

Project Motivation

The main purpose of image encryption is to send and receive sensitive material. *Computational Image Encryption Techniques* states “Images contain very sensitive and confidential information. Because images play a significant role in many applications such as military communication, remote-sensing, and medical-imaging, therefore, it is necessary to protect sensitive and confidential information from unauthorized use and modification.” UAVs are widely used in military operations and their video streams need to be encrypted to protect sensitive materials. This means when engineers are designing a drone system that they must create efficient video encryption algorithms so the drone pilot can get a seamless video stream that won't be delayed. *Embedded Real-Time Video Encryption Module on UAV Surveillance Systems* states “Now, there are new mission for UAV, like combat, intelligence, and civil applications [6]. Because any transmission from a military UAV must be secured it's a must to use an encryption method to protect de confidentiality of the transmitted data.” Drones have a lot more advantages in the military than regular aircraft: they are cheaper to build, easier to maintain, harder to detect, and don't put human life at risk. Turkey has been a world leader in small drones and exports this technology all over the world. A research paper from Gazi University talks about the benefits of putting the image encryption locally on a drone, to increase the reliability of the information being transmitted. “The UAVs/drones' low cost and easy obtainability have also increased the questions about their reliabilities. As the UAVs themselves can be used as an attack tool, also the attacks made to them have become a situation that is often encountered. It is very important that air vehicles are physically reliably that software and data transfer are reliable. To achieve this goal, the first concern to consider and improve is to increase the reliability of data link usage in UAVs. In both the world and our country, although UAVs are produced by many companies, the data link/communication security problem continues. As well as transmitting data to long distances, it is very important to send the right information to the right spot.”

Another application of image encryption is in Biomedical Engineering where patients' sensitive data must be encrypted and stored. Since most medical images are extremely detailed, big, and sometimes 3D; engineers need to create secure and efficient algorithms to make sure patient data is secure and accessible. As more medical technology becomes digital these encryption algorithms are key to progress. *Simultaneous encryption and compression of medical images based on optimized tensor compressed sensing with 3D Lorenz* states “In recent years, numerous studies on encryption of medical images, such as computed tomography (CT) and magnetic resonance imaging (MRI), have been reported [1–6], although most of them did not consider compression during encryption. The storage, transmission, and retrieval of massive bio-information should meet several compulsory requirements [7]: (1) high efficiency for rapid transmission and prompt retrieval; (2) strict information security to guarantee users' privacy; and (3) high data fidelity to preserving the pathological information. It requires decreasing the quantity of data to be transmitted (compression) and protecting such data against unauthorized access (encryption). Therefore, simultaneous compression and encryption technology of medical images that are represented as three-dimensional (3D) volumes has additional meanings.”

References:

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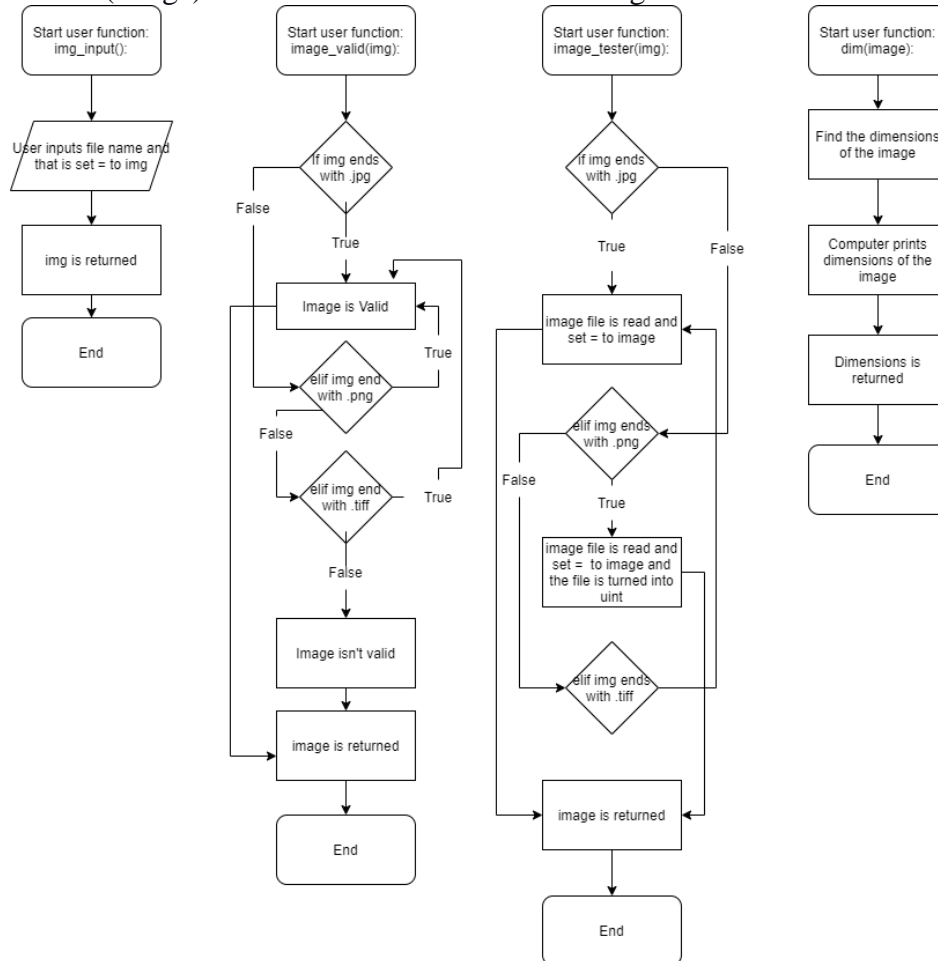
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Project Overview and Methods

