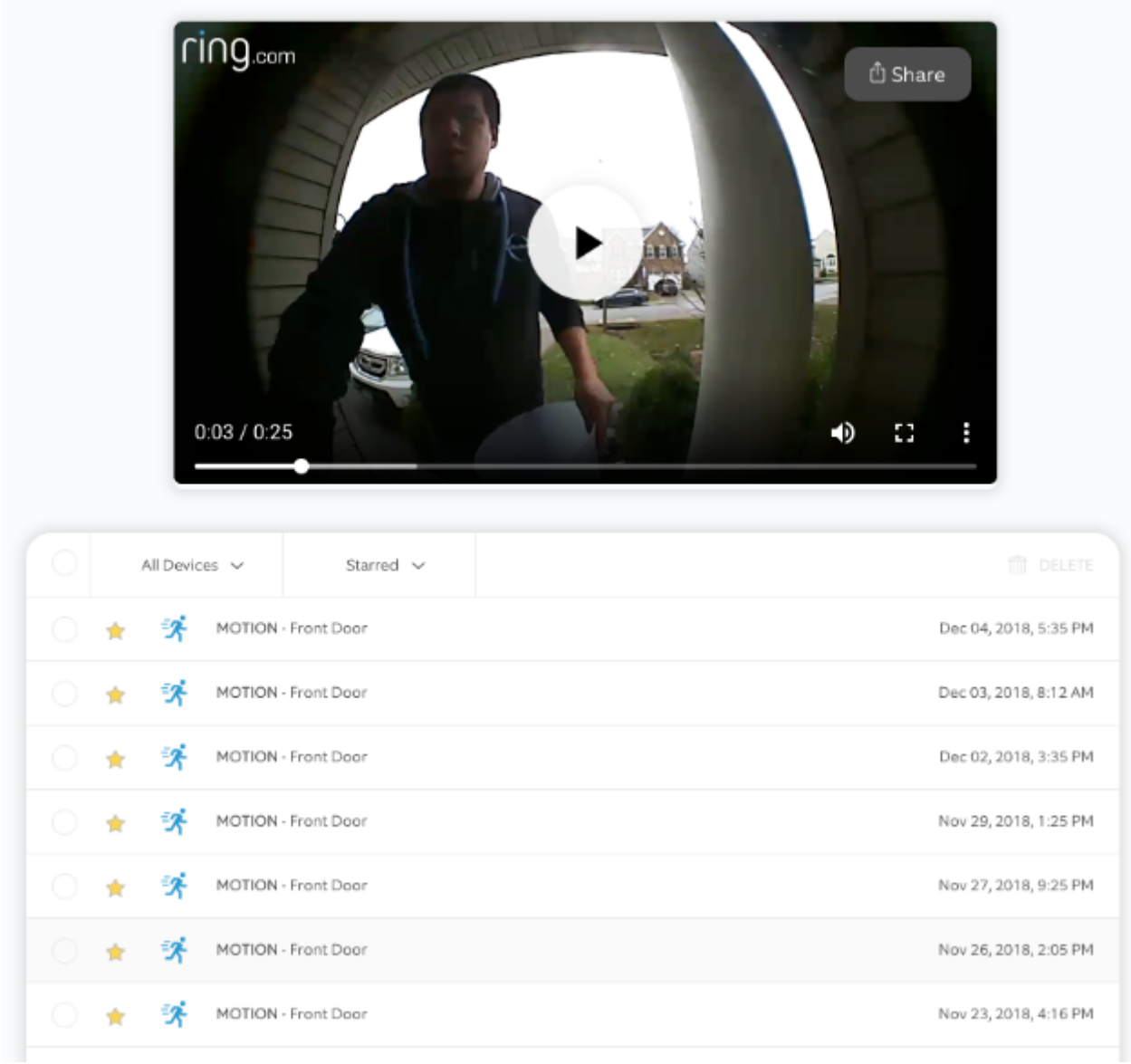
CS745 Final Project

Choice of dataset:

Dataset is a set of surveillance videos from my ring doorbell that have been downloaded in MP4 format. The videos will be converted to image sequences for processing.



Goal:

The goal of the project is to detect faces in the video using pre-trained classifiers from openCV and then to segment and isolate those faces within the bounding box of the detected face.

Proposed techniques:

Use of pre-trained classifiers from openCV for frontal, angled, and side view faces will be used to detect faces within the the image as well as their bounding boxes. An example of using a pre-trained openCV classifier within scikit-image can be found at: http://scikit-image.org/docs/dev/auto_examples/xx_applications/plot_face_detection.html (http://scikit-image.org/docs/dev/auto_examples/xx_applications/plot_face_detection.html) Once the bounding boxes have been identified, segmentation techniques will then be used to isolate the faces within the image and to save them to a folder of detected faces. A thresholded image will be used to isolate the detected face and covert remaining background to black.

Resources/libraries:

Two common classifiers are used for face detection in openCV LBP cascade classifier Haar feature-based classifier (uses edges/lines as features)

https://docs.opencv.org/2.4/modules/objdetect/doc/cascade_classification.html (https://docs.opencv.org/2.4/modules/objdetect/doc/cascade_classification.html)
https://docs.opencv.org/3.4/d7/d8b/tutorial_py_face_detection.html (https://docs.opencv.org/3.4/d7/d8b/tutorial_py_face_detection.html)

openCV contains a number of pre-trained models for frontal face recognition. Additional pre-trained models for side or profile faces may be downloaded and used as well.

openCV may also be used to convert video to image sequences and back to video:
https://docs.opencv.org/2.4/modules/highgui/doc/reading_and_writing_images_and_video.html (https://docs.opencv.org/2.4/modules/highgui/doc/reading_and_writing_images_and_video.html)

Imports

In [1]:
```
# To display inline videos in jupyter notebook
import io
import base64
from IPython.display import HTML

# For video capture
import cv2
import numpy as np

# To display real-time stills from video capture
%pylab inline
from IPython.display import clear_output

# Make full copies rather than references
from copy import copy
```

```
Populating the interactive namespace from numpy and matplotlib
```

Test Video (Indoors, Closeup with Ideal Lighting)

In [3]:
```
path = "ring-videos/inside-test.mp4"
```

In [552]:
```
video = io.open(path, 'r+b').read()
encoded = base64.b64encode(video)
HTML(data='''<video alt="test" controls width="900">
                <source src="data:video/mp4;base64,{0}" type="video/mp4" /
             </video>'''.format(encoded.decode('ascii')))
```

Out[552]:

Display Video Capture in Real-Time and Save Every Keyframe

In [8]:
```
def createKeyframes(path):

    # Create capture for video resource
    vid = cv2.VideoCapture(path)

    captureNumber = 0

    try:
        while(True):

            # Capture frame-by-frame
            ret, frame = vid.read()

            # Release the video resource if ret is false
            if not ret:
                vid.release()
                print("Finished saving keyframes")
                break

            # Save keyframe
            #if(captureNumber % 5 == 0):
            cv2.imwrite("keyframes/" + path.split("/")[1].split(".")[0] +

            # Convert the image from OpenCV BGR format to matplotlib RGB f
            # to display the image
            frame = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)
            axis('off')
            title("Input Video, Frame %d" % (captureNumber))

            # Display the frame
            imshow(frame)
            show()

            # Display the frame until new frame is available
            clear_output(wait=True)

            captureNumber += 1


    except KeyboardInterrupt:
        vid.release()
        print("Video capture interrupted")
```

