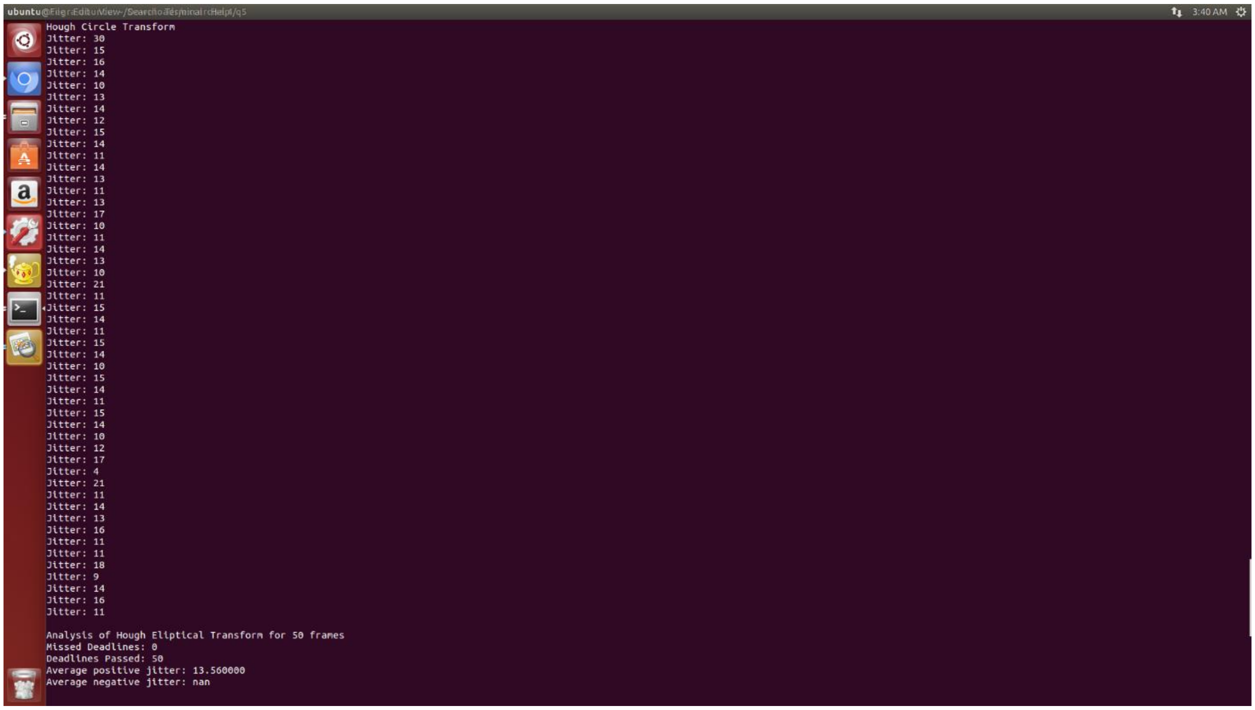
160x120

Canny Transform



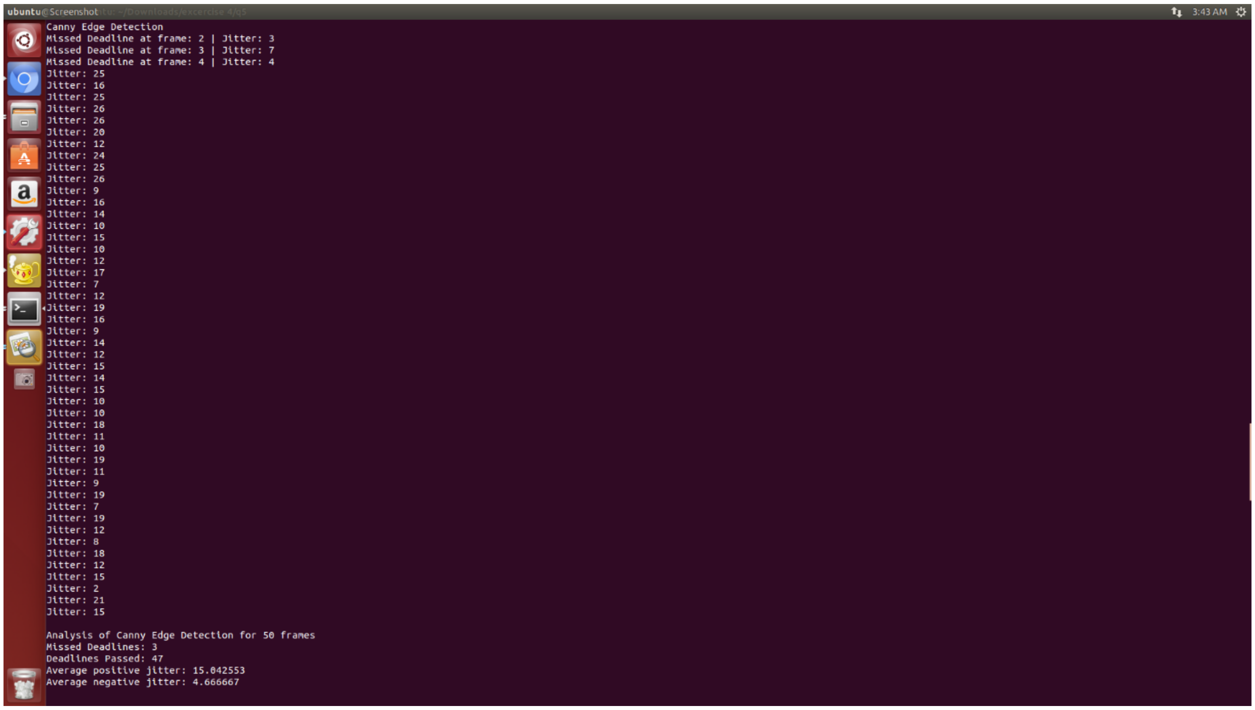
Hough Transform

Hough Elliptical Transform



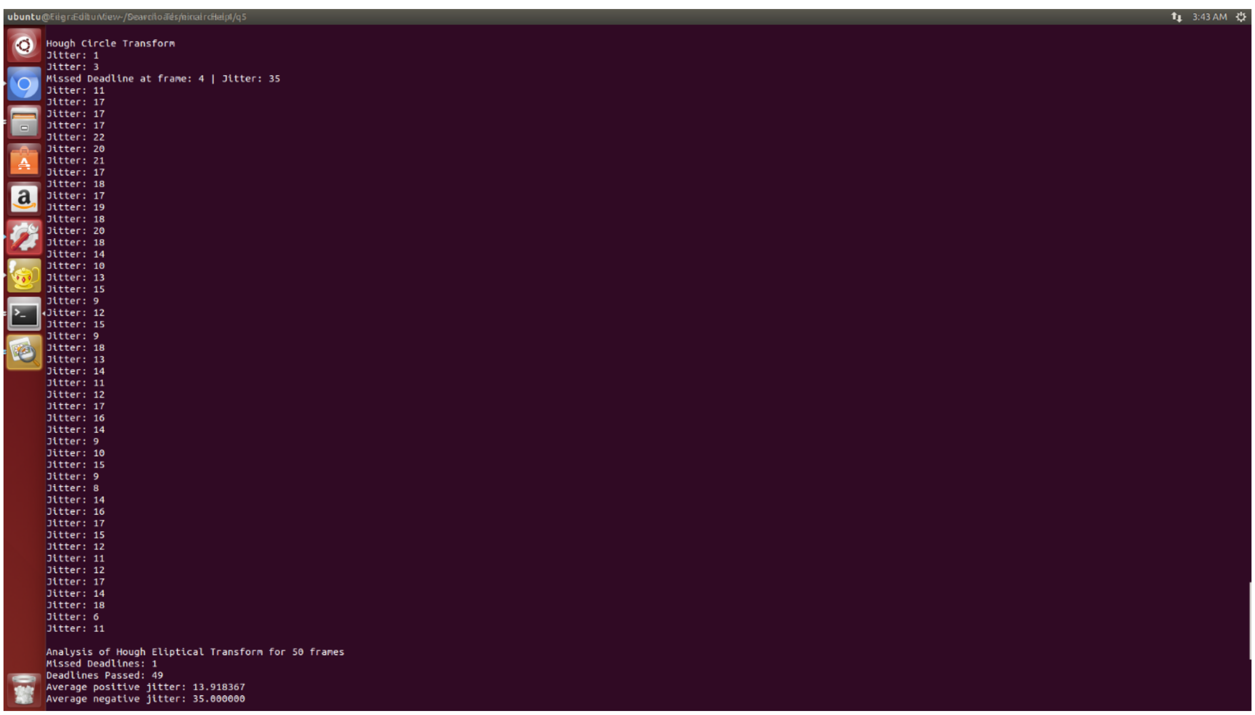
<u>320x240</u>

Canny Transform



Hough Transform

Hough Elliptical Transform



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REFERENCES

https://docs.opencv.org/2.4/modules/imgproc/doc/feature_detection.html?highlight=houghcircles

https://docs.opencv.org/3.1.0/da/d22/tutorial_py_canny.html

https://docs.opencv.org/3.0-beta/doc/py_tutorials/py_imgproc/py_houghlines/py_houghlines.html

https://docs.opencv.org/3.4/d4/d70/tutorial_hough_circle.html