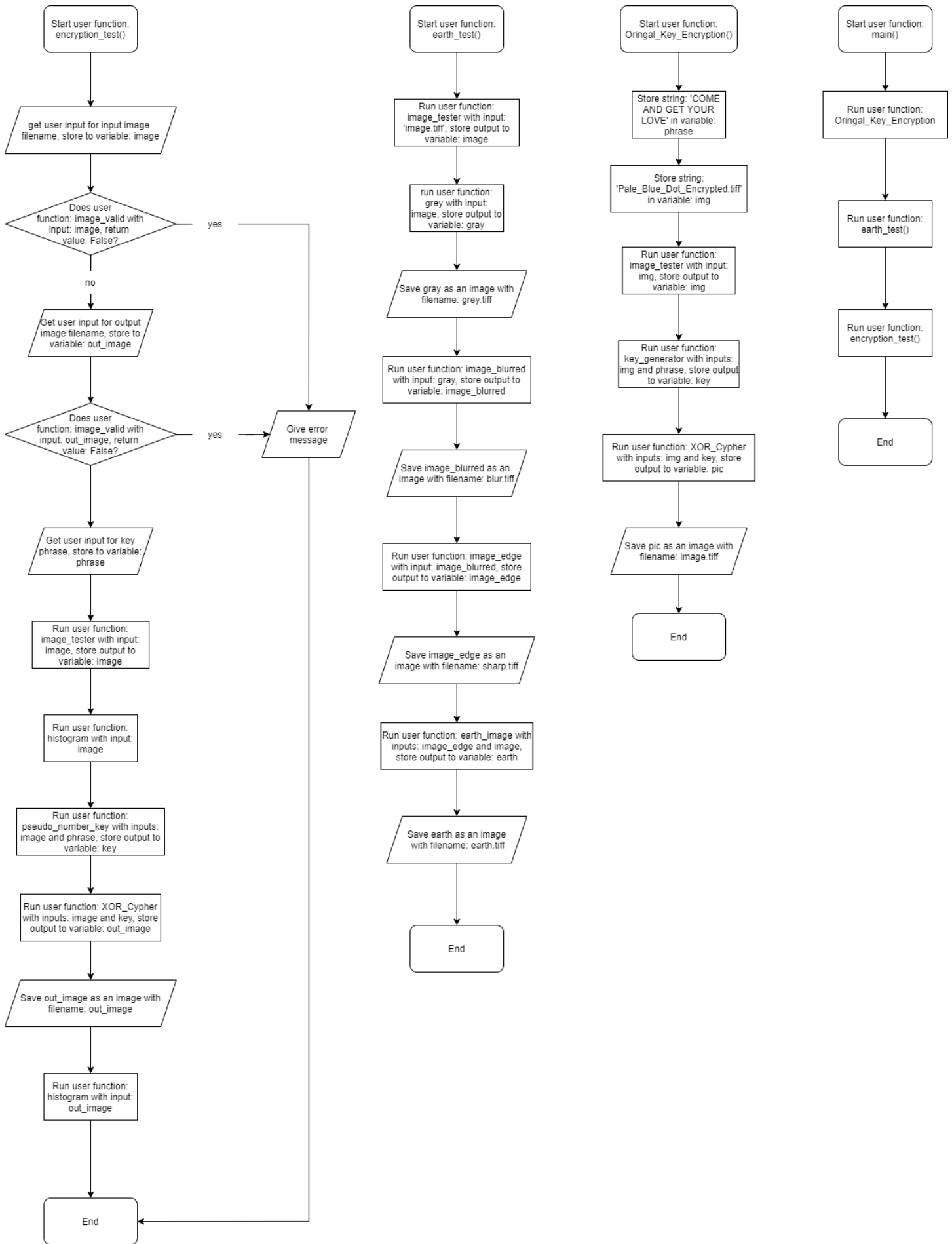
- Image encryption and decryption is a method of hiding the information in an image by scrambling (encryption) the information using a key or password of some sort so that it can be unscrambled (decryption) by anyone else who has the key.
- The XOR cipher compares each binary bit of the image and the key using the exclusive or logic operation to alter each bit of the image according to the key. The upside to this method of encryption is that the XOR operator acts a lot like a Palindrome, as comparing the key with either the encrypted or decrypted image will decrypt or encrypt the image respectively.
- To get the gradient map, a few steps must be taken:
 - The image must first be smoothed to remove noise. Noise in the image may be interpreted as an edge later on in image processing
 - Next, the gradient of the image must be taken across each row of the image, treating each row as a function of brightness in terms of the position and taking the first derivative of that function with respect to position.
 - Next, the gradient of the image must be taken across each column of the image, treating each row as a function of brightness in terms of the position and taking the first derivative of that function with respect to position.
 - The row-wise and column-wise gradients must then be combined by finding $\sqrt{(\text{row gradient})^2 + (\text{column gradient})^2}$ for each pixel of the two gradients to obtain the gradient map
- The edges in the original image are where the brightest spots in the gradient map are, so edge detection looks at these parts of the gradient map to find edges.
- We used an XOR cipher and key to encrypt our images because an XOR statement can be applied once to encrypt it and applying the XOR cipher again can decrypt it.