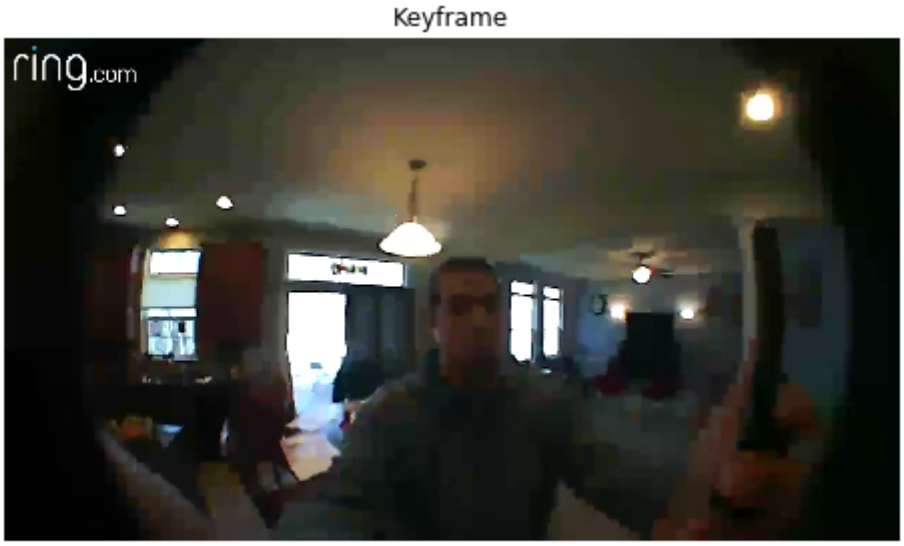
In [438]:
```
createKeyframes(path)
```

```
Finished saving keyframes
```

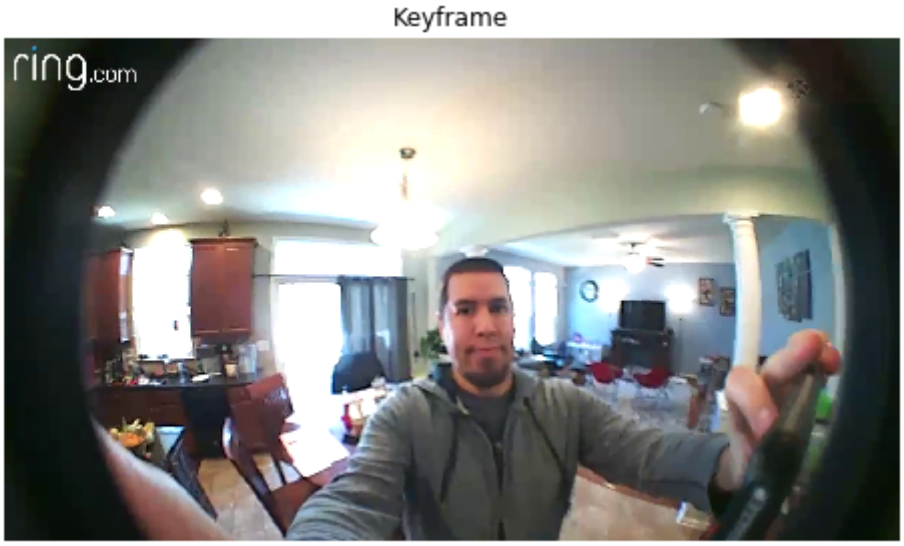
Display Sample Keyframe

In [9]:
```
def getKeyframe(file, keyframeNumber):
    keyframePath = "keyframes/" + file.split("/")[1].split(".")[0] + "_" +
    frame = cv2.imread(keyframePath)

    if frame is None:
        print("No keyframe available")
    else:
        return frame


def displayFrame(frame, frameTitle="Keyframe"):

    try:
        convertFrame = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)
    except:
        convertFrame = cv2.cvtColor(frame,cv2.COLOR_GRAY2RGB)

    axis('off')
    title(frameTitle)
    imshow(convertFrame)
    show()
```

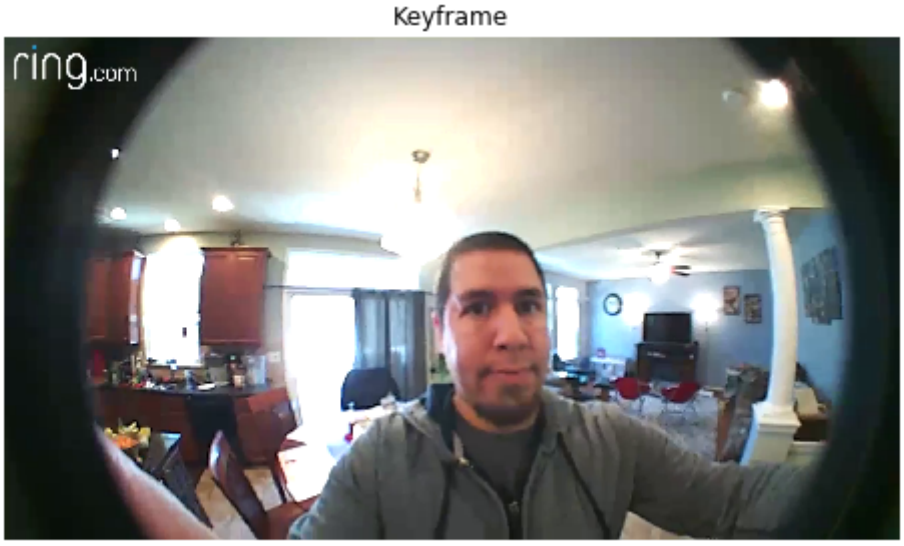
In [565]:
```
mpl.rcParams['figure.figsize'] = [8.0, 6.0]

keyframe10 = getKeyframe(path, 10)
displayFrame(keyframe10)
```