Discussion of Algorithm Design

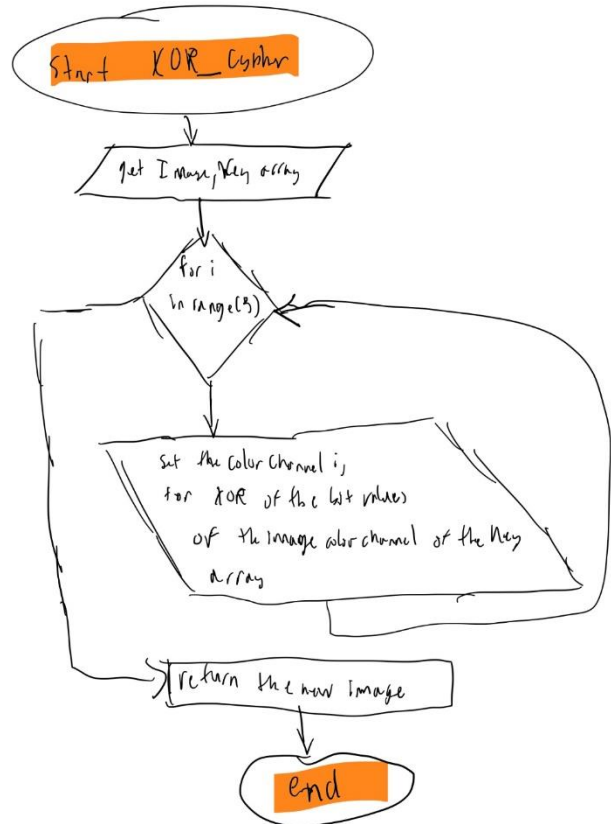
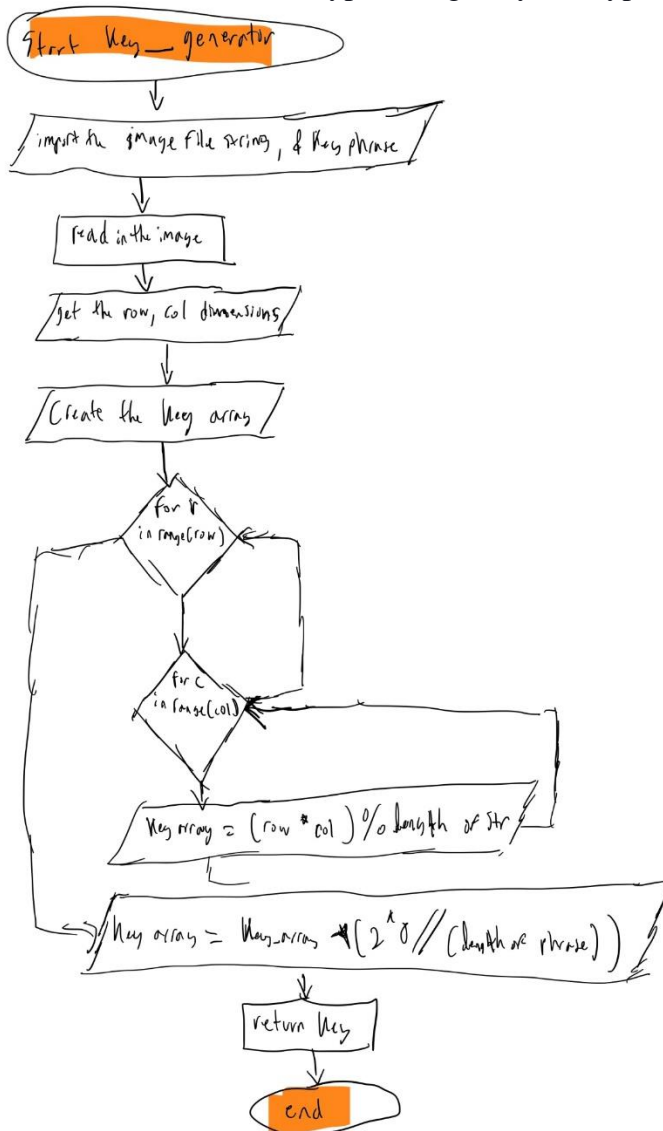
- We split the code into 4 separate python files: Image_analysis, grey_search, key_generator, histo_key based on the 4 different parts of the project.
 - Image_analysis** contains 4 user defined functions
 - Img_input asks the user to input a file name
 - Image valid checks to see whether the image is either a .jpg, .png, or .tiff file
 - Image tester test the ending of the input file and then reads the file correctly depending on the ending
 - Dim(image) shows the dimensions of the image



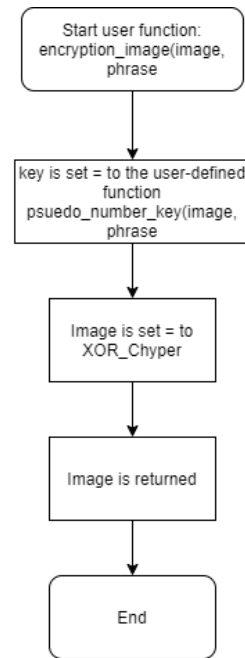
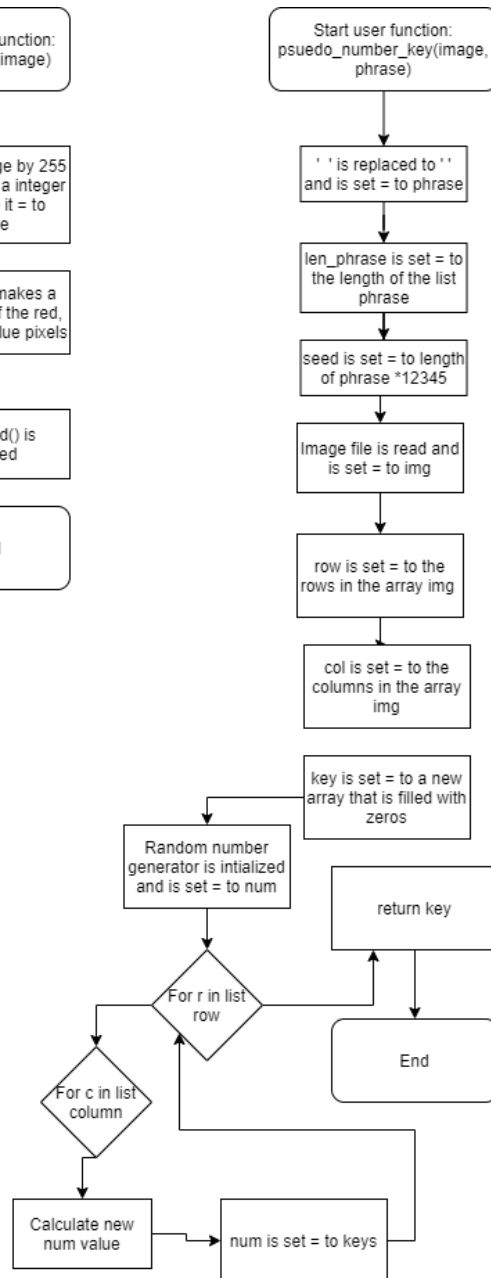
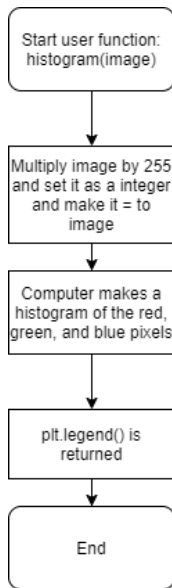
- Grey_search** contains 7 user-defined functions
 - Grey(image) gets the RGB values & dimension of the image and inserts the grey RGB values into the grey photo
 - Earth_finder finds the location of the brightest dot in the mage
 - Earth image teas the location from the earth finder and gets the array from the original image and outputs 50 in each direction
 - Image_blur(image) blurs the image
 - edge_dectector(blurred_image) gets the gradient of the blurred image in both the x and y direction and then combines the horizontal and vertical edges
 - Float64_uint8(img) gets the max number the data could be and then times the RGB values by 255 to get uint8
 - Uint8_float64(img) divides the uint8 valeus to get the 0-1 float64 values



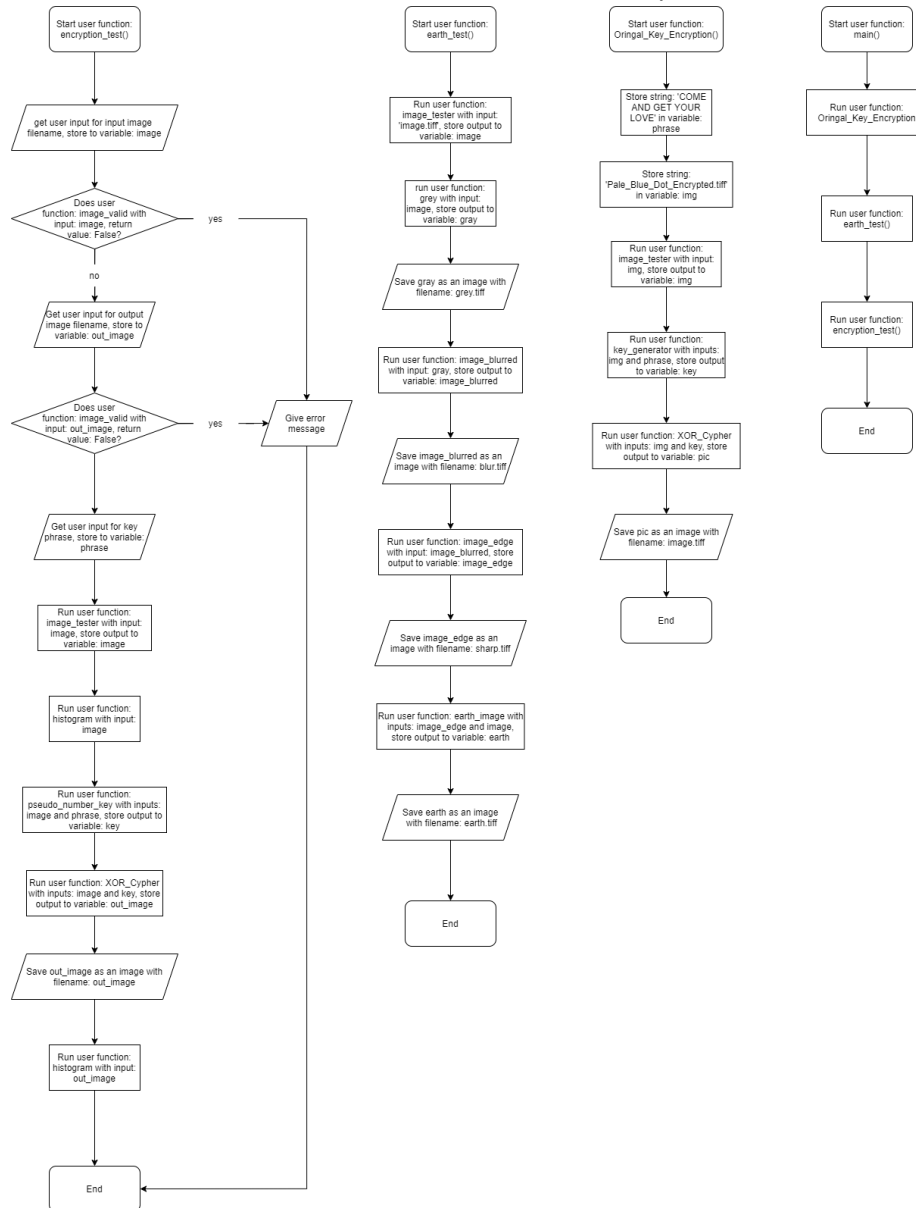
- **Key_generator** contains 2 user-defined functions
 - Key_generator(img, key_str) gets the dimensions of the image, creates a new array, and then loads the key values into the key array
 - XOR_Cypher(Img, Key) encrypts the image