In [566]:
```
keyframe85 = getKeyframe(path, 85)
displayFrame(keyframe85)
```



In [567]:
```
keyframe155 = getKeyframe(path, 155)
displayFrame(keyframe155)
```

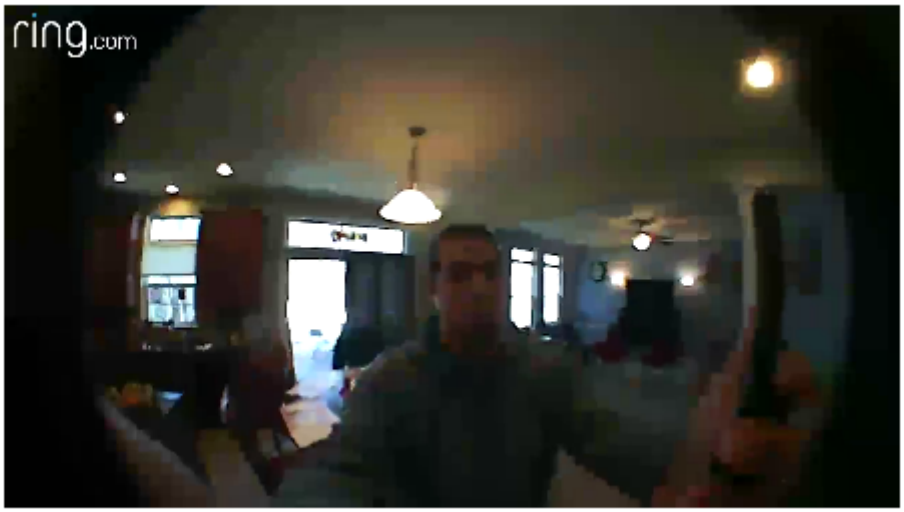


Experimentation with Pre-Processing

In [568]:

```
checkFrame = keyframe10

displayFrame(checkFrame, "Keyframe 10, Original")

displayFrame(cv2.cvtColor(checkFrame,cv2.COLOR_BGR2GRAY), "Keyframe 10, Gr

displayFrame(cv2.equalizeHist((cv2.cvtColor(checkFrame,cv2.COLOR_BGR2GRAY)

clahe = cv2.createCLAHE(clipLimit=2.0, tileGridSize=(8,8))
cl1 = clahe.apply(cv2.cvtColor(checkFrame,cv2.COLOR_BGR2GRAY))
displayFrame(cl1, "Keyframe, adaptive histogram equalization (8x8 tile)")

clahe = cv2.createCLAHE(clipLimit=2.0, tileGridSize=(32,32))
cl1 = clahe.apply(cv2.cvtColor(checkFrame,cv2.COLOR_BGR2GRAY))
displayFrame(cl1, "Keyframe, adaptive histogram equalization (32x32 tile)"
```

Keyframe 10, Original



Keyframe 10, Grayscale

Keyframe 10, Equalized

Keyframe, adaptive histogram equalization (8x8 tile)

Keyframe, adaptive histogram equalization (32x32 tile)

In [569]:

```
checkFrame = keyframe85
num = 85

displayFrame(checkFrame, "Keyframe %d" % (num))

displayFrame(cv2.cvtColor(checkFrame,cv2.COLOR_BGR2GRAY), "Keyframe %d, Gr

displayFrame(cv2.equalizeHist((cv2.cvtColor(checkFrame,cv2.COLOR_BGR2GRAY)

clahe = cv2.createCLAHE(clipLimit=2.0, tileGridSize=(8,8))
cl1 = clahe.apply(cv2.cvtColor(checkFrame,cv2.COLOR_BGR2GRAY))
displayFrame(cl1, "Keyframe %d, adaptive histogram equalization" % (num))
```

Keyframe 85

Keyframe 85, Grayscale

Keyframe 85, Equalized

Keyframe 85, adaptive histogram equalization

In [570]:

```
checkFrame = keyframe155
num = 155

displayFrame(checkFrame, "Keyframe %d" % (num))

displayFrame(cv2.cvtColor(checkFrame,cv2.COLOR_BGR2GRAY), "Keyframe %d, Gr

displayFrame(cv2.equalizeHist((cv2.cvtColor(checkFrame,cv2.COLOR_BGR2GRAY)

clahe = cv2.createCLAHE(clipLimit=2.0, tileGridSize=(8,8))
cl1 = clahe.apply(cv2.cvtColor(checkFrame,cv2.COLOR_BGR2GRAY))
displayFrame(cl1, "Keyframe %d, adaptive histogram equalization" % (num))
```

Keyframe 155

Keyframe 155, Grayscale

Keyframe 155, Equalized

Keyframe 155, adaptive histogram equalization

Detecting Faces in Keyframes

In [11]:
```
face_cascade = cv2.CascadeClassifier('cascade/haarcascade_frontalface_defa
profile_cascade = cv2.CascadeClassifier('cascade/haarcascade_profileface.x
```

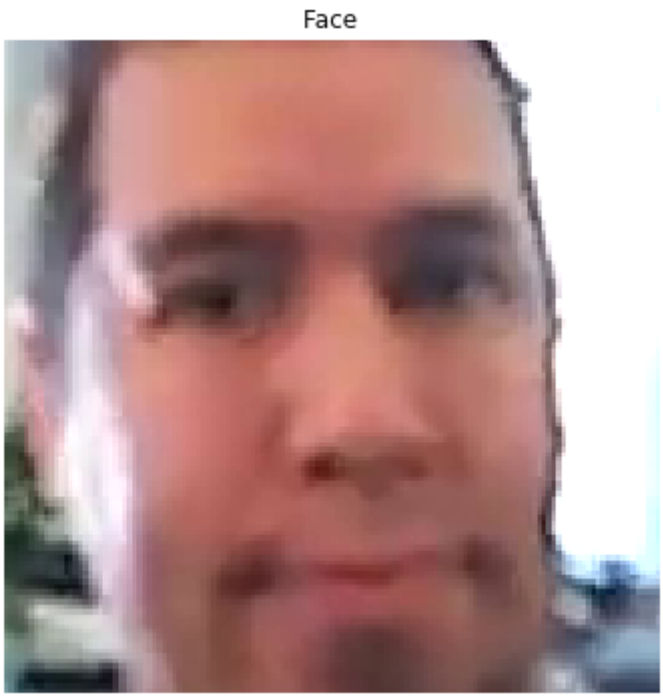
In [33]:
```
clahe = cv2.createCLAHE(clipLimit=2.0, tileGridSize=(8,8))

def detectFaces(frame,show=True):
    checkFrame = clahe.apply(cv2.cvtColor(frame,cv2.COLOR_BGR2GRAY))

    faceBoxes = []

    frontalFaces = face_cascade.detectMultiScale(checkFrame, 1.3, 5)
    #sideFaces = profile_cascade.detectMultiScale(checkFrame, 1.3, 5)

    allFaces = frontalFaces

    #if(not any(frontalFaces)):
    #    allFaces = sideFaces

    #if(any(sideFaces)):
    #    allFaces = allFaces + sideFaces

    for (x,y,w,h) in allFaces:
            faceBox = frame[y:y+h, x:x+w]
            faceBoxes.append((x,y,w,h))

            if(show):
                displayFrame(faceBox, "Face")

    if(not any(allFaces)):
        print("No faces detected")

    return faceBoxes
```

In [581]:
```
detectFaces(keyframe10)
```

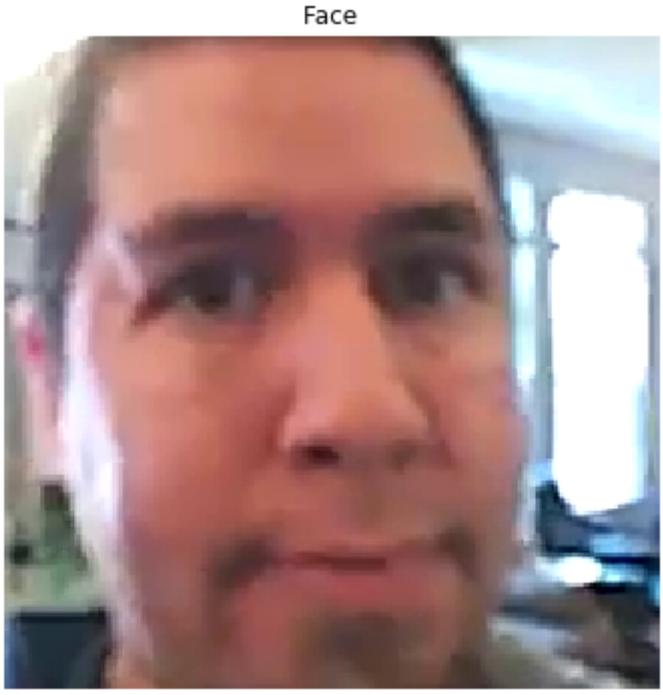
```
No faces detected
```

Out[581]:
```
[]
```

In [582]:
```
_ = detectFaces(keyframe85)
```



In [583]:
```
_ = detectFaces(keyframe155)
```

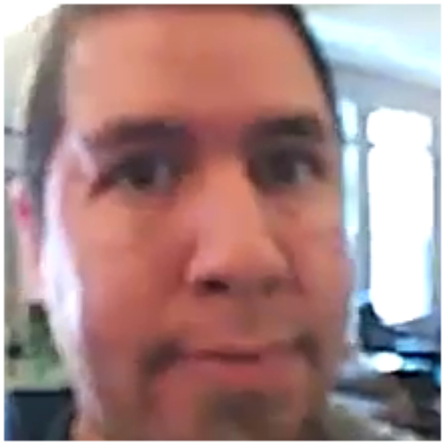


Segmenting Face

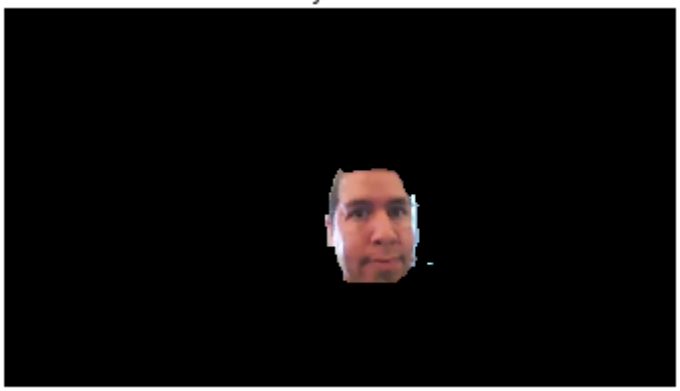
In [382]:

```
for faceBox in detectFaces(keyframe155):
    mask = np.zeros(keyframe155.shape[:2],np.uint8)
    bgdModel = np.zeros((1,65),np.float64)
    fgdModel = np.zeros((1,65),np.float64)
    rect = faceBox
    cv2.grabCut(keyframe155,mask,rect,bgdModel,fgdModel,3,cv2.GC_INIT_WITH
    mask2 = np.where((mask==2)|(mask==0),0,1).astype('uint8')
    img = keyframe155*mask2[:,:,np.newaxis]
    displayFrame(img)
```

Face



Keyframe



In [395]:

```
frame = cv2.imread("two-people.jpg")
displayFrame(frame, "Example with multiple faces")

final_img = []

for faceBox in detectFaces(frame):
    mask = np.zeros(frame.shape[:2],np.uint8)
    bgdModel = np.zeros((1,65),np.float64)
    fgdModel = np.zeros((1,65),np.float64)
    rect = faceBox
    cv2.grabCut(frame,mask,rect,bgdModel,fgdModel,3,cv2.GC_INIT_WITH_RECT)
    mask2 = np.where((mask==2)|(mask==0),0,1).astype('uint8')
    if(not any(final_img)):
        final_img = frame*mask2[:,:,np.newaxis]
    else:
        final_img = final_img + frame*mask2[:,:,np.newaxis]

displayFrame(final_img, "Segmented Faces")
```

Face

Face

Segmented Faces

Creating 4 Panel Displays

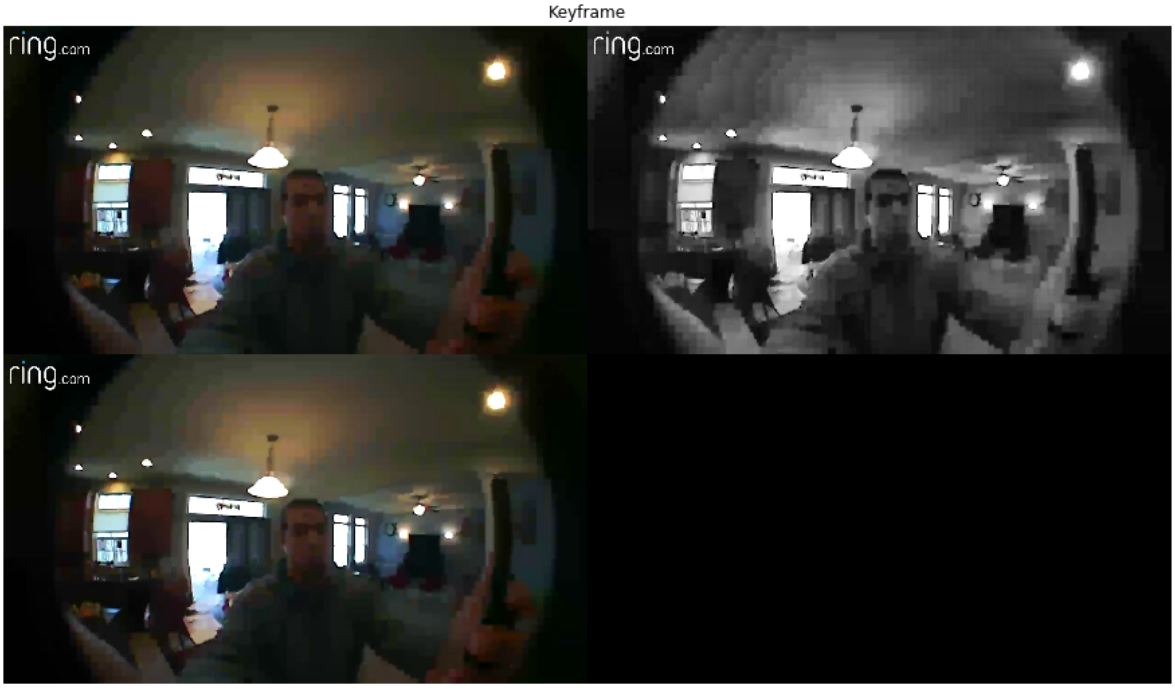
1. Original
2. Preprocessed
3. Bounding box over detected faces
4. Segmented faces

In [12]:

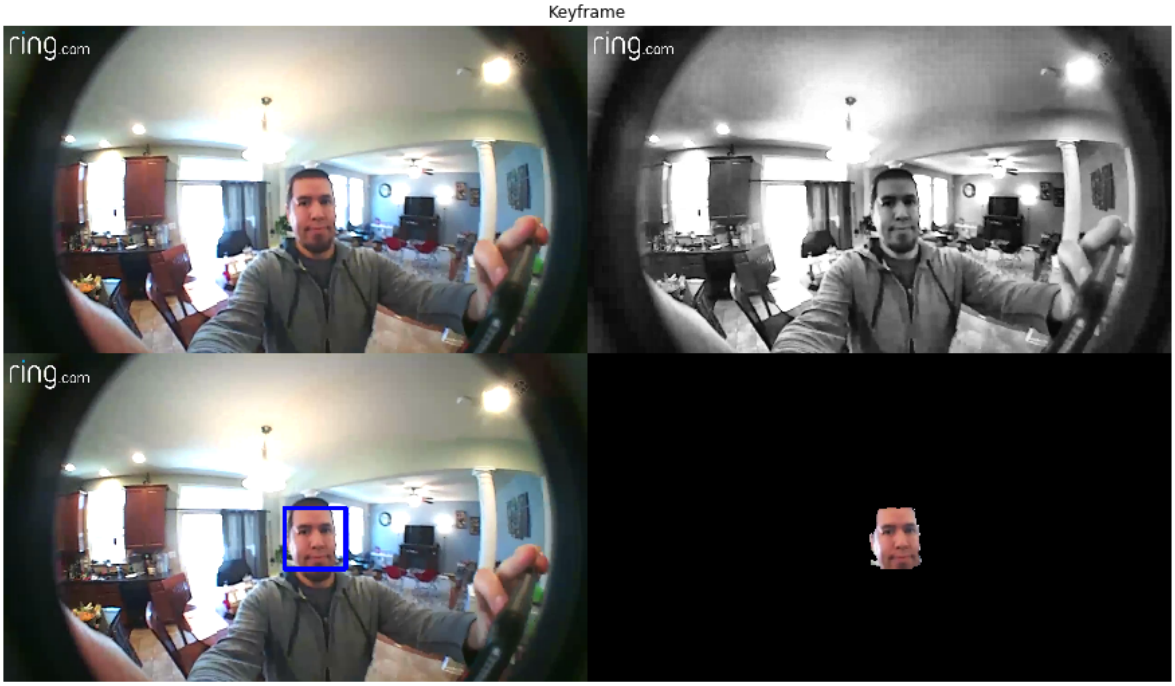
```
def display4Panel(frame, show=True):
    clahe = cv2.createCLAHE(clipLimit=2.0, tileGridSize=(8,8))

    preprocessed = clahe.apply(cv2.cvtColor(frame,cv2.COLOR_BGR2GRAY))
    preprocessed = cv2.cvtColor(preprocessed, cv2.COLOR_GRAY2BGR)

    frameWithBox = copy(frame)
    faceBoxes = detectFaces(frame, show=False)
    for (x,y,w,h) in faceBoxes:
        frameWithBox = cv2.rectangle(frameWithBox,(x,y),(x+w,y+h),(255,0,0

    segmentedFaces = []

    for faceBox in faceBoxes:
        mask = np.zeros(frame.shape[:2],np.uint8)
        bgdModel = np.zeros((1,65),np.float64)
        fgdModel = np.zeros((1,65),np.float64)
        rect = faceBox
        cv2.grabCut(frame,mask,rect,bgdModel,fgdModel,3,cv2.GC_INIT_WITH_R
        mask2 = np.where((mask==2)|(mask==0),0,1).astype('uint8')
        if(not any(segmentedFaces)):
            segmentedFaces = frame*mask2[:,:,np.newaxis]
        else:
            segmentedFaces = segmentedFaces + frame*mask2[:,:,np.newaxis]

    if(not any(segmentedFaces)):
        frameWithBox = frame
        mask = cv2.cvtColor(np.zeros(frame.shape[:2],np.uint8), cv2.COLOR_
        segmentedFaces = mask

    row1 = np.hstack((frame, preprocessed))
    row2 = np.hstack((frameWithBox, segmentedFaces))
    final_frame = np.vstack((row1, row2))

    if(show):
        displayFrame(final_frame)

    return final_frame
```

In [590]:
```
mpl.rcParams['figure.figsize'] = [16.0, 9.0]

_ = display4Panel(keyframe10)
```

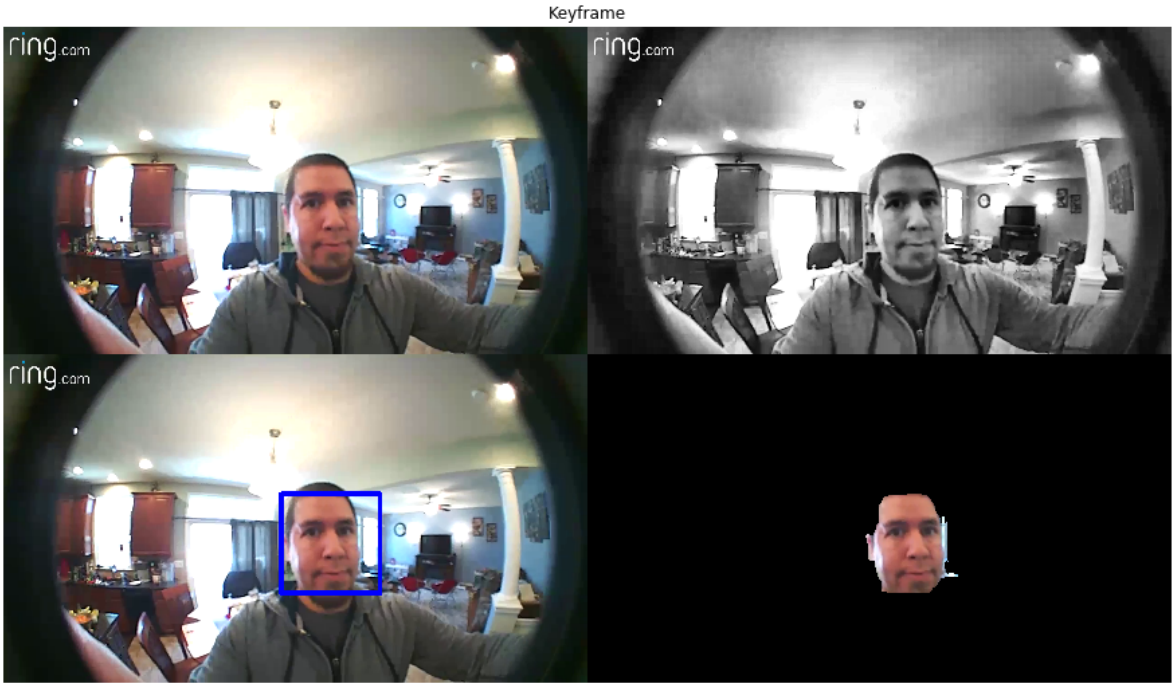
```
No faces detected
```



In [591]:
```
_ = display4Panel(keyframe85)
```



In [592]:
```
_ = display4Panel(keyframe155)
```



Creating Output Video

In [17]:
```
def createVideoFrames(path):

    createKeyframes(path)

    vid = cv2.VideoCapture(path)
    numberFrames = int(vid.get(int(cv2.CAP_PROP_FRAME_COUNT)))

    outputPath = "output-videos/" + path.split('/')[1].split('.')[0] + "_c

    for i in range(numberFrames):
        clear_output(wait=False)
        print("Frame %d" % (i))
        frame = getKeyframe(path, i)

        panelOfFour = display4Panel(frame, show=False)
        panelOfFour = cv2.resize(panelOfFour, (0,0), fx=0.5, fy=0.5)

        cv2.imwrite("final-frames/" + path.split("/")[1].split(".")[0] + "


    clear_output(wait=False)
    print("Finished processing image sequence, output video at %s" % (outp
```

In [451]:
```
createVideoFrames("ring-videos/inside-test.mp4")
```

```
Finished saving keyframes
```

In [18]:
```
createVideoFrames("ring-videos/kids-out-front.mp4")
```

```
Finished processing image sequence, output video at output-videos/kids-ou
t-front_output.mp4
```