- **Histo_key** has two user-defined functions
 - Histogram(key) creates a histogram from the image inputted back in image_analysis
 - Pseudo_number_key(images, phrase) creates the seed by the length of the phrase. It then loads the dimensions of the image and creates a new key array. Finally, it loads the seed values into the array



- Demonstrates that the code works for the TA's and anyone who wants to test the code



Questions

Part 1

- For a PNG file, the data type is float32. For a JPG file and a TIFF image, the data type is uint8.
- We used the `.astype(np.uint8)` to convert the image data to a uint8 type.

Part 2

- Yes, the XOR cipher worked correctly. We were able to verify that since the cipher decrypted the image on the first run of the code and encrypted the image on the second run of the code.
- Originally, we use a nested loop that would cover the rows and columns. In the for loop, we converted the integers to bits and then used an XOR stamen by using the '^' operator. We then found a better way to use the NumPy library. Using `NumPy.bitwise_xor` we used and for loop in `range(3)` for the color channels, we used that XOR the two matrices. 0.005871514854 seconds

3. It took 0.005871514854 seconds for the smaller 6 MB image and 0.1974872185480 seconds for the larger 150 MB image. The number of rows and columns does make a difference in the run time of the program.
4. The cons of the XOR cipher is that if one of the subkeys is known then the image can be partially decrypted and the person can brute force the encryption for the master key. Compared to other logical operators the XOR is equally likely to be a 0 or a 1. The XOR cipher will also not leak information about the original value and the same XOR function can be used to both decrypt and encrypt the information.

Part 3

1. The range of the gradient map is the size of the original image
2. The exact location of the earth was found by looking at the brightest point on the gradient map. If there is more than one point or edge in the image, only the sharpest (and therefore brightest on the gradient map) edge will be looked at even though all the edges of the image are found
3. The Gaussian filter for smoothing the image removed noise from areas, thus preventing edge detection in places where edges were not present.

Part 4

1. First, the computer creates the seed by the length of the phrase. It then loads the dimensions of the image and creates a new key array. Finally, it leads the seed values into the array. Key is then returned.
2. The results are better. In the histogram, the color values are scrambled much better which indicated better encryption.

References

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Appendices

a)

Image_analysis.py

Img_input()

- Will prompt the user for the image file name and return the string.

Image_valid(img)

- Given an image file name, will output true or false to tell if it's a .tiff, .jpg, .png or not
- Returns a bool.

image_tester(img)

- Make sure the type(img) == string and the image file is in your directory.
- This will read the image file input and read the file into an array.

dim(image)

- Make sure type(image) == <class 'numpy.dtype'> .
- This will print the dimensions of the array and return the dimensions.

```
image = image_tester('image.tiff')
dim(image)
>>> Dimensions of the image is (1152, 1304, 3)
```

```
print(image_valid(image))
>>> True
```

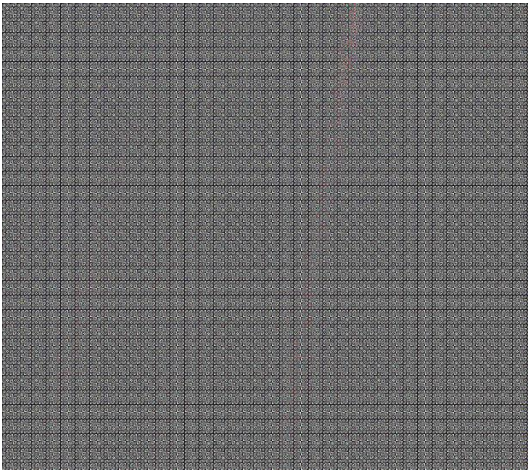
key_generator.py

key_generator(img, key_str)

- Make sure type(image) == <class 'numpy.dtype'> with dtype == uint8, type(key_str) == string.
- Will return a key, that is the same dimensions as the image inputed.

XOR_Cypher(img, Key)

- Make sure type(image) == <class 'numpy.dtype'> with dtype == uint8 and type(Key) == np.array.
- Will do an XOR operation on the img with the Key inputed.
- Then it will return the image after the XOR operations are complete.



```
phrase = 'COME AND GET YOUR LOVE'
img = 'Pale_Blue_Dot_Encrypted.tiff'
img = plt.imread(img)[:,:,:3]
key = key_generator(img, phrase)
print(key)
```

```
pic = XOR_Cypher(img, key)
plt.imshow(pic)
```

```
>>> [[ 0  0  0 ...  0  0  0]
 [ 0 14 28 ... 70 84 98]
 [ 0 28 56 ... 140 168 196]
 ...
 [ 0 210 168 ... 42  0 210]
 [ 0 224 196 ... 112 84 56]
 [ 0 238 224 ... 182 168 154]]
```



grey_search.py

grey(image)

- Make sure type(image) == <class 'numpy.dtype'> with dtype == uint8.
- Will read the image color values and set the color to greyscale using the ITU-R Recommendation BT.601 method.
- Will return a greyscale image of the input string file.

earth_finder(grey_image)

- Make sure type(image) == <class 'numpy.dtype'> with dtype == uint8.
- Will find the brightest spot on the picture then return the coordinates of that picture.

earth_image(sharpened_image, original_image)

- Make sure type(sharpened_image, original_image) == <class 'numpy.dtype'> with dtype == uint8 and the images file are in your directory.
- Find the earth location from the earth_finder function.
- Will outputs a 101x101 picture with specified location coordinates.