In [21]:
```
createVideoFrames("ring-videos/night-face-short.mp4")
```

```
Finished processing image sequence, output video at output-videos/night-f
ace-short_output.mp4
```

In [24]:
```
createVideoFrames("ring-videos/night-face-long.mp4")
```

```
Finished processing image sequence, output video at output-videos/night-f
ace-long_output.mp4
```

In [34]:
```
createVideoFrames("ring-videos/inside-different-angles.mp4")
```

```
Finished processing image sequence, output video at output-videos/inside-
different-angles_output.mp4
```

In [35]:
```
createVideoFrames("ring-videos/inside-gray.mp4")
```

```
Finished processing image sequence, output video at output-videos/inside-
gray_output.mp4
```

In [36]:
```
createVideoFrames("ring-videos/daytime-face-short.mp4")
```

```
Finished processing image sequence, output video at output-videos/daytime
-face-short_output.mp4
```

Writing Images Sequences to Video with ffmpeg

In [15]:
```
! ffmpeg -i final-frames/inside-test_%05d.png -framerate 15 -y output-vide
```

```
ffmpeg version 4.0 Copyright (c) 2000-2018 the FFmpeg developers
  built with clang version 4.0.1 (tags/RELEASE_401/final)
  configuration: --prefix=/Users/Anthony/anaconda3 --cc=x86_64-apple-darw
in13.4.0-clang --disable-doc --enable-shared --enable-static --enable-zli
b --enable-pic --enable-gpl --enable-version3 --disable-nonfree --enable-
hardcoded-tables --enable-avresample --enable-libfreetype --disable-opens
sl --disable-gnutls --enable-libvpx --enable-pthreads --enable-libopus --
enable-postproc --disable-libx264
  libavutil      56. 14.100 / 56. 14.100
  libavcodec     58. 18.100 / 58. 18.100
  libavformat    58. 12.100 / 58. 12.100
  libavdevice    58.  3.100 / 58.  3.100
  libavfilter     7. 16.100 /  7. 16.100
  libavresample   4.  0.  0 /  4.  0.  0
  libswscale      5.  1.100 /  5.  1.100
  libswresample   3.  1.100 /  3.  1.100
  libpostproc    55.  1.100 / 55.  1.100
Input #0, image2, from 'final-frames/inside-test_%05d.png':
  Duration: 00:00:08.40, start: 0.000000, bitrate: N/A
    Stream #0:0: Video: png, rgb24(pc), 1280x720, 25 fps, 25 tbr, 25 tbn,
25 tbc
Stream mapping:
  Stream #0:0 -> #0:0 (png (native) -> mpeg4 (native))
Press [q] to stop, [?] for help
Output #0, mp4, to 'output-videos/inside-test.mp4':
  Metadata:
    encoder         : Lavf58.12.100
    Stream #0:0: Video: mpeg4 (mp4v / 0x7634706D), yuv420p, 1280x720, q=2
-31, 200 kb/s, 25 fps, 12800 tbn, 25 tbc
    Metadata:
      encoder         : Lavc58.18.100 mpeg4
    Side data:
      cpb: bitrate max/min/avg: 0/0/200000 buffer size: 0 vbv_delay: -1
frame=  210 fps=184 q=31.0 Lsize=    1049kB time=00:00:08.36 bitrate=102
7.7kbits/s speed=7.33x
video:1047kB audio:0kB subtitle:0kB other streams:0kB global headers:0kB
muxing overhead: 0.166479%
```

In [20]:
```
! ffmpeg -i final-frames/kids-out-front_%05d.png -framerate 15 -y output-v
```

```
ffmpeg version 4.0 Copyright (c) 2000-2018 the FFmpeg developers
  built with clang version 4.0.1 (tags/RELEASE_401/final)
  configuration: --prefix=/Users/Anthony/anaconda3 --cc=x86_64-apple-darw
in13.4.0-clang --disable-doc --enable-shared --enable-static --enable-zli
b --enable-pic --enable-gpl --enable-version3 --disable-nonfree --enable-
hardcoded-tables --enable-avresample --enable-libfreetype --disable-opens
sl --disable-gnutls --enable-libvpx --enable-pthreads --enable-libopus --
enable-postproc --disable-libx264
  libavutil      56. 14.100 / 56. 14.100
  libavcodec     58. 18.100 / 58. 18.100
  libavformat    58. 12.100 / 58. 12.100
  libavdevice    58.  3.100 / 58.  3.100
  libavfilter     7. 16.100 /  7. 16.100
  libavresample   4.  0.  0 /  4.  0.  0
  libswscale      5.  1.100 /  5.  1.100
  libswresample   3.  1.100 /  3.  1.100
  libpostproc    55.  1.100 / 55.  1.100
Input #0, image2, from 'final-frames/kids-out-front_%05d.png':
  Duration: 00:00:18.72, start: 0.000000, bitrate: N/A
    Stream #0:0: Video: png, rgb24(pc), 1280x720, 25 fps, 25 tbr, 25 tbn,
25 tbc
Stream mapping:
  Stream #0:0 -> #0:0 (png (native) -> mpeg4 (native))
Press [q] to stop, [?] for help
Output #0, mp4, to 'output-videos/kids-out-front.mp4':
  Metadata:
    encoder         : Lavf58.12.100
    Stream #0:0: Video: mpeg4 (mp4v / 0x7634706D), yuv420p, 1280x720, q=2
-31, 200 kb/s, 25 fps, 12800 tbn, 25 tbc
    Metadata:
      encoder         : Lavc58.18.100 mpeg4
    Side data:
      cpb: bitrate max/min/avg: 0/0/200000 buffer size: 0 vbv_delay: -1
frame=  468 fps=106 q=31.0 Lsize=    1499kB time=00:00:18.68 bitrate= 65
7.3kbits/s speed=4.25x
video:1496kB audio:0kB subtitle:0kB other streams:0kB global headers:0kB
muxing overhead: 0.189371%
```

In [28]:
```
! ffmpeg -i final-frames/night-face-long_%05d.png -framerate 15 -y output-
```

```
ffmpeg version 4.0 Copyright (c) 2000-2018 the FFmpeg developers
  built with clang version 4.0.1 (tags/RELEASE_401/final)
  configuration: --prefix=/Users/Anthony/anaconda3 --cc=x86_64-apple-darw
in13.4.0-clang --disable-doc --enable-shared --enable-static --enable-zli
b --enable-pic --enable-gpl --enable-version3 --disable-nonfree --enable-
hardcoded-tables --enable-avresample --enable-libfreetype --disable-opens
sl --disable-gnutls --enable-libvpx --enable-pthreads --enable-libopus --
enable-postproc --disable-libx264
  libavutil      56. 14.100 / 56. 14.100
  libavcodec     58. 18.100 / 58. 18.100
  libavformat    58. 12.100 / 58. 12.100
  libavdevice    58.  3.100 / 58.  3.100
  libavfilter     7. 16.100 /  7. 16.100
  libavresample   4.  0.  0 /  4.  0.  0
  libswscale      5.  1.100 /  5.  1.100
  libswresample   3.  1.100 /  3.  1.100
  libpostproc    55.  1.100 / 55.  1.100
Input #0, image2, from 'final-frames/night-face-long_%05d.png':
  Duration: 00:00:18.64, start: 0.000000, bitrate: N/A
    Stream #0:0: Video: png, rgb24(pc), 1280x720, 25 fps, 25 tbr, 25 tbn,
25 tbc
Stream mapping:
  Stream #0:0 -> #0:0 (png (native) -> mpeg4 (native))
Press [q] to stop, [?] for help
Output #0, mp4, to 'output-videos/night-face-long.mp4':
  Metadata:
    encoder         : Lavf58.12.100
    Stream #0:0: Video: mpeg4 (mp4v / 0x7634706D), yuv420p, 1280x720, q=2
-31, 200 kb/s, 25 fps, 12800 tbn, 25 tbc
    Metadata:
      encoder         : Lavc58.18.100 mpeg4
    Side data:
      cpb: bitrate max/min/avg: 0/0/200000 buffer size: 0 vbv_delay: -1
frame=  466 fps=118 q=31.0 Lsize=    1398kB time=00:00:18.60 bitrate= 61
5.7kbits/s speed=4.72x
video:1395kB audio:0kB subtitle:0kB other streams:0kB global headers:0kB
muxing overhead: 0.202501%
```

In [27]:
```
! ffmpeg -i final-frames/night-face-short_%05d.png -framerate 15 -y output
```

```
ffmpeg version 4.0 Copyright (c) 2000-2018 the FFmpeg developers
  built with clang version 4.0.1 (tags/RELEASE_401/final)
  configuration: --prefix=/Users/Anthony/anaconda3 --cc=x86_64-apple-darw
in13.4.0-clang --disable-doc --enable-shared --enable-static --enable-zli
b --enable-pic --enable-gpl --enable-version3 --disable-nonfree --enable-
hardcoded-tables --enable-avresample --enable-libfreetype --disable-opens
sl --disable-gnutls --enable-libvpx --enable-pthreads --enable-libopus --
enable-postproc --disable-libx264
  libavutil      56. 14.100 / 56. 14.100
  libavcodec     58. 18.100 / 58. 18.100
  libavformat    58. 12.100 / 58. 12.100
  libavdevice    58.  3.100 / 58.  3.100
  libavfilter     7. 16.100 /  7. 16.100
  libavresample   4.  0.  0 /  4.  0.  0
  libswscale      5.  1.100 /  5.  1.100
  libswresample   3.  1.100 /  3.  1.100
  libpostproc    55.  1.100 / 55.  1.100
Input #0, image2, from 'final-frames/night-face-short_%05d.png':
  Duration: 00:00:19.00, start: 0.000000, bitrate: N/A
    Stream #0:0: Video: png, rgb24(pc), 1280x720, 25 fps, 25 tbr, 25 tbn,
25 tbc
Stream mapping:
  Stream #0:0 -> #0:0 (png (native) -> mpeg4 (native))
Press [q] to stop, [?] for help
Output #0, mp4, to 'output-videos/night-face-short.mp4':
  Metadata:
    encoder         : Lavf58.12.100
    Stream #0:0: Video: mpeg4 (mp4v / 0x7634706D), yuv420p, 1280x720, q=2
-31, 200 kb/s, 25 fps, 12800 tbn, 25 tbc
    Metadata:
      encoder         : Lavc58.18.100 mpeg4
    Side data:
      cpb: bitrate max/min/avg: 0/0/200000 buffer size: 0 vbv_delay: -1
frame=  475 fps=112 q=31.0 Lsize=    1194kB time=00:00:18.96 bitrate= 51
5.8kbits/s speed=4.48x
video:1191kB audio:0kB subtitle:0kB other streams:0kB global headers:0kB
muxing overhead: 0.240515%
```

In [37]:
```
! ffmpeg -i final-frames/daytime-face-short_%05d.png -framerate 15 -y outp
```

```
ffmpeg version 4.0 Copyright (c) 2000-2018 the FFmpeg developers
  built with clang version 4.0.1 (tags/RELEASE_401/final)
  configuration: --prefix=/Users/Anthony/anaconda3 --cc=x86_64-apple-darw
in13.4.0-clang --disable-doc --enable-shared --enable-static --enable-zli
b --enable-pic --enable-gpl --enable-version3 --disable-nonfree --enable-
hardcoded-tables --enable-avresample --enable-libfreetype --disable-opens
sl --disable-gnutls --enable-libvpx --enable-pthreads --enable-libopus --
enable-postproc --disable-libx264
  libavutil      56. 14.100 / 56. 14.100
  libavcodec     58. 18.100 / 58. 18.100
  libavformat    58. 12.100 / 58. 12.100
  libavdevice    58.  3.100 / 58.  3.100
  libavfilter     7. 16.100 /  7. 16.100
  libavresample   4.  0.  0 /  4.  0.  0
  libswscale      5.  1.100 /  5.  1.100
  libswresample   3.  1.100 /  3.  1.100
  libpostproc    55.  1.100 / 55.  1.100
Input #0, image2, from 'final-frames/daytime-face-short_%05d.png':
  Duration: 00:00:15.28, start: 0.000000, bitrate: N/A
    Stream #0:0: Video: png, rgb24(pc), 1280x720, 25 fps, 25 tbr, 25 tbn,
25 tbc
Stream mapping:
  Stream #0:0 -> #0:0 (png (native) -> mpeg4 (native))
Press [q] to stop, [?] for help
Output #0, mp4, to 'output-videos/daytime-face-short.mp4':
  Metadata:
    encoder         : Lavf58.12.100
    Stream #0:0: Video: mpeg4 (mp4v / 0x7634706D), yuv420p, 1280x720, q=2
-31, 200 kb/s, 25 fps, 12800 tbn, 25 tbc
    Metadata:
      encoder         : Lavc58.18.100 mpeg4
    Side data:
      cpb: bitrate max/min/avg: 0/0/200000 buffer size: 0 vbv_delay: -1
frame=  382 fps=123 q=31.0 Lsize=    1117kB time=00:00:15.24 bitrate= 60
0.3kbits/s speed= 4.9x
video:1114kB audio:0kB subtitle:0kB other streams:0kB global headers:0kB
muxing overhead: 0.221653%
```

In [38]:
```
! ffmpeg -i final-frames/inside-different-angles_%05d.png -framerate 15 -y
```

```
ffmpeg version 4.0 Copyright (c) 2000-2018 the FFmpeg developers
  built with clang version 4.0.1 (tags/RELEASE_401/final)
  configuration: --prefix=/Users/Anthony/anaconda3 --cc=x86_64-apple-darw
in13.4.0-clang --disable-doc --enable-shared --enable-static --enable-zli
b --enable-pic --enable-gpl --enable-version3 --disable-nonfree --enable-
hardcoded-tables --enable-avresample --enable-libfreetype --disable-opens
sl --disable-gnutls --enable-libvpx --enable-pthreads --enable-libopus --
enable-postproc --disable-libx264
  libavutil      56. 14.100 / 56. 14.100
  libavcodec     58. 18.100 / 58. 18.100
  libavformat    58. 12.100 / 58. 12.100
  libavdevice    58.  3.100 / 58.  3.100
  libavfilter     7. 16.100 /  7. 16.100
  libavresample   4.  0.  0 /  4.  0.  0
  libswscale      5.  1.100 /  5.  1.100
  libswresample   3.  1.100 /  3.  1.100
  libpostproc    55.  1.100 / 55.  1.100
Input #0, image2, from 'final-frames/inside-different-angles_%05d.png':
  Duration: 00:00:15.92, start: 0.000000, bitrate: N/A
    Stream #0:0: Video: png, rgb24(pc), 1280x720, 25 fps, 25 tbr, 25 tbn,
25 tbc
Stream mapping:
  Stream #0:0 -> #0:0 (png (native) -> mpeg4 (native))
Press [q] to stop, [?] for help
Output #0, mp4, to 'output-videos/inside-different-angles.mp4':
  Metadata:
    encoder         : Lavf58.12.100
    Stream #0:0: Video: mpeg4 (mp4v / 0x7634706D), yuv420p, 1280x720, q=2
-31, 200 kb/s, 25 fps, 12800 tbn, 25 tbc
    Metadata:
      encoder         : Lavc58.18.100 mpeg4
    Side data:
      cpb: bitrate max/min/avg: 0/0/200000 buffer size: 0 vbv_delay: -1
frame=  398 fps=107 q=31.0 Lsize=    2082kB time=00:00:15.88 bitrate=107
3.9kbits/s speed=4.29x
video:2079kB audio:0kB subtitle:0kB other streams:0kB global headers:0kB
muxing overhead: 0.122913%
```