Image_blur(image):

- Make sure type(image) == <class 'numpy.dtype'> with dtype == uint8.
- Will use the gaussian filter to blur the image and return the blurred image.

edge_detector(blurred_image)

- Make sure type(image) == <class 'numpy.dtype'> with dtype == uint8 .
- The program will then blur your image, then find the partial derivatives of the x,y values, then use the gradient to sharpen your image, then it will combine the two values to get the new sharpened image.
- This will allow your detection program to be more accurate in it's search.

float64_uint8(img)

- Make sure type(image) == <class 'numpy.dtype'> with dtype == uint8 .
- Will convert the float64(0-1) to unit8 (0-255).

uint8_float64(img)

- Make sure type(image) == <class 'numpy.dtype'> with dtype == uint8.
- Will convert the unit8 (0-255) to float64(0-1).



```
import numpy as np
import matplotlib.pyplot as plt
import scipy
from scipy import ndimage
image = plt.imread('img_plain9.tiff')[:, :, :3]
gray = grey(image)
plt.imshow(gray)
```

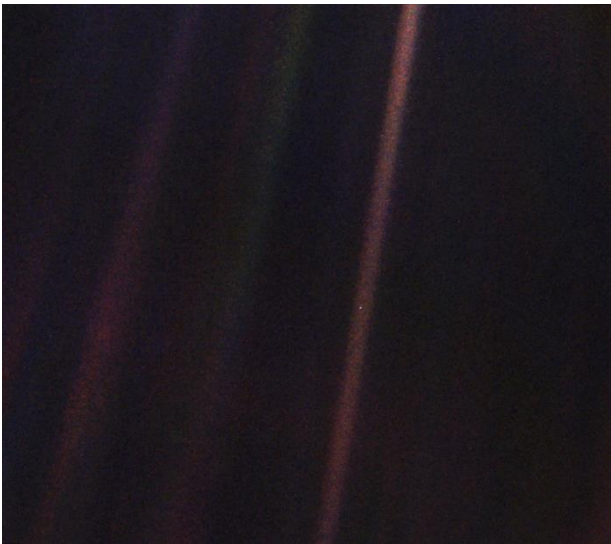


```
image_blurred = image_blur(gray)
plt.imshow(image_blurred)
```



```
image_edge = edge_detector(image_blurred)
plt.imshow(image_edge)
```





```
image = ia.image_tester('image.tiff')
gray = grey(image)

image_blurred = image_blur(gray)

image_edge = edge_detector(image_blurred)
plt.imshow(image_edge)

earth = earth_image(image_edge, image)
plt.imshow(earth)
```



Histo_key.py

histogram(image)

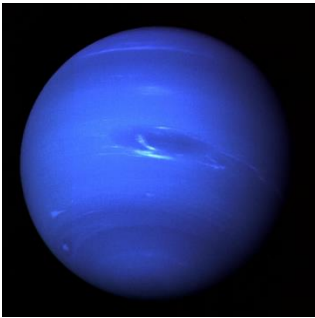
- Make sure `type(image) == <class 'numpy.dtype'>` with `dtype == uint8`.
- Will return a histogram of the color values of the inputted image.

pseudo_number_key(image, phrase)

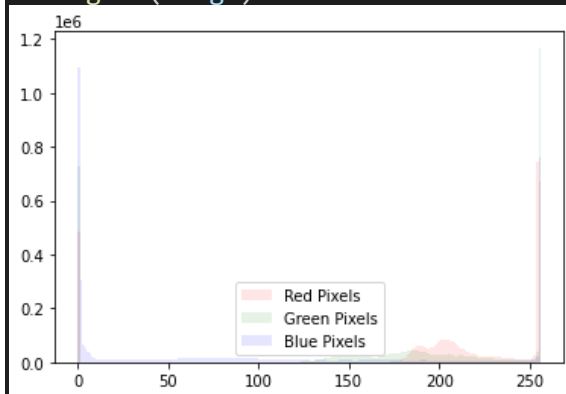
- Make sure `type(image) == <class 'numpy.dtype'>` with `dtype == uint8` and `type(phrase) == <class 'string'>`.
- Will return an array of the numbers with the same dimensions as the image, using pseudo-number generator.

encryption_image(image, phrase)

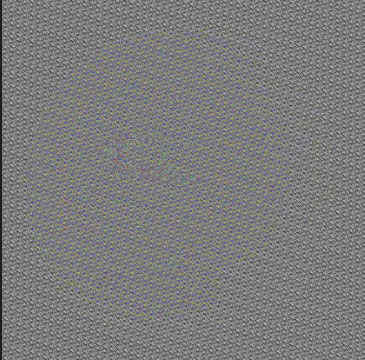
- Does a full encryption/decryption on the phrase and image .



```
image = plt.imread('img_plain3.tiff')[:, :, :3]
histogram(image)
```



```
image = plt.imread('img_plain3.tiff')[:, :, :3]
nKey = pseudo_number_key(image, 'Test')
encrypted_image = encryption_image(image, 'Test')
plt.imshow(encrypted_image)
```



main0.py

encryption_test()

- Shows the functionality of our new encryption key.

earth_test()

- Shows the functionality of the image filter, image sharpening, earth search algorithm, and gray scale function.

Oringal_Key_Encryption()

- Shows that the old encryption key works and returns the proper image.

main()

- This will show the functionality of the Team 07 Project 1.

b.

As a team, we worked primarily in overlapping smaller groups of two, and every week we had a group meeting time to discuss the progress and algorithms. The flowcharts were written in the group meetings so everyone could knowledgeably learn about the algorithms. All parts of the project were worked on by two people to make sure that no one would be overwhelmed since team members could help innovate algorithms and debug together. We used GitHub to centralize all our work since all participants could have immediate access to each other's code and created a centralized folder. We used discord to communicate meeting times, but most of the actual communication was in person. For future projects, we will continue to use GitHub as the advantages have been huge.

c.

Our team process involved first finding out what the question was asking us. From there we would create tasks to try and solve the questions. All the tasks would then be delegated to different members to create an algorithm for. We would then start to design the algorithms to answer the questions as a group during the team meetings. After the meetings were over, everyone was expected to meet up with their task partner and code up their algorithms. During these meeting times, the programs would be debugged and analyzed for functionality. Improvements would be discussed after the code was uploaded to GitHub and everyone could test the code. An example of this improvement was when the numpy.bitwise function was implemented because the code was taking too long to run for the bigger images. Overall, our team process involved a lot of delegating tasks and partnership work. This process minimizes the feeling of being overwhelmed on a big task/project since everyone felt they coded more efficiently when there was someone there to brainstorm their ideas with and help them.

d.

Code Appendix

```
import numpy as np
```

```
import matplotlib.pyplot as plt
```

```
import scipy
```

```
from scipy import ndimage
```

```
def img_input():
```

```
    #gets file name
```



```
img = input('Enter image file name: ')
```

```
return img
```

```
def image_valid(img):
```

```
    if img.endswith('.jpg'):
```

```
        image = True
```

```
    elif img.endswith('.png'):
```

```
        image = True
```

```
    elif img.endswith('.tiff'):
```

```
        image = True
```

```
    else:
```

```
        image = False
```

```
    return image
```

```
def image_tester(img):
```

```
    #test the ending of the image file input
```

```
    #then reads the file in correctly depending on the ending
```

```
    if img.endswith('.jpg'):
```

```
        image = plt.imread(img)
```

```
    elif img.endswith('.png'):
```

```
        image = plt.imread(img)
```

```
        image = image.astype(np.uint8)
```

```
    elif img.endswith('.tiff'):
```

```
        image = plt.imread(img)[:,:,:3]
```

```
    return image
```

```
def dim(image):
```

```
    #shows the dimension
```

```
    #image = image_tester(image)
```

```

dim = image.shape

print(f'Dimensions of the image is {image.shape}')

return dim

def key_generator(img, key_str):

    key_str = key_str.replace(' ', '')

    len_key_str = len(key_str)

    #img = ia.image_tester(img) #plt.imread(img)[:,:,:3]

    #gets the dimensions of the image

    row = img.shape[0]

    col = img.shape[1]

    #creates hte new array

    key_array = np.zeros([row, col], dtype=np.uint8)

    #loads the key values into the key array

    for r in range(row):

        for c in range(col):

            key_array[r][c] = ((r*c)%len_key_str)

    Key = key_array*(2**8//(len_key_str))

    return Key

def XOR_Cypher(lmg, Key):

    #reads the image

    #lmg = ia.image_tester(lmg) #plt.imread(lmg)[:,:,:3]

    #is a quicker way to encrypt the iage

    for i in range(3):

        #the i is the color channels to encrypt

```

#the np.bitwise converts to bit then takes the xor operator by dot properties

```
Img[:, :, i] = np.bitwise_xor(Img[:, :, i], Key)
```

```
return Img
```

```
def grey(image):
```

```
    #image = ia.image_tester(image)
```

```
    #uses matrix multiplication on the rgb values of the photo
```

```
    grey_values = (image[:, :, 0]*.299 + image[:, :, 1]*.587 + image[:, :, 2]*.114)
```

```
    #this automatically gets the dim from the image, by just copying
```

```
    grey = image.copy()
```

```
    #this inserts the grey rgb values in to the grey photo, since the rgb values should all the be same for the same row, col
```

```
    for i in range(3):
```

```
        grey[:, :, i] = grey_values
```

```
    return grey
```

```
def earth_finder(grey_image):
```

```
    #reads the string
```

```
    #grey_image = ia.image_tester(grey_image)
```

```
    #makes sure the border exception is taken out
```

```
    grey_image = grey_image[1:, 1:, :]
```

```
    #gets the brightest spot on the image
```

```
    brightest_spot = np.amax(grey_image)
```

```
    #finds the index where the maximum value is
```

```
    index_max = np.where(grey_image == brightest_spot)
```

```
#takes where first items(ie earth row, earth col) of each list return, the turns the tuple to a list
```

```
coordinates = list(zip(index_max[0], index_max[1]))
```

```
#since all rgb values are the same, we only need the first item of the list
```

```
return coordinates[0]
```

```
def earth_image(sharpened_image, original_image):
```

```
    #gets the location
```

```
    location = earth_finder(sharpened_image)
```

```
    #it take the location and get the row-50 to row+50 and the same for the column with the color values the same
```

```
    #gets the 101x101 image by take the place 0,0 as the location of the earth from the last fuction earth_finder
```

```
    #then is takes the 50 pixels, in front, above, behind and below it
```

```
    earth = original_image[location[0]-50:location[0]+51, location[1]-50:location[1]+51,:]
```

```
    return earth
```

```
def image_blur(image):
```

```
    image = uint8_float64(image)
```

```
    #image = ia.image_tester(image)
```

```
    #using the guassian filter, blurres the image
```

```
    blurred1 = scipy.ndimage.gaussian_filter(image, sigma=2.5)
```

```
    return blurred1
```

```
def edge_detector(blurred_image):
```

```
    #no need for th absolute value since the both the x and y compnenet gonna be squared
```

```

#gets the gradient of the blurred image in the x-direction
sx = ndimage.sobel(blurred_image, axis=0, output=None, mode='constant', cval=0.0)

#gets the gradient of the blurred image in the y-direction
sy = ndimage.sobel(blurred_image, axis=1, output=None, mode='constant', cval=0.0)

#hypot get the hypotenuse, or ie  $\sqrt{a^2 + b^2} = C$ , this is get the gradient edge detection
#ie this combine the vertical and horizontal edges
sob = np.hypot(sx, sy)

sob = float64_uint8(sob)
sob = grey(sob)

return sob

```

```

def float64_uint8(img):
    #gets the max number the data could be
    #img_data_max = np.iinfo(img.dtype).max()
    #print(img_data_max)
    #img = img.astype(np.float64)/img_data_max
    #img = ia.image_tester(img)
    #times the image rgb value by 255 to get the unit8
    img = 255*img
    img = img.astype(np.uint8)

    return img

```

```

def uint8_float64(img):
    #img_data_max = np.iinfo(img.dtype).max
    #img = ia.image_tester(img)
    #divides the uint8 values to get the 0-1 float64 values
    img = img/255
    img = img.astype(np.float64)

```

```
return img
```

```
def histogram(image):
```

```
    #image = ia.image_tester(image)
```

```
    image=(image*255).astype(np.uint8)
```

```
    plt.hist(image[:, :, 0].reshape(image.shape[0]*image.shape[1]), bins=np.arange(2**8+1), color='red', alpha=.1,  
label='Red Pixels')
```

```
    plt.hist(image[:, :, 1].reshape(image.shape[0]*image.shape[1]), bins=np.arange(2**8+1), color='green', alpha=.1,  
label='Green Pixels')
```

```
    plt.hist(image[:, :, 2].reshape(image.shape[0]*image.shape[1]), bins=np.arange(2**8+1), color='blue', alpha=.1,  
label='Blue Pixels')
```

```
    plt.legend()
```

```
    plt.show()
```

```
def pseudo_number_key(image, phrase):
```

```
    phrase = phrase.replace(' ', '')
```

```
    len_phrase = len(phrase)
```

```
    #creates the seed, by the length of the phrase
```

```
    seed = len_phrase*12345
```

```
    #loads the image dim
```

```
    #img = ia.image_tester(image)
```

```
    row = image.shape[0]
```

```
    col = image.shape[1]
```

```
    #Creates a new key array
```

```

key = np.zeros([row,col], dtype=np.uint8)

#creates the n0, n1, ...nx to make the series work

num = seed

for r in range(row):
    for c in range(col):
        num = ((1103515245*num) + seed)%(2**31)
        #loads the seed values into the array
        key[r][c] = num

return key

def encryption_image(image, phrase):
    key = pseudo_number_key(image, phrase)
    image = XOR_Cypher(image, key)
    return image

def encryption_test():
    image = input('Enter your image: ')
    if image_valid(image) == False:
        raise ValueError('This is not a valid image, please use a .tiff, .jpg, .png')

    out_image_str = input('Enter your output image file (as a .tiff): ')
    if image_valid(out_image_str) == False:
        raise ValueError('This is not a valid image, please use a .tiff, .jpg, .png')

    phrase = input('Enter your phrase: ')

    image = image_tester(image)
    histogram(image)
    key = pseudo_number_key(image, phrase)
    print(key)
    out_image = encryption_image(image, phrase)

```

```
#out_image = XOR_Cypher(image, key)

plt.imshow(out_image_str, out_image)

histogram(out_image)
```

```
def earth_test():
```

```
    image = image_tester('image.tiff')
```

```
    gray = grey(image)
```

```
    plt.imshow('grey.tiff', gray)
```

```
    image_blurred = image_blur(gray)
```

```
    plt.imshow('blur.tiff', image_blurred)
```

```
    image_edge = edge_detector(image_blurred)
```

```
    plt.imshow('sharp.tiff', image_edge)
```

```
    earth = earth_image(image_edge, image)
```

```
    plt.imshow('earth.tiff', earth)
```

```
def Orignal_Key_Encryption():
```

```
    phrase = input('Enter the phrase "COME AND GET YOUR LOVE": ')

```

```
    img = input('Enter "Pale_Blue_Dot_Encrypted.tiff": ')

```

```
    #phrase = 'COME AND GET YOUR LOVE'

```

```
    #img = 'Pale_Blue_Dot_Encrypted.tiff'

```

```
    img = image_tester(img)

```

```
    key = key_generator(img, phrase)

```

```
    pic = XOR_Cypher(img, key)
```



```
plt.imsave("image.tiff", pic)
```

```
def main():
```

```
    Oringal_Key_Encryption()
```

```
    earth_test()
```

```
    #encryption_test()
```

```
if __name__ == '__main__':
```

```
    main()
```