In [39]:
```
! ffmpeg -i final-frames/inside-gray_%05d.png -framerate 15 -y output-vide
```

```
ffmpeg version 4.0 Copyright (c) 2000-2018 the FFmpeg developers
  built with clang version 4.0.1 (tags/RELEASE_401/final)
  configuration: --prefix=/Users/Anthony/anaconda3 --cc=x86_64-apple-darw
in13.4.0-clang --disable-doc --enable-shared --enable-static --enable-zli
b --enable-pic --enable-gpl --enable-version3 --disable-nonfree --enable-
hardcoded-tables --enable-avresample --enable-libfreetype --disable-opens
sl --disable-gnutls --enable-libvpx --enable-pthreads --enable-libopus --
enable-postproc --disable-libx264
  libavutil      56. 14.100 / 56. 14.100
  libavcodec     58. 18.100 / 58. 18.100
  libavformat    58. 12.100 / 58. 12.100
  libavdevice    58.  3.100 / 58.  3.100
  libavfilter     7. 16.100 /  7. 16.100
  libavresample   4.  0.  0 /  4.  0.  0
  libswscale      5.  1.100 /  5.  1.100
  libswresample   3.  1.100 /  3.  1.100
  libpostproc    55.  1.100 / 55.  1.100
Input #0, image2, from 'final-frames/inside-gray_%05d.png':
  Duration: 00:00:08.68, start: 0.000000, bitrate: N/A
    Stream #0:0: Video: png, rgb24(pc), 1280x720, 25 fps, 25 tbr, 25 tbn,
25 tbc
Stream mapping:
  Stream #0:0 -> #0:0 (png (native) -> mpeg4 (native))
Press [q] to stop, [?] for help
Output #0, mp4, to 'output-videos/inside-gray.mp4':
  Metadata:
    encoder         : Lavf58.12.100
    Stream #0:0: Video: mpeg4 (mp4v / 0x7634706D), yuv420p, 1280x720, q=2
-31, 200 kb/s, 25 fps, 12800 tbn, 25 tbc
    Metadata:
      encoder         : Lavc58.18.100 mpeg4
    Side data:
      cpb: bitrate max/min/avg: 0/0/200000 buffer size: 0 vbv_delay: -1
frame=  217 fps=127 q=24.8 Lsize=     964kB time=00:00:08.64 bitrate= 91
4.1kbits/s speed=5.04x
video:962kB audio:0kB subtitle:0kB other streams:0kB global headers:0kB m
uxing overhead: 0.182757%
```

Output Videos

Inside, Straight on, Optimal Lighting

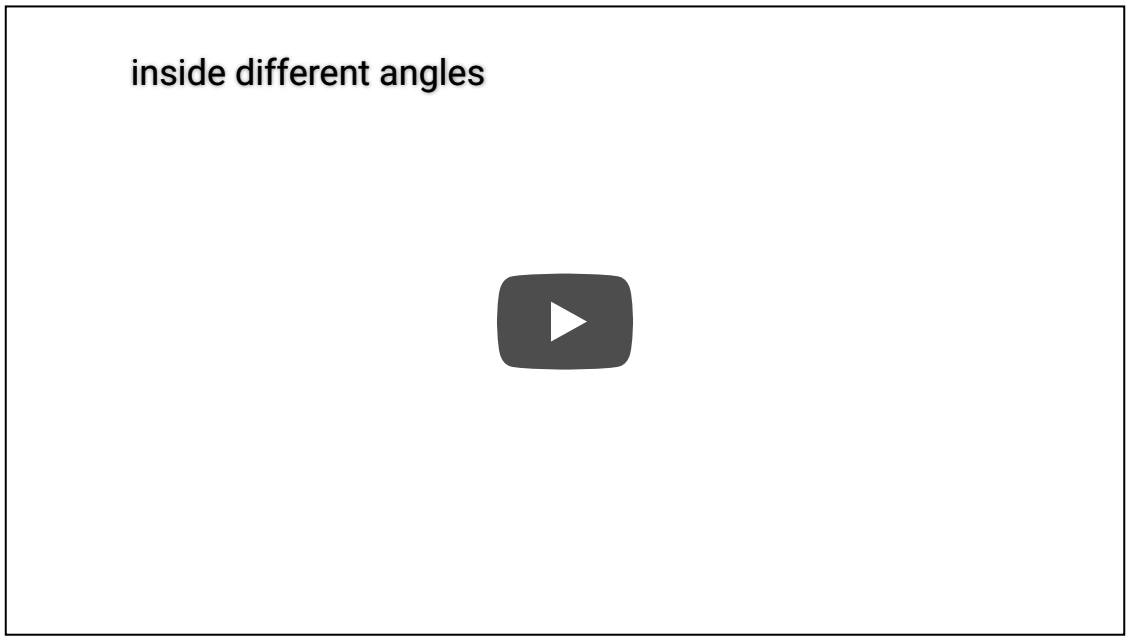
In [3]:
```
HTML(data='''<iframe width="560" height="315" src="https://www.youtube.com
```

Out[3]:

Inside, Different Angles, Optimal Lighting

In [4]:
```
HTML(data='''<iframe width="560" height="315" src="https://www.youtube.com/em
```

Out[4]:



Inside, Night Mode, Straight On

In [5]:
```
HTML(data='''<iframe width="560" height="315" src="https://www.youtube.com
```

Out[5]:

Outside, Daytime, Face for Short Amounts

In [6]:
```
HTML(data='''<iframe width="560" height="315" src="https://www.youtube.com
```

Out[6]:

Outside, Night Mode, Face for Long Amounts of Time

In [7]:
```
HTML(data='''<iframe width="560" height="315" src="https://www.youtube.com
```

Out[7]:

Outside, Night Mode, Face for Short Amounts of Time

In [8]:
```
HTML(data='''<iframe width="560" height="315" src="https://www.youtube.com
```

Out[8]:

Outside, Daytime, Kids from Side and My Face from Front Briefly

In [9]:
```
HTML(data='''<iframe width="560" height="315" src="https://www.youtube.com
```

Out[9]:

In [ ]: