Analysis

Project Idea:

The idea for my project, is to have a program that acts as a vault for important files. It will encrypt files given, and store them in a specified location. Once they are encrypted, they will only be accessible from within the program, and will only be accessible within the program if you know the encryption key (passphrase) that you set when creating the “vault”.

Within the vault, you should be able to easily organise your files, add more to the vault, and remove (decrypt) files from the vault to any location (if possible).

My program would be useful for teachers, as they have to keep documents on student’s grades, and any other student details secure. Since this is my use case, I will have to thoroughly test the security and practicality of my program to make sure teachers want to use it, and trust the program with these files. Also, I will add an optional mobile app that the user can download, which lets them connect to the program via Bluetooth to unlock the vault. This is would be useful if you are a teacher, as if you leave the room with your phone in your pocket, and it is connected to the vault, if you have forgotten to lock the vault then a student might try to browse through it while you are gone, but with the app, as soon as you disconnect the Bluetooth connection it locks the vault, so if you forgot to close it then it closes itself.

The Bluetooth app should also be able to receive files from the PC app, so that the user can download files that are in the vault onto their mobile device. This would be useful for teachers that do not take their PC home (e.g not a laptop), so they can upload the files from the computer, to their phone so that they can edit the file at home or on the move (with another mobile app).

The program needs to work on both Windows, Linux and MacOS, as then teachers/users have more flexibility with what operating systems they can use it on, so they can easily go from machine to machine and carry their vault with them (on a USB stick for example), and they know that they can reliably use the program on most machines.

The user experience has to be pretty good. Good design practice will have to be used when making the GUI (e.g not putting the delete button next to the decrypt button), as I want my program to be easy to use by a wide range of people, so that even people who are not so good with computers can easily use the program. The way the user is directed around the program has to be logical as to not confuse the user, and adding a panic button to take you back to the main screen may be a good idea.

Client:

An example client for my project could be a teacher/school, as they have to keep files about students secure. For example, pupil details, exam results and other important student details. My program aims to help the teacher/school keep the pupil’s files safe, and prevent the files from being accessed if their device is stolen. It will encrypt files given to the program, and be secured by a pin code that is transferred over Bluetooth to the computer from a mobile device. Once the mobile device is unpaired from the computer, the app will lock again. This will prevent someone from having access to the files if the computer is unlocked and is stolen, as the mobile device will go out of range of the computer, so the app on the computer will lock.

I sent a questionnaire to a member of the IT office at my school to ask what regulations there were about keeping a teacher's files safe, and what encryption they would suggest for keeping the files secure.

Hi Josh,

What encryption should I use when encrypting the user's files? The bare minimum would be 128 bit AES, though 256 bit is recommended.

Are there any standards or laws about what encryption method I should be using for files such as a teacher's student files (one of the clients for this program)? Data protection laws. The current UK Law is the Data Protection Act 1998. Though as of 25th May, the law will be General Data Protection Regulations (EU Law regarding all EU Citizens). This is a very complicated law, that is causing headaches for businesses worldwide. I've attached some links you might find useful regarding GDPR towards the end of this email.

Hope this helps!

Many thanks Mr ___

https://www.eugdpr.org/

https://itpeernetwork.intel.com/gdpr-opportunity-rethink-security/

https://ico.org.uk/for-organisations/guide-to-the-general-data-protection-regulation-gdpr/

https://media.datalocker.com/marketing/GDPR_infographic_2017.pdf

https://www.kingston.com/en/usb/resources/eu-gdpr

I will be using this information as guidance for what I have to take into consideration. I will keep in mind the data protection laws when I am storing the user's files, and make sure I am within the regulations.

The EU General Data Protection Regulations consist of (As of 25/05/18):

Breach Notification:

If a data breach has been found and it might "result in a risk for the rights and freedoms of individuals", then the person that the data belongs to has to be notified within 72 hours.

Right to Access:

The person who's data it is can at any point ask for confirmation as to whether or not data concerning them is being processed, where it is being processed if it is and for what purpose.

Right to be Forgotten:

The data subject can ask for their data to be erased, and stop the processing of their data. This will be done depending on whether there is public interest in their data (e.g if a politician says something stupid then they can't ask Google to delete it just because it makes them look bad), and if the data is no longer relevant (e.g your cookies from last week that were used for targeted ads).

Data Portability:

The data subject should be allowed to ask to receive the data, and they should also be able to change which company is controlling their data.

Privacy by Design:

Tells the controllers of the data to only use the data absolutely necessary for the purposes they need it for. For example, an advertisement company might use your cookies to target ads to you, however they can't then use your location unless they are also using that to target ads. Basically don't take more than you need.

For my project, as the user is the data controller, then they already have the right to access, the right to be forgotten and data portability. For the breach notification, they will probably know it has happened as someone needs to have physical access to where the data is stored to breach it. However, with privacy by design, I will not be using any of the user's data for advertising, or any other agenda. I will make this clear to the user when they first use the program. Also the security will be

Another issue could be that if a file is deleted, the contents of the file might still remain. To fully remove the file I may have to use a one way function that ruins the data before deletion so that it cannot be accessed after it is deleted.

Choosing the right algorithms:

When encrypting, decrypting and hashing data in my program, I want it to be as fast as possible without compromising too much on security.

Hashing:

When hashing the key when it is input, the algorithm has to be very secure, and speed does not matter as much. A member of the SHA2 family of algorithms would be a good algorithm to do this, as it is quite slow, but it is very secure (SHA1 was found to have a lot of hash collisions). Speed does not matter as much for the key, as the input data will only ever be less than 16 bytes. A faster algorithm will only provide a few milliseconds over SHA, so there is no point compromising on security for a negligible time decrease.

For getting the checksum of files, the algorithm has to be very fast, as it will be done on the data in the file before and after the file is opened to check for changes. If this algorithm is slow, then the overall user experience will be much worse if the algorithm takes ages to open and close files. I will test each algorithm I am thinking of using for hashing and compare them using this algorithm (Python):

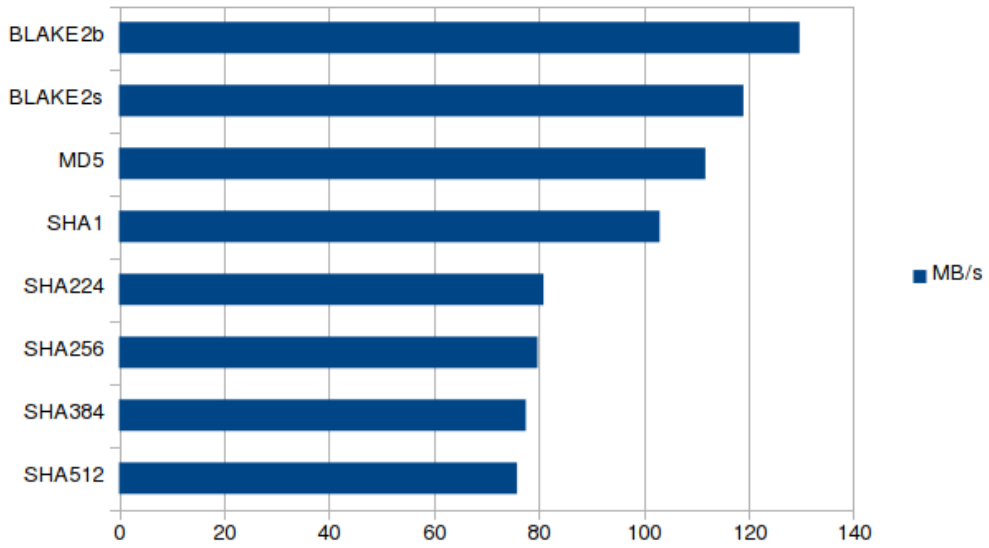
```
import hashlib        # Library of hashing algorithms.
from random import randint  # Used to generate the data.
from time import time   # Used to measure how long the operation takes.

def generate(times, size):  # Generates data, each block of length "size", and "times" number of blocks.
    data = []
    for i in range(times):
        for j in range(size):
            data.append(randint(0, 255))  # Randomly generate a byte.
    return bytearray(data)

def test(times, size):
    data = generate(times, size)    # Generate the data
    start = time()          # Get the start time
    for i in range(times):
```

```
        hashlib.sha256(data[i*size:(i+1)*size]).hexdigest() # Do the hash (in this case SHA256)

    return (times*size)/(time()-start)    # Return the bytes per second.

print(test(1000, 128))  # Run the program.
```

I will run this algorithm on the same computer and make sure background tasks are closed, so that the results are not affected by other programs.

Here are the results:

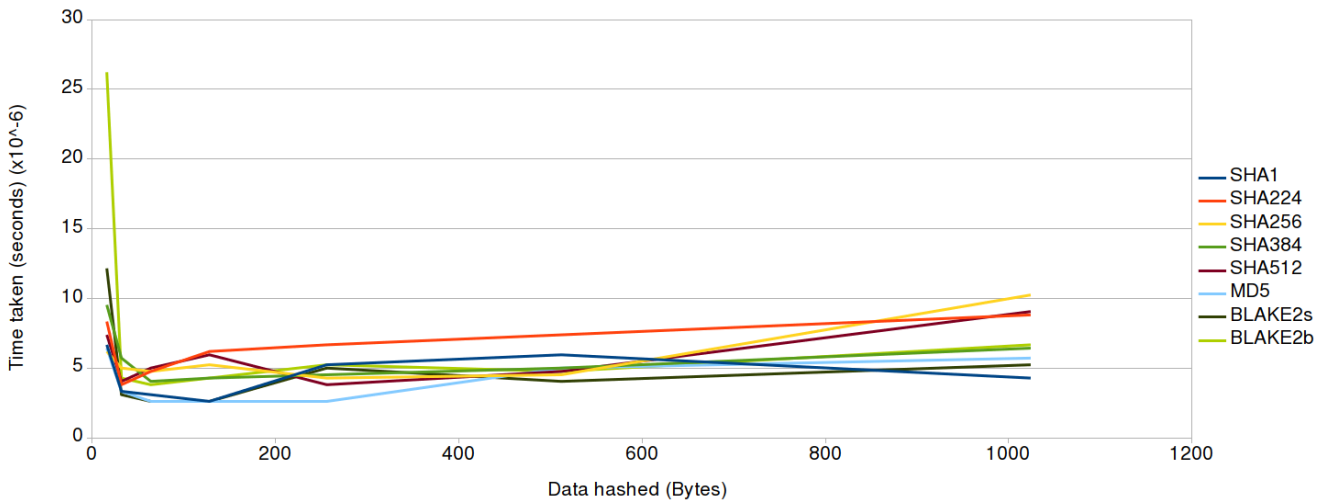
Megabytes per second for each hash function (using 1000 blocks of 128 bytes (128 kilobytes)):



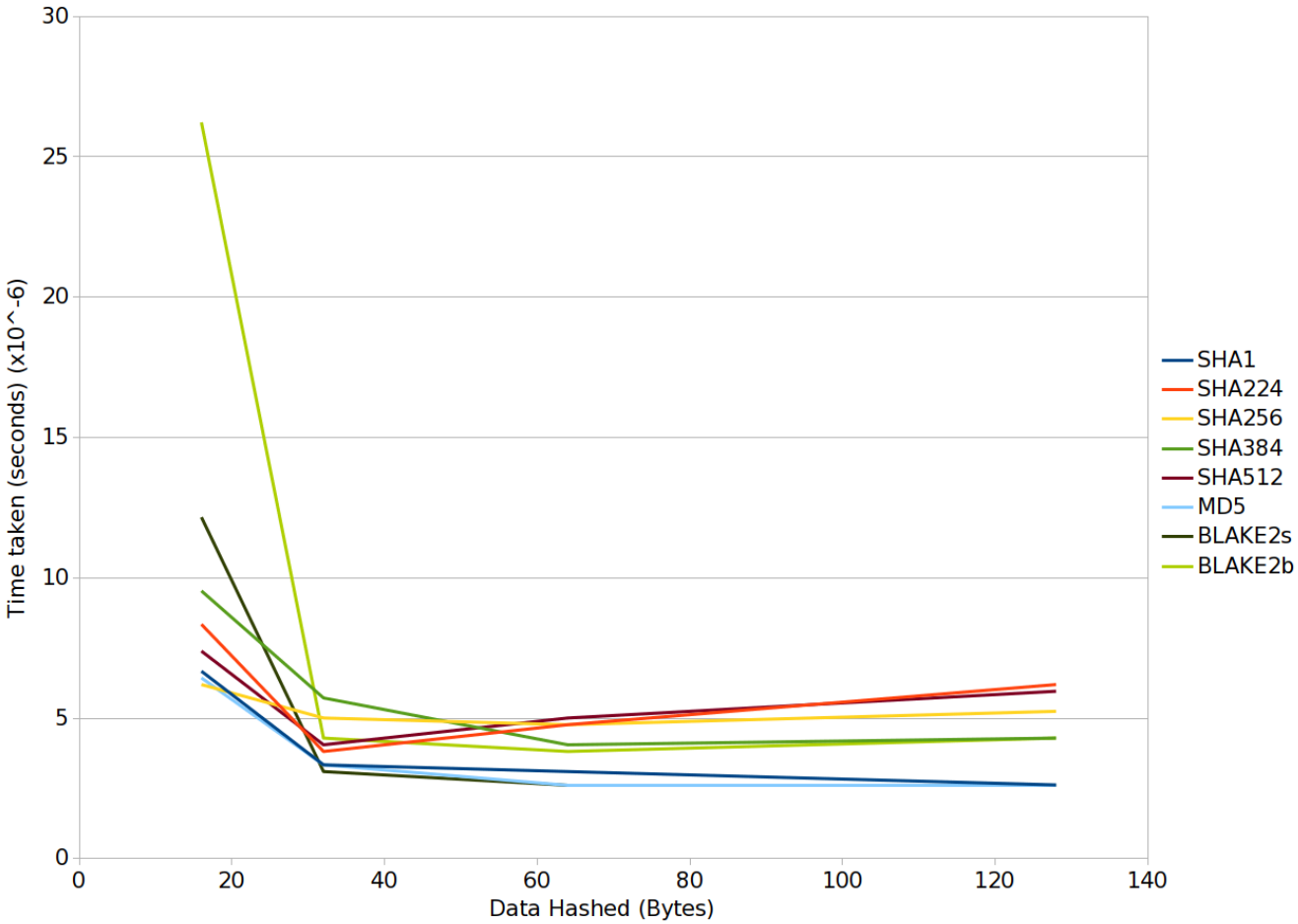
For my next tests, I will do data hashed against time. For this I will be using different sized files that I will make using this function:

```
def generateFile(name, totalSize):
    fo = open(name, "wb")
    a = bytearray()
    for i in range(totalSize):
        a.append(randint(0, 255))
    fo.write(a)
    fo.close()
```

First I will test each hash function with encrypting very small data (<= 1 KiB). These were the results:

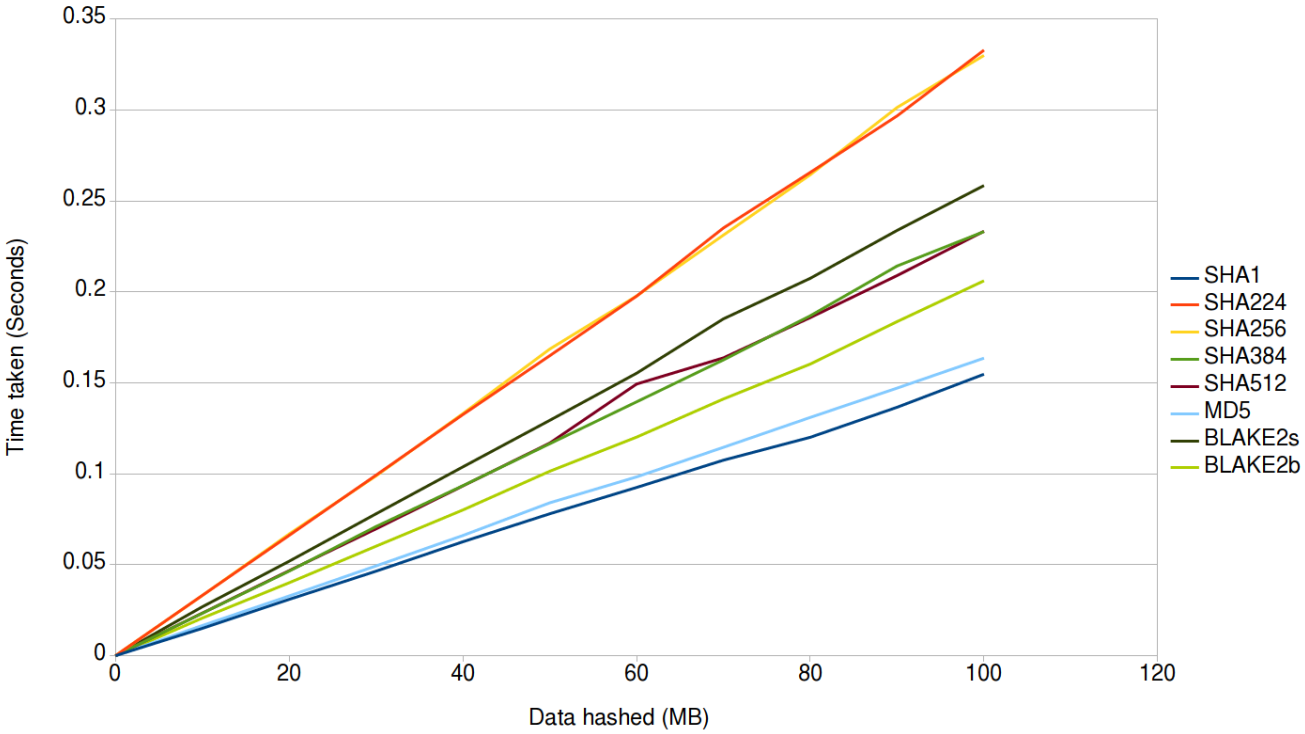


Here is the start of the graph, as that is the most interesting bit:



Here we can see that SHA256 is the fastest at hashing 16 bytes, but is quickly surpassed by most of the algorithms. Both BLAKE algorithms had a bad performance at the start, but after 64 bytes both were doing alright. MD5 is the quickest overall out of the group. From these results I think I will use SHA256 for hashing the key, since the key is 16 bytes in length, and also because SHA is more aimed at security than BLAKE, and MD5 and SHA1 are obsolete in terms of security.

The BLAKE algorithms were designed for big data, which is what I am going to look at next:



In this graph, the gradient (rate of change) of each line is the ratio of seconds to megabytes of each function (so $\frac{x}{y} = megabytes/second$). So the less steep the line is, the faster the operation.

SHA256 and SHA224 have taken the longest, at almost identical rates. BLAKE2s is quite slow, and this is because BLAKE2s is designed for 32-bit CPU architectures, and my CPU is 64-bit. MD5 and SHA1 are both the fastest, and have similar performance, but have security problems. BLAKE2b was the fastest out of the secure functions, so I will be using BLAKE2b for checksums in the program, as checksums need to be calculated quickly, as discussed before.

Objectives:

1. GUI should:
    a. Be easy to use:
    i. Logically laid out.
    ii. Have simple options.
    b. Display the files currently stored in the vault, along with the file extension and the size of the file.
    c. Display the storage space remaining on the storage device the program is running on.
    d. The user should be able to easily encrypt and decrypt files:
    i. Using easy to access buttons in the UI.
    ii. Using drag and drop from outside of the program.
    iii. Decrypt to a directory specified.
    e. Have an options menu, including the options to:
    i. Change from 128 bit security to 256 security. 128 bit is the bare minimum.
    ii. Change the location of the vault.

iii. Set the default login method (Bluetooth or no Bluetooth).

iiii. Change if the search in the file browser is recursive or not.

f. Make it easy to manage the files in the vault (move to other folders in the vault, rename, delete, etc).

g. Have a secure login screen.

i. Ask the user to either input the key via their keyboard (no Bluetooth for that session), or connect via the app.

ii. Tell the user if the key is invalid or not, and smoothly transition into the main program.

iii. Validate all input.

h. Look relatively good without being bloated.

i. Don't be costly on system resources when you are idle.

ii. Don't overdo animations.

i. Allow the user to easily read file names, and easily tell folders and files apart.

j. Let the user preview images without opening them (using thumbnails or an information screen).

k. Be resizeable, and all items on the screen should look ok.

l. Allow the user to switch between using Bluetooth and using regular login.

m. Make it easy for the user to return to the root folder of the Vault in case they get lost (a "panic" button).

n. Give the user statistics during files being enc/decrypted, including:

i. What percentage of the file/folder has been completed. (Visual progress bar to show this too)

ii. The current speed of enc/decryption.

iii. An estimate of how long it should take to finish enc/decryption.

iv. If part of a folder then show the progress of the current file.

o. Allow the user to sort the files by name or by size.

p. Allow the user to configure default settings using a configuration file that is easy to use.

q. Allow the user to search for file names in the vault.

r. Not break when doing arbitrary tasks such as browsing the files.

2. App should:

a. Be easy to use.

b. Connect via Bluetooth to the PC.

c. Allow the user to input their pin code easily.

d. Tell the user if the pin code is invalid or not.

e. Make it easy to recover from mistakes (e.g invalid pin code, or if they make a typo).

f. Allow the user to see a list of files currently in the vault, and let the user download those files onto their mobile device.

3. File handling:

a. Store the encrypted contents in the location specified by the user.

b. Encrypt and decrypt relatively quickly, while still being secure.

c. When the Bluetooth device goes out of range or disconnects (if using Bluetooth), encrypt all decrypted files and lock the program until the pin code is input correctly again.

e. Have a recycling bin so that the user can recover their files.

f. When a file is opened, check for changes once it is closed.

g. Files stored in the vault should not be accessible from outside of the app.

h. Names of the files stored in the vault should also not be view-able from outside of the app (encrypt the name).

i. Allow the files/folders to be decrypted to an external location.

4. Overall system should work on Windows, MacOS and Linux.

Design

Bluetooth:

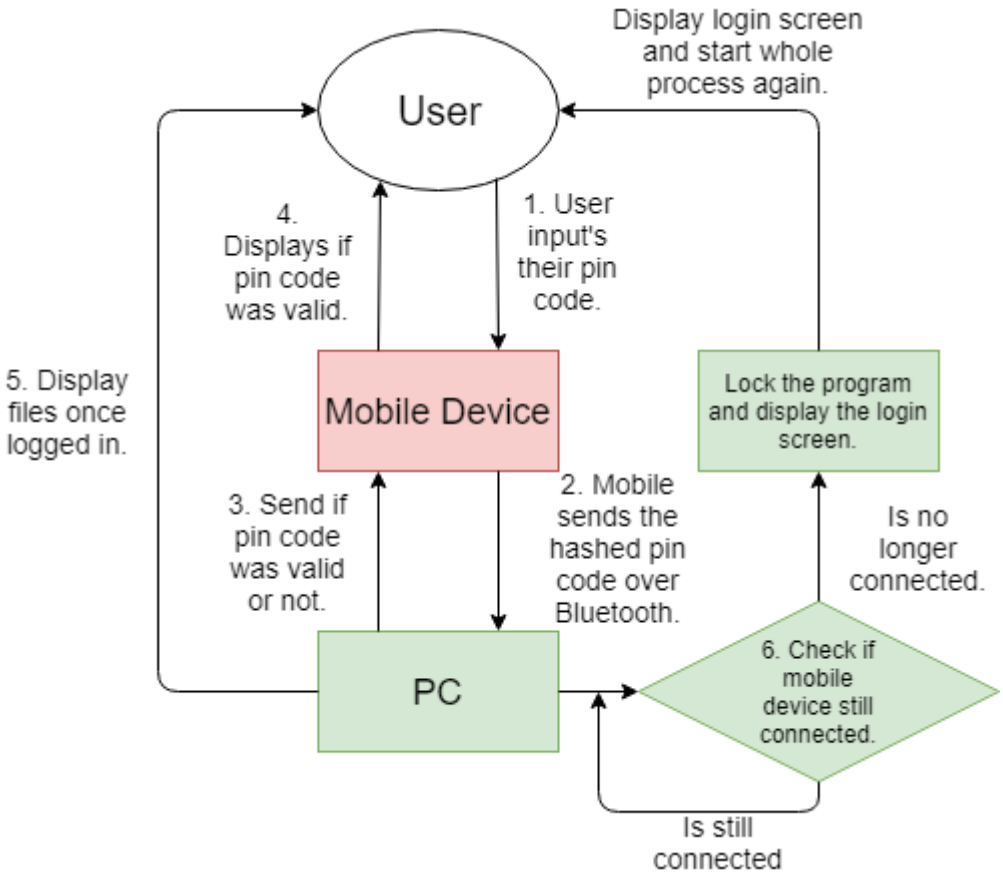
For the file store to be unlocked, I need to send the passcode to the computer via a Bluetooth connection.

For the computer and android device to connect to each other, one device has to be assigned as the server, so it makes sense to me to use the computer as the server, as it will be running for the entire duration that the user wants to use the program.

For the mobile app, I will be using Kivy to program the app. I am using Kivy so that the design is consistent with the design of the PC app. I will be using the android.bluetooth library that is included in the android SDK to transmit the data via Bluetooth.

For the Bluetooth server (on the pc), I will be using Python to receive the pin from the mobile device using PyBluez, check the sent pin, and send a message back saying if the code was valid or not. If the code is not valid, a message will be displayed on the computer that the code is invalid, and the code on the screen of the phone will be erased.

Here is a flow diagram for what Bluetooth will be like:



To send the files, I will need a protocol. A protocol is a set of rules for communicating over a network. A protocol will allow the program to distinguish data that is being sent is a key, file list or a file itself.

Protocol

The protocol rules all have to be strings of bytes that are not likely to appear in a key, file list or a file. This is a necessity because otherwise mid way through sending a key, file list or file, if the program encounters a protocol rule within the key, list or file, then it may cause the program to get confused as to what is being sent, or if the current key, list or file has finished being sent.

For each of the possible items that are going to be sent, each item needs a start header, and an end header. Start header:

```
!<operation>!
```

End header:

```
~!END!
```

For operations that do not have any extra data (arguments), then only the start header is sent.

For sending more complex operations, I will use objects that hold the data, pickle them (object sterilisation), and send the object data sandwiched between the `!<operation>!` header (start header) and the `~!END!` header. For more complex operations that have multiple arguments, a separator is used to separate those arguments:

```
~~!~~
```

Here is an example with multiple arguments:

```
!<operation>!<argument1>~~!~~<argument2>~!END!
```

This is especially useful for files, as this way I can send the metadata in one big lump, then send the file bit by bit. Here is what a file would look like when it is sent:

```
!FILE!<metadata_object>~~!~~<data>~!END!
```

For the key however, since it will always be small (< 16 bytes), I will just send it with a `#` at the start, and a `~` to finish the message. This is acceptable because when the PC program starts, it doesn't expect any requests from the client, so it is just waiting for the key. The key should also only be made up of numbers.

```
#<key>~
```

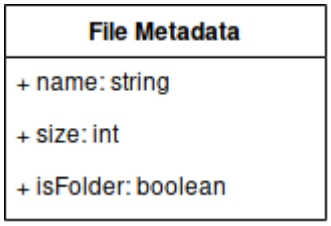
For items such as file metadata, I will use Python pickle to send an object (more of a structure) containing the metadata, rather than using separators, as then it is much easier for me to add information I want to send.

Sending files over Bluetooth:

To send a file from the vault, first it has to be decrypted to a temporary location. I could instead send the data from within AES, so that when a block is decrypted it is sent, however I don't plan on writing AES in Python since speed is essential for AES (and a new Bluetooth socket would have to be set up if using a different language).

Metadata will be sent as an object before sending the file contents, as talked about in the above section.

An example class for file metadata may look like this:




```python
class fileMetadata:
    def __init__(self, name, size, isFolder):
        self.name = name         # The name of the file being sent.
        self.size = size         # The size of the file being sent.
        self.isFolder = isFolder # Boolean for if the file is actually a folder.
```

This is more of a structure than an object, as it has no methods, and is just a collection of data.

After the metadata is sent, a separator will have to be sent to separate the metadata from the file data itself. I discuss this in the above section.

For the file itself, I will send the file in chunks, so that

1. I don't use too much memory (since mobile devices usually have a small amount of memory compared to regular computers).
2. The Bluetooth adapter can keep up with the amount being sent.

This reduces the stress on both the mobile device and the PC.

Once the full file is sent, an end header is sent to tell the program that the full file has been transmitted.

File Storage:

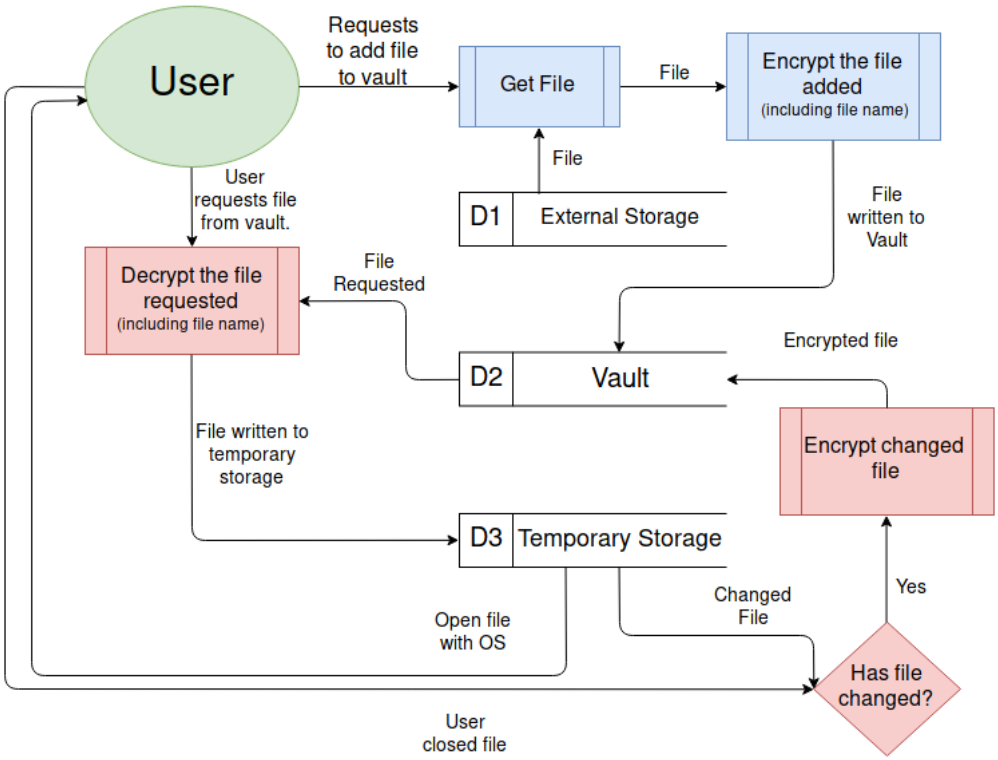
For storing the files, I will store the encrypted files in a directory set by the user (I will call this the 'vault' from now on). The files will be stored just like regular files, however the names of the folders and files within the vault will all be encrypted, and encoded to base 64 (better than encoding to hexidecimal as there is a file name limit on most operating systems, so this allows for longer file names as each byte will be represented by less characters).

The encryption method I will use AES 128 bit, as it will slightly compromise security over using 256 bit, however it will be faster to decrypt files for use, giving the user a better experience, however I can add an option to use 256 in the settings if the user needs more security over performance. For the encryption key, the key will be set up every time a new vault is created (this includes first starting the program). It will tell the user to enter the new key, and then from that moment forwards in that vault, that key will remain the same, and will be used every time a file is encrypted/decrypted in the vault.

When a file is encrypted, the key is appended to the start of the data, and is then encrypted. This is so that when the data is decrypted, only the first block has to be decrypted and compared with the key entered to check if the key entered was correct, rather than decrypting the whole file just to find out that the file can't open, or is corrupted. This will also be used to check the key entered at login, where the login will try to find the first file it can within the vault, decrypt the first block of that file and compare it with the input.

The key will have to be hashed if I send it over Bluetooth, as it may get intercepted, and it is also a good idea to hash it on the computer program as well, as if someone somehow manages to get the key, it will not be the user's original input, so if the user uses it for something else, their other accounts will be fine.

Here is a data flow diagram showing how the data is handled once logged into the program:



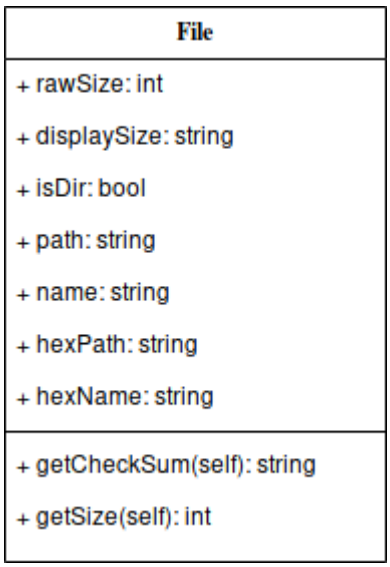
The key is also passed to any stages that encrypt or decrypt, as at this point the user should already be logged in.

When a file is edited, the file should be checked to see if any changes have been made, and if there has been changes, remove the version of the file currently in the vault, and encrypt the latest version into the vault. Also, if there are any new files in the temporary folder (for example if the user renames the file), then encrypt them to the vault as well.

To do this, I need a way of getting a checksum of the file before and after it has been opened. I need a fast algorithm so that the user is not waiting too long for the file to open and close, but it also needs to be unlikely that there will be a collision (where if they change the file and the checksum gives an answer that is the same as before the file was changed, that would be a collision). I will discuss which checksum I will be using in the next section.

When viewing the files in my program, I will use an object that holds all of the information I need about the file, and any methods that I need to get that information.

Here is what I expect the class to be like:



Where `getCheckSum` will get the BLAKE2b checksum of the file. The hexPath and the hexName will hold the encrypted path and encrypted name of the file, so that I don't keep encrypting and decrypting the file name.

Encryption:

For encryption, I will definitely be using AES, because it is the standard and has been tested extremely thoroughly by the public. I do not want to compromise on security, and AES is still pretty fast anyway.

I will use 128 bit AES mainly, as it is still proven to be secure from attacks, and may include the option to use 256 bit if desired by the user. The majority of users will not need AES 256 level security, but I will include it for people that may need it.

AES:

History:

In 1997, the encryption standard at the time, DES, was becoming obsolete due to the advancements in the computer industry. This resulted in the National Institute of Standards and Technology in the United States to call for a new advanced encryption standard (AES).

They held a competition that consisted of 15 different algorithms that had been submitted by different teams. The algorithm that won was an algorithm called Rijndael, an algorithm created by two Belgian cryptographers – Vincent Rijamen and Joan Daemen.

One of the reasons AES has been more successful than DES so far is that AES was thoroughly tested by members of the public during the competition, analysing every aspect of the algorithms to find a way to break them. On the other hand, DES was created in secrecy by IBM in the 70s, and the algorithm was only released a few years later.

This open-source approach ended up helping the new Advanced Encryption Standard, as the program could be heavily analysed by people all across the globe.

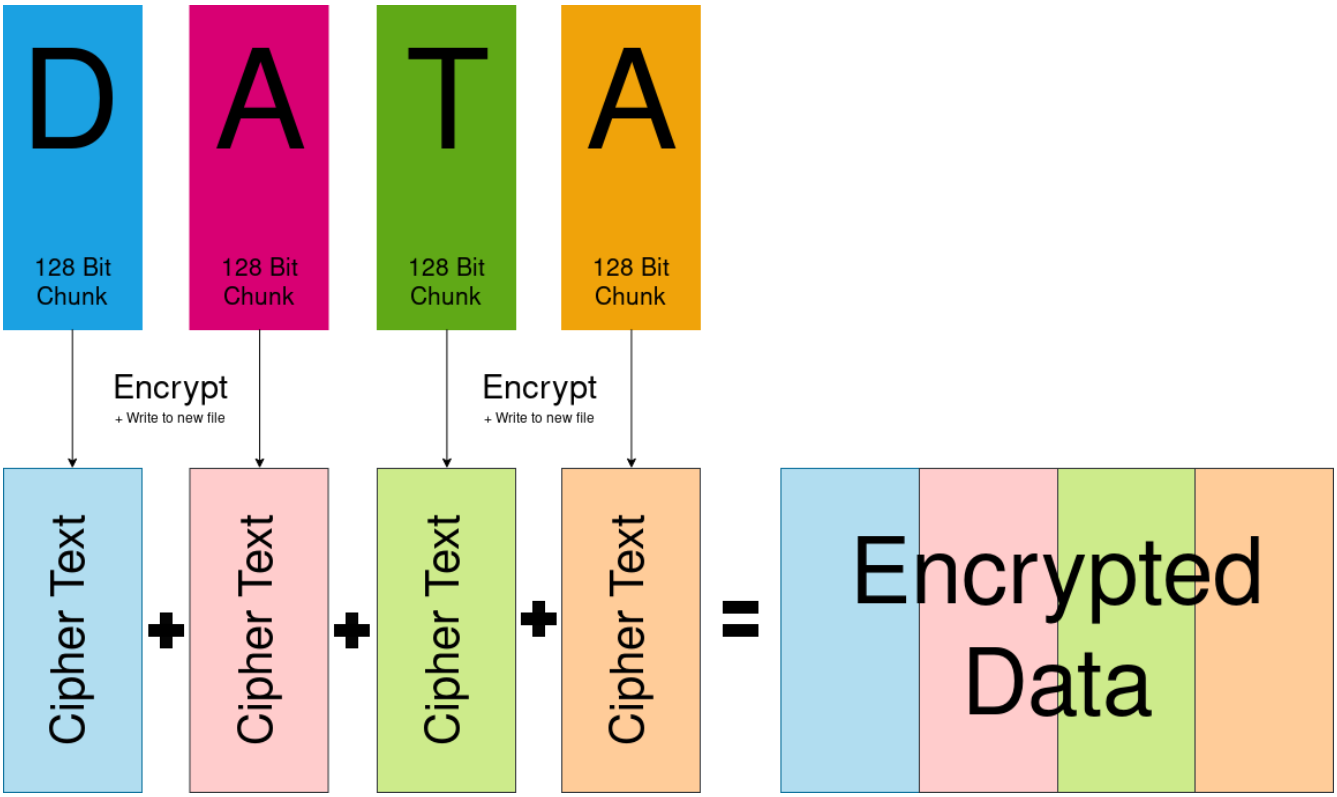
The Algorithm (128 bit AES):

How the data is handled:

AES works by using a block cipher, so it splits the data given into 128 bit, 192 bit or 256 bit chunks depending on what AES you choose (128, 192 or 256). You then use the algorithm on each block to get the cipher text, then you write it to the new file, and move onto the next block.

AES is a symmetric cipher, so only one key is needed to both encrypt and decrypt the data.

Here is an example for 128 bit AES encryption:



Decryption works exactly the same, however the cipher text is split up and decrypted.

Each 128 bit "block" of data can also be called a "state".

Before the operation starts:

First, the data has to be a multiple of 16 in length. If it isn't then more bytes need to be added to the end such that the data is 16 bytes in length (padding).

However, the padding cannot just be 0's at the end, as when we decrypt the block, we have no way of distinguishing these 0's from the rest of the data, or know if they are supposed to be there. To get around this, when we add the padding, we give each byte the value of how many more bytes we need to add to get the length of the block to 16 bytes. This sounds confusing, but here is an example:

Say we had a block that was = **[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13]**

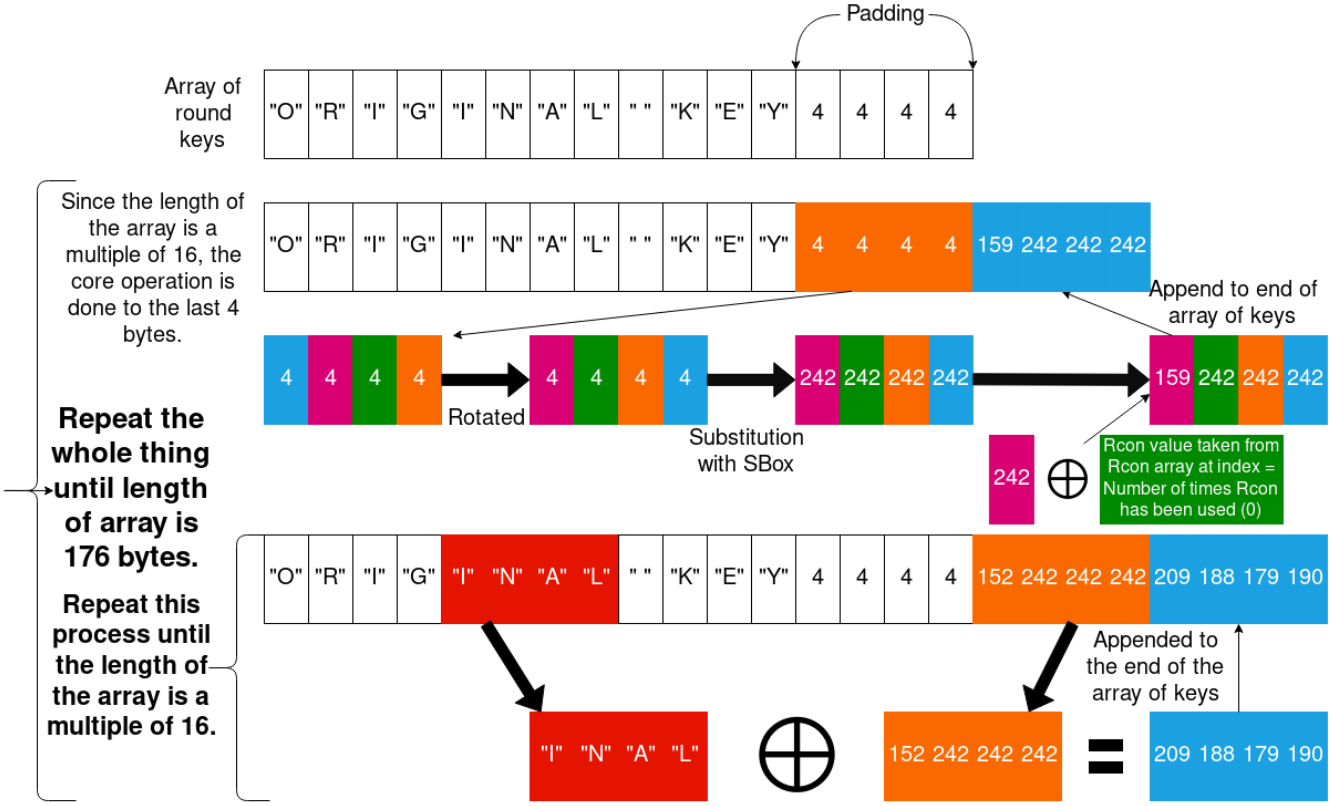
This block is not 16 bytes in length. To pad this block, we need to add 3 lots of the number 3 to the end (since 16 - length of the block = 3). The new block would look like this:

[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, **3, 3, 3**]

When we go to decrypt this block, we check to see if the value of the last byte in the block is lower than 16, and that if the number occurs the same number of times as the value, then we remove these bytes.

For each round of the encryption, a different key has to be used. To make the cipher decipherable, these keys have to be derived from the original key given. For 128 bit AES (the main one I will be using in the program), the 16 byte key has to be transformed into a 176 byte list of 16 byte keys (11 keys in total, one for every round).

The first 16 bytes are the key, and then from there, the algorithm is started. Here is the algorithm with example: **Figure 1 (A larger version can be found in the "Large Images" section)**



The algorithm in psudocode:

```
function expandKey(inputKey)
    expanded := inputKey
    bytesGenerated := 16
    rconIteration  := 1
    temp := uint8[4]

    while bytesGenerated < 176
        temp = expanded[bytesGenerated - 4:bytesGenerated]

        if bytesGenerated MOD 16 == 0 then
            temp[0], temp[1], temp[2], temp[3] = temp[1], temp[2], temp[3], temp[0]
            temp[0], temp[1], temp[2], temp[3] = sBox[temp[0]], sBox[temp[1]], sBox[temp[2]], sBox[temp[3]]

            temp[0] = temp[0] XOR rcon[rconIteration]
            rconIteration = rconIteration + 1
        end if

        for i := 0 to 4
```

```
            expanded[bytesGenerated] = expanded[bytesGenerated - 16] XOR temp[y]
            bytesGenerated = bytesGenerated + 1
        end
    return expanded
end
```

The array of round keys starts off the exact same as the original key. Then if the length of the round key array is a multiple of 16 (which it is), the last 4 bytes of the previous round key (in this case the last 4 bytes of the original key) is:

1. Rotated (The first element of the 4 bytes is put at the end).
2. Substituted (Using the Rijndael Substitution-Box found at: https://en.wikipedia.org/wiki/Rijndael_S-box).
3. First byte of the 4 is XOR-ed with it's corresponding Round Constant (depending on the round number the key will be used in).
4. The result is appended to the array of round keys.

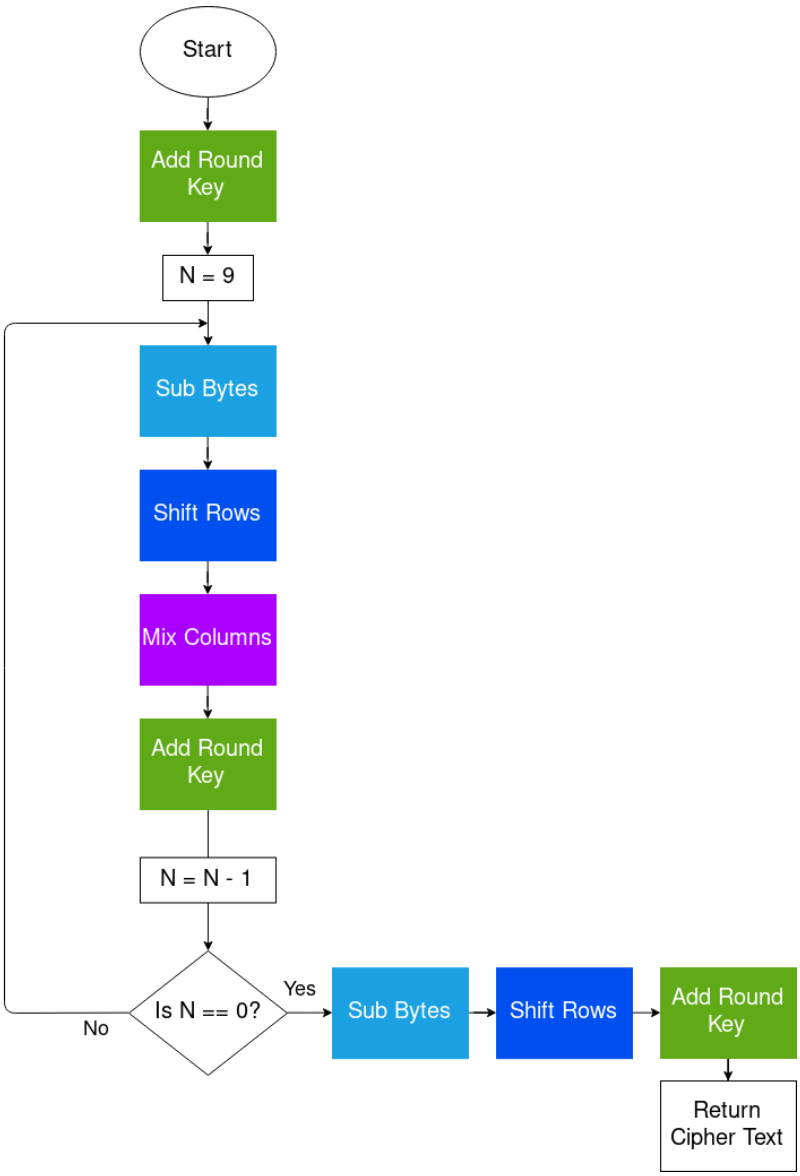
If the length of the round key array is not a multiple of 16, then the last 4 bytes in the array are XOR-ed with 4 bytes of the array that are 16 bytes before hand (shown in **Figure 1**).

This process is repeated until the length of the round key array is 176 bytes, then we will have one 16 byte key for each of the 11 rounds.

And that's all of the preparations done.

The operation:

Here is a diagram of the operation (I will explain each step in detail below):



In total there are 11 rounds (9 regular rounds). For each round, the corresponding round key (that we calculated beforehand) is used in the operation.

The 16 bytes in the state can be represented in a 4x4 grid, to make it easier to visualise what is happening at each stage:

Add Round Key:

The Add Round Key step is literally just XOR-ing each byte in the current block of 16 bytes, with each byte in the 16 byte round key, and returning the state.

Here is pseudocode for the **Add Round Key** step:

```
function addRoundKey(state, roundKey)
    for i := to 16
        state[i] = state[i] XOR roundKey[i]
    return state
```

Sub Bytes:

Sub bytes substitutes each byte in the state with it's corresponding value in the Rijndael substitution box:

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	63	7C	77	7B	F2	6B	6F	C5	30	01	67	2B	FE	D7	AB	76
1	CA	82	C9	7D	FA	59	47	F0	AD	D4	A2	AF	9C	A4	72	C0
2	B7	FD	93	26	36	3F	F7	CC	34	A5	E5	F1	71	D8	31	15
3	04	C7	23	C3	18	96	05	9A	07	12	80	E2	EB	27	B2	75
4	09	83	2C	1A	1B	6E	5A	A0	52	3B	D6	B3	29	E3	2F	84
5	53	D1	00	ED	20	FC	B1	5B	6A	CB	BE	39	4A	4C	58	CF
6	D0	EF	AA	FB	43	4D	33	85	45	F9	02	7F	50	3C	9F	A8
7	51	A3	40	8F	92	9D	38	F5	BC	B6	DA	21	10	FF	F3	D2
8	CD	0C	13	EC	5F	97	44	17	C4	A7	7E	3D	64	5D	19	73
9	60	81	4F	DC	22	2A	90	88	46	EE	B8	14	DE	5E	0B	DB
A	E0	32	3A	0A	49	06	24	5C	C2	D3	AC	62	91	95	E4	79
B	E7	C8	37	6D	8D	D5	4E	A9	6C	56	F4	EA	65	7A	AE	08
C	BA	78	25	2E	1C	A6	B4	C6	E8	DD	74	1F	4B	BD	8B	8A
D	70	3E	B5	66	48	03	F6	0E	61	35	57	B9	86	C1	1D	9E
E	E1	F8	98	11	69	D9	8E	94	9B	1E	87	E9	CE	55	28	DF
F	8C	A1	89	0D	BF	E6	42	68	41	99	2D	0F	B0	54	BB	16

When using the sub-box, you have to think of each byte as hexadecimal (0xYZ). Each row of the sub box is the value of the Y value (16s) in the hexadecimal representation of the byte. Each column of the sub box is the value of the Z value (1s) in the hexadecimal representation of the byte.

For example, if I had the hex `0x1A`, it would be substituted by the value: `0xA2` , as it is row "1", column "A".

Here is the pseudocode for the **Sub Bytes** step:

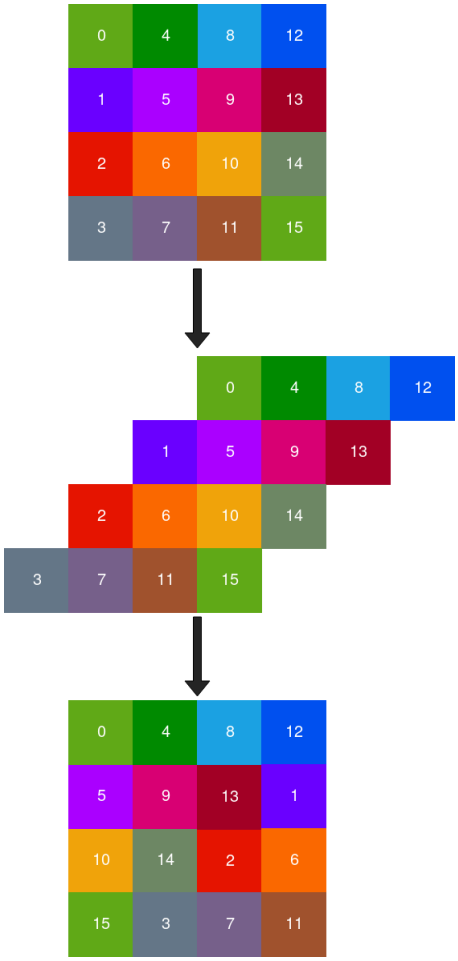
```
function subBytes(state)
    for i := 0 to 16
        state[i] = sBox[state[i]]
    return state
```

It is pretty much the same as **Add Round Key** but instead of XORing you substitute each byte of the state with the corresponding byte in the sub-box (sBox).

Shift Rows:

Shift Rows shifts the rows (really?) left depending on the row number.

For example, the first row is shifted left by 0, second row shifted by 1 and so on:



Here is the algorithm for **Shift Rows**:

```
function shiftRows(state)
    temp := []

    temp[ 0] = state[ 0]
    temp[ 1] = state[ 5]
    temp[ 2] = state[10]
    temp[ 3] = state[15]

    temp[ 4] = state[ 4]
    temp[ 5] = state[ 9]
    temp[ 6] = state[14]
    temp[ 7] = state[ 3]

    temp[ 8] = state[ 8]
    temp[ 9] = state[13]
    temp[10] = state[ 2]
    temp[11] = state[ 7]

    temp[12] = state[12]
    temp[13] = state[ 1]
    temp[14] = state[ 6]
    temp[15] = state[11]

    return temp
```

The array is indexed to correspond to the images above.

Mix Columns:

Mix columns is the most confusing step of AES, so I will try to break it down into small pieces.

The mix columns calculation is this:

$$\begin{bmatrix} r_0 \\ r_1 \\ r_2 \\ r_3 \end{bmatrix} = \begin{bmatrix} 2 & 3 & 1 & 1 \\ 1 & 2 & 3 & 1 \\ 1 & 1 & 2 & 3 \\ 3 & 1 & 1 & 2 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \end{bmatrix}$$

Where r_0 to r_3 is the result of the operation, and a_0 to a_3 is the 4 bytes that make up the input column.

This is matrix multiplication, but we need to do dot product multiplication. This is where we multiply each corresponding element in each row of the pre-defined matrix (the one with numbers already in it), with the corresponding element in a_0 to a_3, and then adds them up MOD2, also known as XOR (so that it is still 1 byte).

One way to represent this is like this:

$$\begin{aligned} r_0 &= (2 \times a_0) \oplus (3 \times a_1) \oplus (1 \times a_2) \oplus (1 \times a_3) \\ r_1 &= (1 \times a_0) \oplus (2 \times a_1) \oplus (3 \times a_2) \oplus (1 \times a_3) \\ r_2 &= (1 \times a_0) \oplus (1 \times a_1) \oplus (2 \times a_2) \oplus (3 \times a_3) \\ r_3 &= (3 \times a_0) \oplus (1 \times a_1) \oplus (1 \times a_2) \oplus (2 \times a_3) \end{aligned}$$

To dot product two binary numbers, they need to be represented using a Galois field.

A number can be represented by using a Galois field. A Galois field is just a way to represent a number as a polynomial, e.g $5x^2 + 2x + 3$, where x^2 is 10^2, so the number of 100s in the number (for decimal), while x is the number of tens. In this case, this Galois field would represent the number 523, as there are 5 hundreds, 2 tens and 3 ones.

For example, if we wanted to represent the decimal number: 25301 as a Galois field, it would be:

$$2x^4 + 5x^3 + 3x^2 + 1$$

Note that the 0 in 25301 is not included, as $0x = 0$.

To represent a binary number, the same logic applies. For example, to represent the binary number `10011011` as a Galois field, it would be:

$$x^7 + x^4 + x^3 + x^1 + 1$$

To get back to decimal, we can replace the x with the number 2, as binary is base 2:

$$2^7 + 2^4 + 2^3 + 2^1 + 1 = 155 = 10011011$$

The dot product of two Galois fields is like expanding brackets: $(x + 2)(x + 3) = x^2 + 5x + 6$, which is $(x \times x) + (2 \times x) + (x \times 3) + (3 \times 2)$, so we just multiply each item in each bracket together.

Now I will do an example of doing one result (r_0) of mix columns.

Lets use these values of a_0 to a_3 for the example:

$$\begin{bmatrix} 2 & 3 & 1 & 1 \\ 1 & 2 & 3 & 1 \\ 1 & 1 & 2 & 3 \\ 3 & 1 & 1 & 2 \end{bmatrix} \begin{bmatrix} d4 \\ d4 \\ d4 \\ d5 \end{bmatrix}$$

To get r_0 I have to do:

$$r_0 = (2 \times a_0) \oplus (3 \times a_1) \oplus (1 \times a_2) \oplus (1 \times a_3)$$

which is:

$$r_0 = (2 * d4) \oplus (3 * d4) \oplus (1 * d4) \oplus (1 * d5)$$

in this example.

I am using $d4, d4, d4, d5$ as test values as they are test vectors used on this page: https://en.wikipedia.org/wiki/Rijndael_MixColumns, to check that we get the right answer.

Now I need to convert the hex values $d4$ and $d5$ to binary:

$d4$ in binary is 11010100

$d5$ in binary is 11010101

Now i need to convert both of these into Galois fields:

$$\begin{aligned} 11010100 &= x^7 + x^6 + x^4 + x^2 \\ 11010101 &= x^7 + x^6 + x^4 + x^2 + 1 \end{aligned}$$

Then I need to multiply them all by their corresponding value in the pre-defined table expressed as a Galois field (e.g. $2 \equiv x$):

$$\begin{aligned} (x^7 + x^6 + x^4 + x^2)(x) &= x^8 + x^7 + x^5 + x^3 \\ (x^7 + x^6 + x^4 + x^2)(x + 1) &= x^8 + x^7 + x^7 + x^6 + x^5 + x^4 + x^3 + x^2 \\ &= x^8 + 2x^7 + x^6 + x^5 + x^4 + x^3 + x^2 \\ (x^7 + x^6 + x^4 + x^2)(1) &= x^7 + x^6 + x^4 + x^2 \\ (x^7 + x^6 + x^4 + x^2 + 1)(1) &= x^7 + x^6 + x^4 + x^2 + 1 \end{aligned}$$

But hang on a second, the answer to $d4 * 3$ and $d4 * 2$ both have a x^8 term, which means it's bigger than 255 (since 2^8 = 256), so it is no longer a byte, which means that it no longer fits in with 128 bit AES.

To fix this, we replace all of the x^8 terms with this pre-determined polynomial (Rijndael's finite field), reducing by MOD2 as we go along:

$$x^8 \equiv x^4 + x^3 + x + 1$$

Let's try this with d4*3 :

$$
\begin{aligned}
3d4 &= x^8 + 2x^7 + x^6 + x^5 + x^4 + x^3 + x^2 \\
&= (x^4 + x^3 + x + 1) + 2x^7 + x^6 + x^5 + x^4 + x^3 + x^2 \\
&= 2x^7 + x^6 + x^5 + 2x^4 + 2x^3 + x^2 + x + 1 \\
&= 0x^7 + x^6 + x^5 + 0x^4 + 0x^3 + x^2 + x + 1 \quad \text{Here is where I did MOD2} \\
&= x^6 + x^5 + x^2 + x + 1
\end{aligned}
$$

Again with d4*2:

$$
\begin{aligned}
2d4 &= x^8 + x^7 + x^5 + x^3 \\
&= (x^4 + x^3 + x + 1) + x^7 + x^5 + x^3 \\
&= x^7 + x^5 + x^4 + 2x^3 + x + 1 \\
&= x^7 + x^5 + x^4 + x + 1
\end{aligned}
$$

Now, with our new values for a_0 to a_3, we can finally do the equation:

$$
\begin{aligned}
r_0 &= (2 \times d4) \oplus (3 \times d4) \oplus (1 \times d4) \oplus (1 \times d5) \\
r_0 &= (x^7 + x^5 + x^4 + x + 1) \oplus (x^6 + x^5 + x^2 + x + 1) \oplus (x^7 + x^6 + x^4 + x^2) \oplus (x^7 + x^6 + x^4 + x^2 + 1) \\
r_0 &= (2^7 + 2^5 + 2^4 + 2 + 1) \oplus (2^6 + 2^5 + 2^2 + 2 + 1) \oplus (2^7 + 2^6 + 2^4 + 2^2) \oplus (2^7 + 2^6 + 2^4 + 2^2 + 1)
\end{aligned}
$$

$$
\begin{aligned}
r_0 &= 10110011 \\
&\quad\ 01100111 \\
&\quad\ 11010100 \\
&\oplus\ 11010101 \\
\hline
&= 11010101
\end{aligned}
$$

$$
r_0 = 213(decimal)
$$

And, thank god, that is the correct answer for the test vector on this page: https://en.wikipedia.org/wiki/Rijndael_MixColumns.

To get r_1, r_2 and r_3, you repeat the process using the equations for each defined at the top of this section.

This whole process has to be done on each column.

On a computer, this would be very demanding on the processor, however since the range of the inputs is 0-255 (since the number has to be represented by 1 byte), you can make a lookup table with all of the 256 possible outputs, for each of the multiplications, for each of the 256 possible inputs. This drastically increases speed, and also makes it easier to program. You would have a table for multiplication by 2 and 3, and for the inverse function of Mix Columns you would need multiplication by 9, 11 and 13.

This trades a few kilobytes of memory for a drastic improvement in speed.

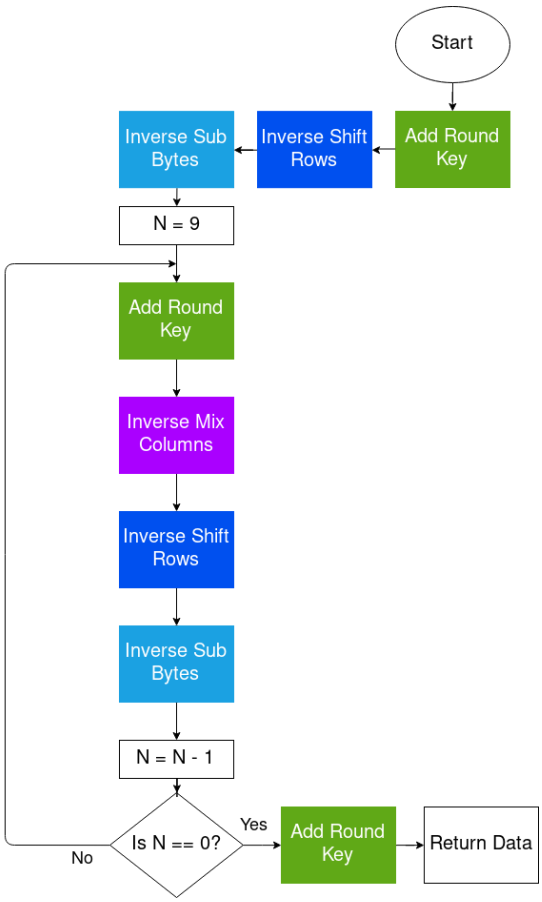
This makes the pseudocode for **Mix Columns** very simple:

```
// mul2 and mul3 are the pre-defined tables talked about above.
function mixColumns(state)
    temp := []

    temp[ 0] = mul2[state[0]] XOR mul3[state[1]] XOR state[2] XOR state[3]
    temp[ 1] = state[0] XOR mul2[state[1]] XOR mul3[state[2]] XOR state[3]
    temp[ 2] = state[0] XOR state[1] XOR mul2[state[2]] XOR mul3[state[3]]
    temp[ 3] = mul3[state[0]] XOR state[1] XOR state[2] XOR mul2[state[3]]
```

```
9
10      temp[ 4] =  mul2[state[4]] XOR mul3[state[5]] XOR state[6] XOR state[7]
11      temp[ 5] =  state[4] XOR mul2[state[5]] XOR mul3[state[6]] XOR state[7]
12      temp[ 6] = state[4] XOR state[5] XOR mul2[state[6]] XOR mul3[state[7]]
13      temp[ 7] = mul3[state[4]] XOR state[5] XOR state[6] XOR mul2[state[7]]
14
15      temp[ 8] = mul2[state[8]] XOR mul3[state[9]] XOR state[10] XOR state[11]
16      temp[ 9] = state[8] XOR mul2[state[9]] XOR mul3[state[10]] XOR state[11]
17      temp[10] = state[8] XOR state[9] XOR mul2[state[10]] XOR mul3[state[11]]
18      temp[11] = mul3[state[8]] XOR state[9] XOR state[10] XOR mul2[state[11]]
19
20      temp[12] = mul2[state[12]] XOR mul3[state[13]] XOR state[14] XOR state[15]
21      temp[13] = state[12] XOR mul2[state[13]] XOR mul3[state[14]] XOR state[15]
22      temp[14] = state[12] XOR state[13] XOR mul2[state[14]] XOR mul3[state[15]]
23      temp[15] = mul3[state[12]] XOR state[13] XOR state[14] XOR mul2[state[15]]
24
25      return temp
26  }
27
```

Decryption

Decryption is just encryption, but in reverse. This uses the inverse functions of each function used to encrypt the data. Here is the algorithm:



It is literally just the encryption algorithm in reverse.

Before decryption, the exact same steps need to be taken as in encryption, apart from the padding because all the blocks should have already been encrypted, so each block should be 16 in length.

Inverse Add Round Key:

Add round key is it's own inverse, as XOR is the same forwards as it is backwards.

Inverse Sub Bytes:

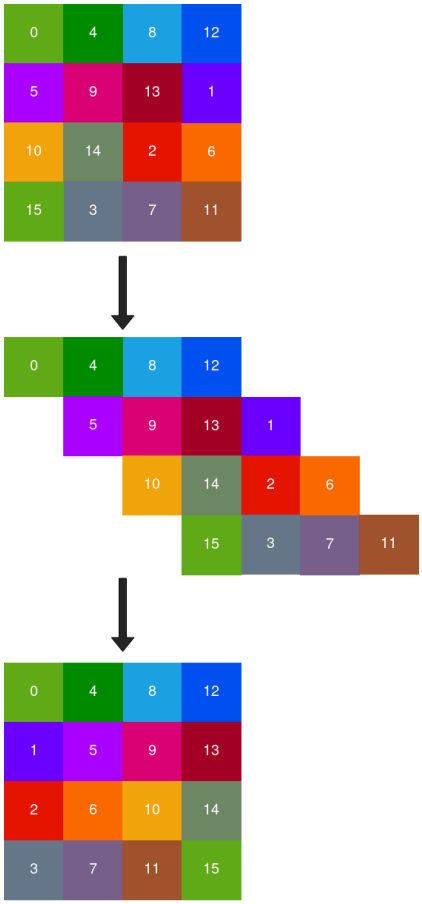
Inverse sub bytes is the same as sub bytes, it just has an inverse of the S-Box.

		y														
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**A**	**B**	**C**	**D**	**E**	**F**
x	**0**	63	7C	77	7B	F2	6B	6F	C5	30	01	67	2B	FE	D7	AB	76
	1	CA	82	C9	7D	FA	59	47	F0	AD	D4	A2	AF	9C	A4	72	C0
	2	B7	FD	93	26	36	3F	F7	CC	34	A5	E5	F1	71	D8	31	15
	3	04	C7	23	C3	18	96	05	9A	07	12	80	E2	EB	27	B2	75
	4	09	83	2C	1A	1B	6E	5A	A0	52	3B	D6	B3	29	E3	2F	84
	5	53	D1	00	ED	20	FC	B1	5B	6A	CB	BE	39	4A	4C	58	CF
	6	D0	EF	AA	FB	43	4D	33	85	45	F9	02	7F	50	3C	9F	A8
	7	51	A3	40	8F	92	9D	38	F5	BC	B6	DA	21	10	FF	F3	D2
	8	CD	0C	13	EC	5F	97	44	17	C4	A7	7E	3D	64	5D	19	73
	9	60	81	4F	DC	22	2A	90	88	46	EE	B8	14	DE	5E	0B	DB
	A	E0	32	3A	0A	49	06	24	5C	C2	D3	AC	62	91	95	E4	79
	B	E7	C8	37	6D	8D	D5	4E	A9	6C	56	F4	EA	65	7A	AE	08
	C	BA	78	25	2E	1C	A6	B4	C6	E8	DD	74	1F	4B	BD	8B	8A
	D	70	3E	B5	66	48	03	F6	0E	61	35	57	B9	86	C1	1D	9E
	E	E1	F8	98	11	69	D9	8E	94	9B	1E	87	E9	CE	55	28	DF
	F	8C	A1	89	0D	BF	E6	42	68	41	99	2D	0F	B0	54	BB	16

Inverse Shift Rows:

Inverse shift rows does what shift rows does, but shifts each row right instead of left.

In the diagram below it takes the shifted data and orders it again.



Inverse Mix Columns:

Inverse mix columns works the same as normal mix columns, but with a different matrix to multiply each element with:

$$\begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \end{bmatrix} = \begin{bmatrix} 14 & 11 & 13 & 9 \\ 9 & 14 & 11 & 13 \\ 13 & 9 & 14 & 11 \\ 11 & 13 & 9 & 14 \end{bmatrix} \begin{bmatrix} r_0 \\ r_1 \\ r_2 \\ r_3 \end{bmatrix}$$

The a's are the original data, the r's are the encrypted data.

Just like with normal mix columns, you can just use lookup tables for each possible answer to each possible input.

And that's all for AES.

SHA256:

SHA256 (in the Secure Hash Algorithm 2 family) takes an input of 32 bytes (256 bits), and gives a 32 byte output based on the input, but is meaningless. This is useful for passwords, or pin codes like in my program, where you don't want the original password to be known, but for the password to still be unique.

A small difference in the input gives you a drastic change in the output. For example, if I put in:

```
"test string"
```

I get:

```
d5579c46dfcc7f18207013e65b44e4cb4e2c2298f4ac457ba8f82743f31e930b
```

But when I put in:

```
"test strinh"
```

I get:

```
4e4d20e9fc77e913bf56cc69a2b4685d761a9e44d833198612e80a72dcd563f1
```

A vastly different output to the one above. This is important, as there should be no pattern to the output, otherwise the original password could be guessed based off of similar inputs.

Now you might be asking "Why are you using 256 bit SHA, when size key you need for AES is 128 bits?". It is because the more bits you have, the less likely you are to have collisions with other inputs. The security of SHA-1 (128 bit SHA) (measured in bits) is less than 63 bits due to collisions (if it was fully secure it would be the full 128 bits).

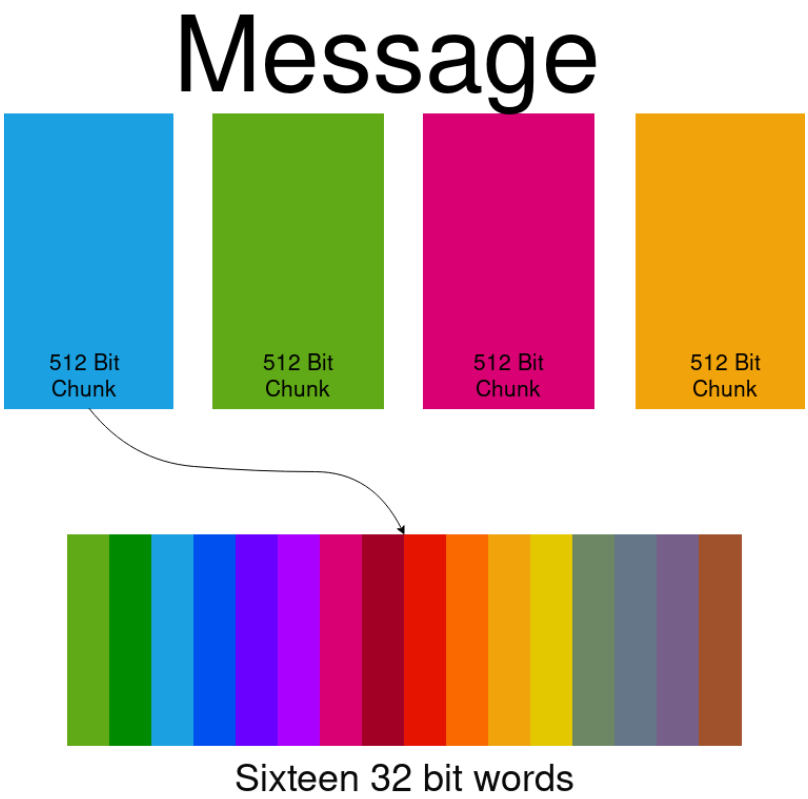
What I am doing instead, is taking the output of SHA256, splitting it in half, and XORing each half with each other to get a 128 bit output. This doesn't affect how secure it is, as you still have the extra step of XOR, making it still more secure than SHA-1.

The Algorithm:

Bear in mind that SHA works on a bitwise level, so while I will be explaining it, I will be talking in terms of bits.

How the message is handled:

When doing operations on the data, it will be done in 32 bit words. The message is split into 512 bit blocks, containing sixteen 32 bit words.



SHA is operates on every 32 bit word.

Since the maximum key size for my AES will be 16 bytes (128 bits), I don't need to worry about splitting the message into 512 bit chunks, as the input will only ever be 128 bits as SHA will only ever be used for the AES key. So, for the examples below I won't go into detail on how a message bigger than 512 bits will be handled.

Before the operation starts:

Before we start, we need to **pad the message** M so that it is 512 bits in length.

Let l = the length of the message M.

First, we need to append the bit 1 to the end of the message, followed by k 0 bits, where k is the smallest positive solution to the equation:

$$l + 1 + k \equiv 448 \ mod 512$$

To get k, the algorithm would look something like this (I wrote this in Python 3):

```
k = 0
while ((l+1+k)-448) % 512 != 0:
    k += 1
```

Then, you append the binary representation of the length of the message l as a 64 bit binary number. This makes the message 256 bits in length.

Let's do an example: M = "i don't know".

$$
\begin{aligned}
&l = 12 \times 8 = 96 \\
&\text{Append a "1":} \\
&M = \text{b"i don't know"} + 1 \\
&448 - (96 + 1) = 351 \text{ Zero Bits} \\
&M = \text{b"i don't know"} + 1 + 351(0s) \\
&l = 96 = 01100000 \\
&\text{Final Padded Message:} \\
&M = \text{b"i don't know"} + 1 + 351(0s) + 56(0s) + 01100000
\end{aligned}
$$

The message has to be 512 bits in length so that it works with the calculations later.

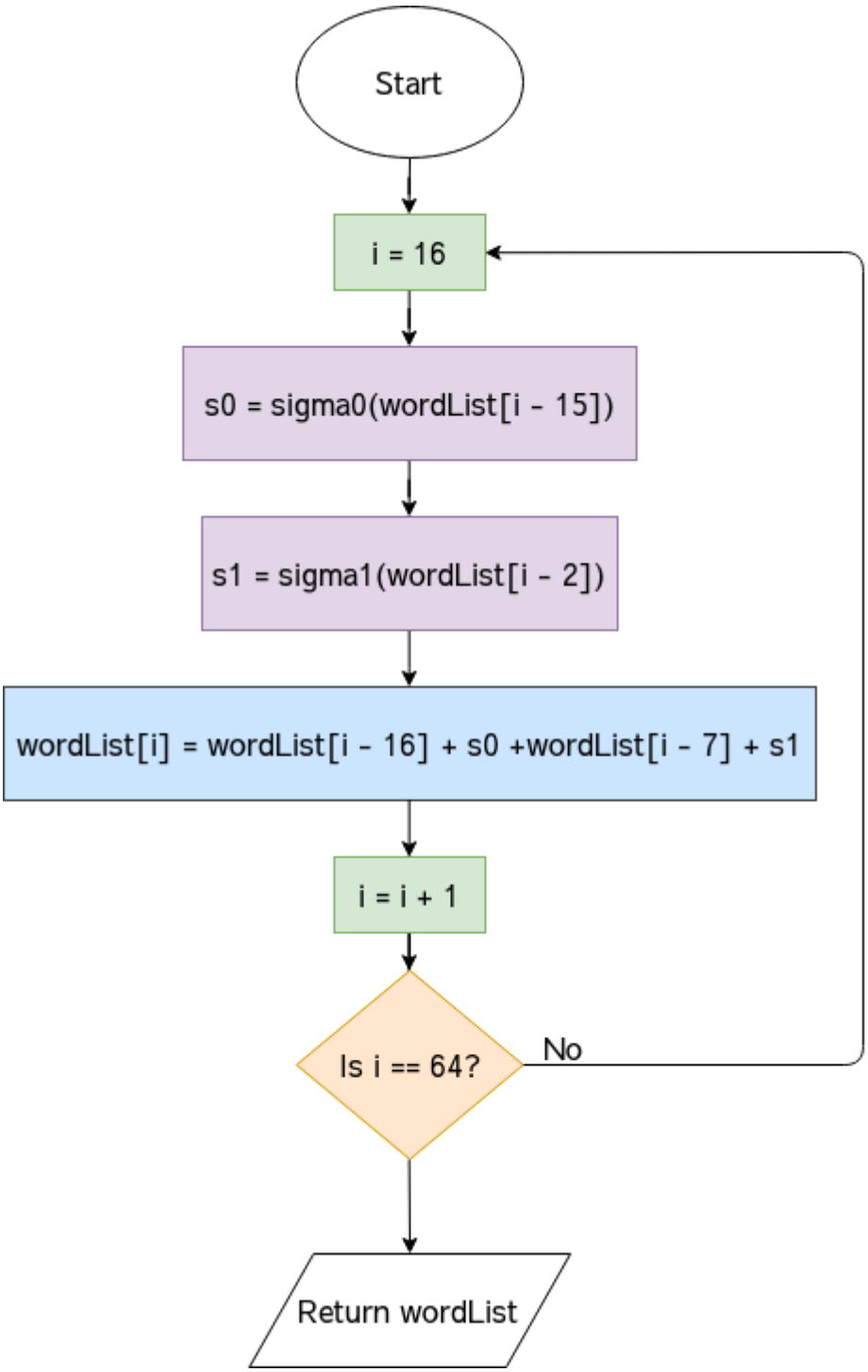
Then, we also need to **set the initial hash values** for each word in the current block. The initial hash values set by the creators of SHA:

> "These words were obtained by taking the first thirty-two bits of the fractional parts of the square roots of the first eight prime numbers. "

$$
\begin{aligned}
H_0 &= 6a09e667 \\
H_1 &= bb67ae85 \\
H_2 &= 3c6ef372 \\
H_3 &= a54ff53a \\
H_4 &= 510e527f \\
H_5 &= 9b05688c \\
H_6 &= 1f83d9ab \\
H_7 &= 5be0cd19
\end{aligned}
$$

Next, each 32 bit word in the message has to be expanded from 32 bits to 64 bits.

Here is the algorithm:



To do this, we need two functions, sigma 0 σ_0 and sigma 1 σ_1.

Sigma 0 (Expansion) (σ_0):

Sigma 0 (Expansion) looks like this:

$$\sigma_0(x) = (x >>> 7) \oplus (x >>> 18) \oplus (x >> 3)$$

$>>>$ means that we rotate the 32 bit word x right by the number given (y). What this does is shift the bytes along y places to the right, and wraps them around to the start of x.

I will do an example of $>>>$ with a 4 bit nibble:

$$f(x) = x >>> 1$$
$$f(1011) = 1011 >>> 1$$
$$f(1011) = 1101$$

As you can see, the 1 bit at the end gets moved to the front, as I shifted it right by 1.

$>>$ Means shift the 32 bit word x right by the number given (y). This is different from $>>>$, because instead of wrapping the bits around to the beginning of the word again, we just shove a 0 bit at the front instead.

$\bigoplus$ is just XOR.

For example:

$$f(x) = x >> 1$$
$$f(1011) = 1011 >> 1$$
$$f(1011) = 0101$$

$$g(x) = x >> 2$$
$$g(0101) = 0101 >> 2$$
$$g(0101) = 0001$$

Here the byte is shifted right, and the bytes are removed as they are shifted.

Sigma 1 (Expansion)(σ_1):

Sigma 1(Expansion)(σ_1) is the same as Sigma 0 (Expansion)(σ_0), apart from how much you rotate and shift the word:

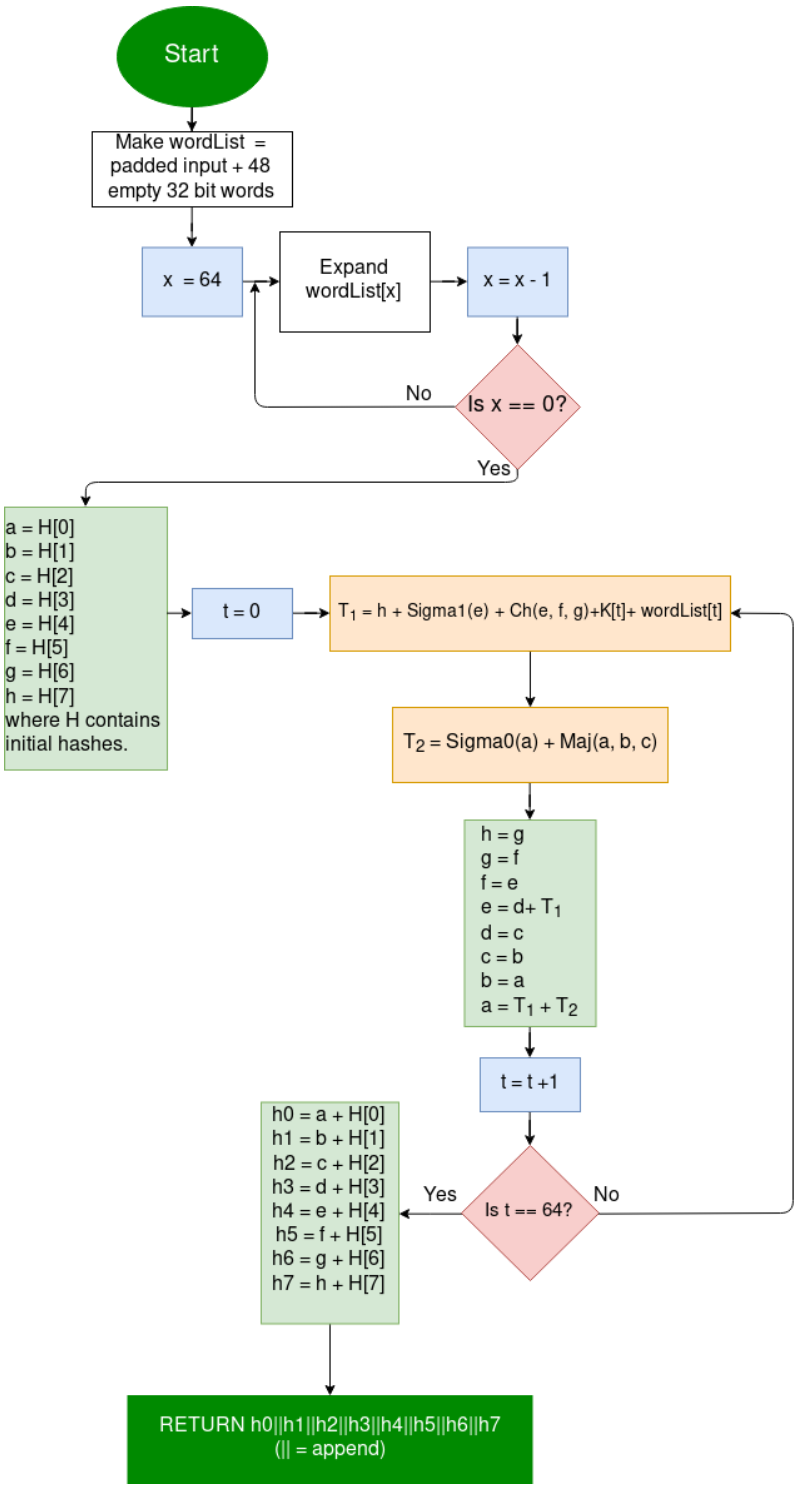
$$\sigma_0(x) = (x >>> 17) \oplus (x >>> 19) \oplus (x >> 10)$$

The operation:

All addition is MOD(2^32).

Here is the full algorithm:

Figure 2 (Found larger on "Large Images" section)



In the diagram above, H is the array of initial hash values discussed earlier, wordList is a 2D array containing the 32 bit words. || means append, so $h0||h1||h2||...$ just appends the items together. K is the array with the round constants in (see https://csrc.nist.gov/csrc/media/publications/fips/180/4/archive/2012-03-06/documents/fips180-4.pdf section 4.2.2).

The step "Expand wordList[x]" is covered in the section above.

All of the SHA functions operate on 32 bit words, and return a new 32 bit word. I will now explain what the functions Sigma0 (Σ_0), Sigma1 (Σ_1), Ch and Maj.

Sigma 0 (Σ_0):

Σ_0 is this equation:

$$\Sigma_0(x) = (x >>> 2) \oplus (x >>> 13) \oplus (x >>> 22)$$

This looks confusing, but let me break it down.

$>>>$ means that we rotate (shift and move displaced numbers to the begining/end of the number) the number right by the number specified.

$\bigoplus$ means that we XOR the items either side with each other.

Here is an example of the rotate function:

$$\begin{aligned} A &= 1001110 \\ A >>> 2 &= 1010011 \quad \text{The last two bits are moved to the end.} \end{aligned}$$

Let me do an example with a 32 bit word:

$A = 10010111011011111000110111011101$
$\Sigma_0 = (10010111011011111000110111011101 >>> 2) \oplus (10010111011011111000110111011101 >>> 13) \oplus$
$\ldots (10010111011011111000110111011101 >>> 22)$
$(10010111011011111000110111011101 >>> 2) = 01100101110110111110001101110111$
$\text{The two bits at the end have been moved to the front one by one.}$
$(10010111011011111000110111011101 >>> 13) = 11110001101110111011001011101101$
$(10010111011011111000110111011101 >>> 22) = 01110111011001011101101111100011$
$01100101110110111110001101110111 \oplus 11110001101110111011001011101101 \oplus 01110111011001011101101111100011$
$= 11100011000001011000101001111001$

Sorry if that is a bit small.

It isn't too difficult it's just understanding what the $>>>$ does.

Sigma 1 (Σ_1):

Sigma 1 (Σ_1) is pretty much the same as Σ_0, the only difference being the amount you rotate by:

$$\Sigma_0(x) = (x >>> 6) \oplus (x >>> 11) \oplus (x >>> 25)$$

Ch:

The Ch function looks like this:

$$Ch(x, y, z) = (x \wedge y) \oplus (\neg x \wedge z)$$

This also looks a bit confusing, but it really isn't too bad.

The $\wedge$ symbol is the bitwise operator AND.

The $\oplus$ symbol is the bitwise operator XOR.

The $\neg$ symbol is the bitwise operator NOT.

I will do one example run with Ch with three 4 bit nibbles to keep it simple:

$$Ch(1011, 1001, 0011) = (1011 \wedge 1001) \oplus (\neg 1011 \wedge 0011)$$

$$\begin{array}{r} 1011 \\ \hline \wedge\ 1001 \\ = 1001 \end{array}$$

$$Ch(1011, 1001, 0011) = 1001 \oplus (\neg 1011 \wedge 0011)$$
$$\neg 1001 = 0110$$

$$\begin{array}{r} 0110 \\ \hline \wedge\ 0011 \\ = 0010 \end{array}$$

$$Ch(1011, 1001, 0011) = 1001 \oplus 0010$$

$$\begin{array}{r} 1001 \\ \hline \oplus\ 0010 \\ = 1011 \end{array}$$

$$Ch(1011, 1001, 0011) = 1011$$

Maj:

the Maj function looks like this:

$$Maj(x, y, z) = (x \wedge y) \oplus (x \wedge z) \oplus (y \wedge z)$$

You should recognise the symbols in this one, since they appear in the other ones used in SHA that we have covered. Here is an example with three 4 bit nibbles:

$$Maj(1011, 1001, 0011) = (1011 \wedge 1001) \oplus (1011 \wedge 0011) \oplus (1001 \wedge 0011)$$

$$\begin{array}{r} 1011 \\ \hline \wedge\ 1001 \\ = 1001 \end{array}$$

$$\begin{array}{r} 1011 \\ \hline \wedge\ 0011 \\ = 0011 \end{array}$$

$$\begin{array}{r} 1001 \\ \hline \wedge\ 0011 \\ = 0001 \end{array}$$

$$Maj(1011, 1001, 0011) = 1001 \oplus 0011 \oplus 0001$$

$$\begin{array}{r} 1001 \\ 0011 \\ \oplus\ 0001 \\ \hline = 0101 \end{array}$$

$$Maj(1011, 1001, 0011) = 0101$$

BLAKE 2b:

BLAKE was a finalist in the SHA 3 contest. The SHA 3 contest was announced on November 2nd 2007, as a new hash function was needed, that was very different from the SHA 2 family of hash functions in case a huge issue was found with the SHA 2 family.

BLAKE did not win, as it was too similar to SHA2:

> *"desire for SHA-3 to complement the existing SHA-2 algorithms ... BLAKE is rather similar to SHA-2."*

https://blake2.net/acns/slides.html

However, BLAKE was the fastest out of all of the competitors (at 8.4 cycles per byte, cycles being the fetch decode execute cycle of a processor), and was tested to be secure. This meant that even though BLAKE did not win the competition, it is still used in numerous programs. Due to BLAKE's speed, it is ideal for getting the checksum of large data.

No preparations have to be done so lets just jump right into the algorithm.

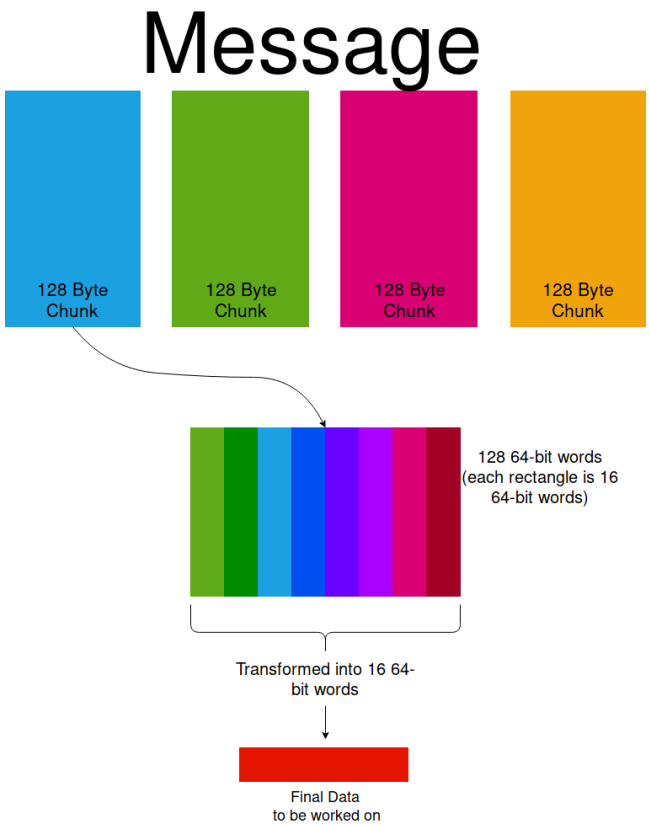
The Algorithm:

How the data is read:

8 initial hash values of size 64-bits are initialised at the start (using pre-defined values), and these are worked on throughout the program.

The data is read in 128 bytes, where each byte is then converted into a 64-bit word (just shove some 0s on the front). Each chunk is operated on using the 8 hash values, creating 8 new hash values. These new hash values are used in computation using the next block and so on.

Here is a diagram showing how the data is converted into data that can be processed:

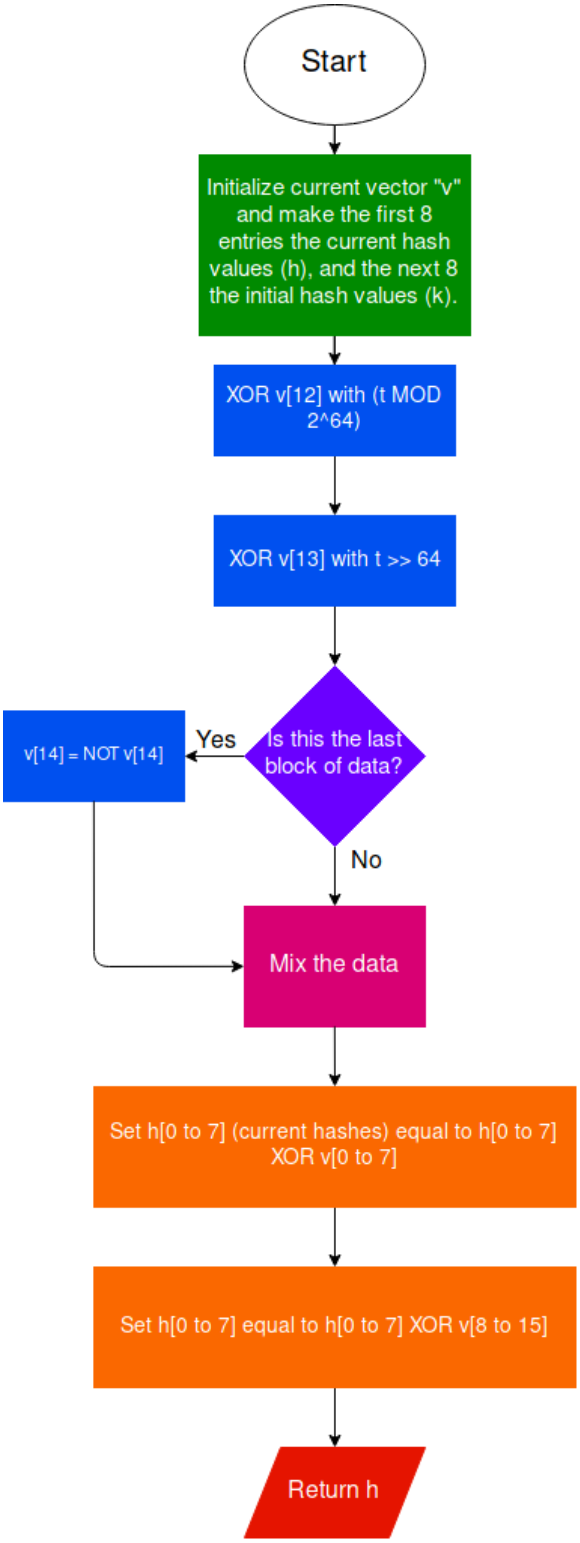


To transform a list of 16 64-bit words into 1 64-bit word, you do this algorithm (where a is the list of words):

$$new = a[0] \oplus (a[1] << 8) \oplus (a[2] << 16) \oplus (a[3] << 24) \oplus (a[4] << 32) \oplus (a[5] << 40) \oplus (a[6] << 48) \oplus (a[7] << 56)$$

What this does is XOR's the bytes in the array with each other in a way that produces a single word at the end.

The operation:



Each block has to be compressed and returned as 8 hash values. Above is the compression function. t is the number of bytes in total that have been compressed so far, h is a list of the 8 current hashes, and k is the list of 8 initial hash values set here ***https://tools.ietf.org/pdf/rfc7693.pdf*** ***section 2.6***, the same initial hash values of SHA512.

The operation is quite simple compared to other hash functions like SHA512, as it was built for speed.

The **Mix the data** step looks like this:

```
for i := 0 to 12
    v = mix(v, 0, 4,  8, 12, m[sigma[i][0]], m[sigma[i][1]])
    v = mix(v, 1, 5,  9, 13, m[sigma[i][2]], m[sigma[i][3]])
    v = mix(v, 2, 6, 10, 14, m[sigma[i][4]], m[sigma[i][5]])
    v = mix(v, 3, 7, 11, 15, m[sigma[i][6]], m[sigma[i][7]])

    v = mix(v, 0, 5, 10, 15, m[sigma[i][ 8]], m[sigma[i][ 9]])
    v = mix(v, 1, 6, 11, 12, m[sigma[i][10]], m[sigma[i][11]])
    v = mix(v, 2, 7,  8, 13, m[sigma[i][12]], m[sigma[i][13]])
    v = mix(v, 3, 4,  9, 14, m[sigma[i][14]], m[sigma[i][15]])
```

Sigma (σ) is a 2-dimensional array containing some constant values, that determine what index of the current working vector v (a 16 length array of 64-bit words) will be mixed with what other index of v. Sigma is defined here: ***https://tools.ietf.org/pdf/rfc7693.pdf*** ***section 2.7*** as:

$$\sigma[0] = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]$$
$$\sigma[1] = [14, 10, 4, 8, 9, 15, 13, 6, 1, 12, 0, 2, 11, 7, 5, 3]$$
$$\sigma[2] = [11, 8, 12, 0, 5, 2, 15, 13, 10, 14, 3, 6, 7, 1, 9, 4]$$
$$\sigma[3] = [7, 9, 3, 1, 13, 12, 11, 14, 2, 6, 5, 10, 4, 0, 15, 8]$$
$$\sigma[4] = [9, 0, 5, 7, 2, 4, 10, 15, 14, 1, 11, 12, 6, 8, 3, 13]$$
$$\sigma[5] = [2, 12, 6, 10, 0, 11, 8, 3, 4, 13, 7, 5, 15, 14, 1, 9]$$
$$\sigma[6] = [12, 5, 1, 15, 14, 13, 4, 10, 0, 7, 6, 3, 9, 2, 8, 11]$$
$$\sigma[7] = [13, 11, 7, 14, 12, 1, 3, 9, 5, 0, 15, 4, 8, 6, 2, 10]$$
$$\sigma[8] = [6, 15, 14, 9, 11, 3, 0, 8, 12, 2, 13, 7, 1, 4, 10, 5]$$
$$\sigma[9] = [10, 2, 8, 4, 7, 6, 1, 5, 15, 11, 9, 14, 3, 12, 13, 0]$$

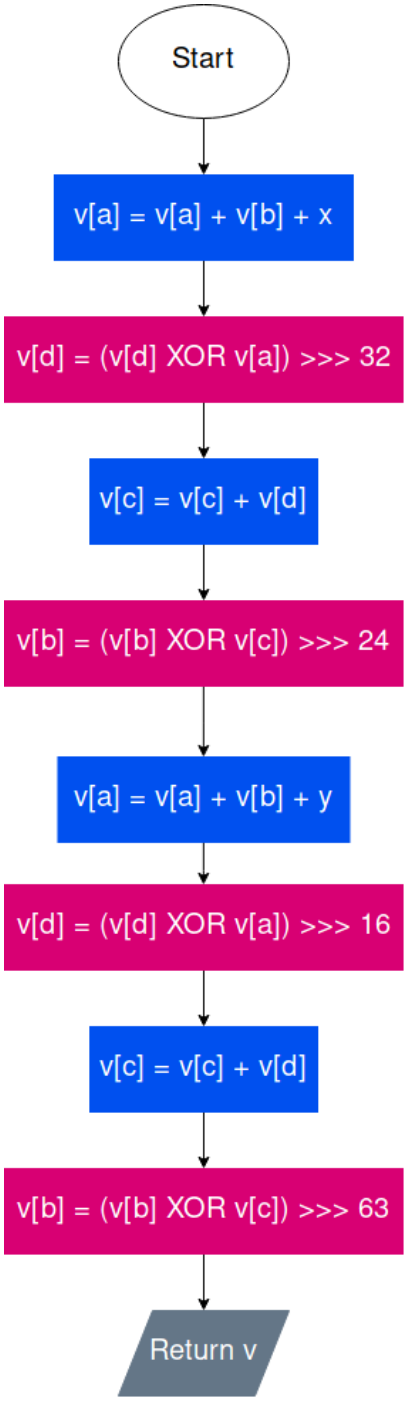
σ is defined for BLAKE2s, and BLAKE2s only has 10 rounds, while BLAKE2b has 12, so σ_0 and σ_1 are repeated again to make the array 12 in length.

Notice that in the first lot of mixing, the vector is mixed row by row normally (with the same indexing as AES), but in the second lot of mixing, the indices change. They shift each column up depending on the column. Column 0 is shifted 0 places, column 1 is shifted 1 place up, column 2 is shifted 2 places up, and column 3 is shifted 3 places up. This is a much better way of shifting each column than doing it before hand.

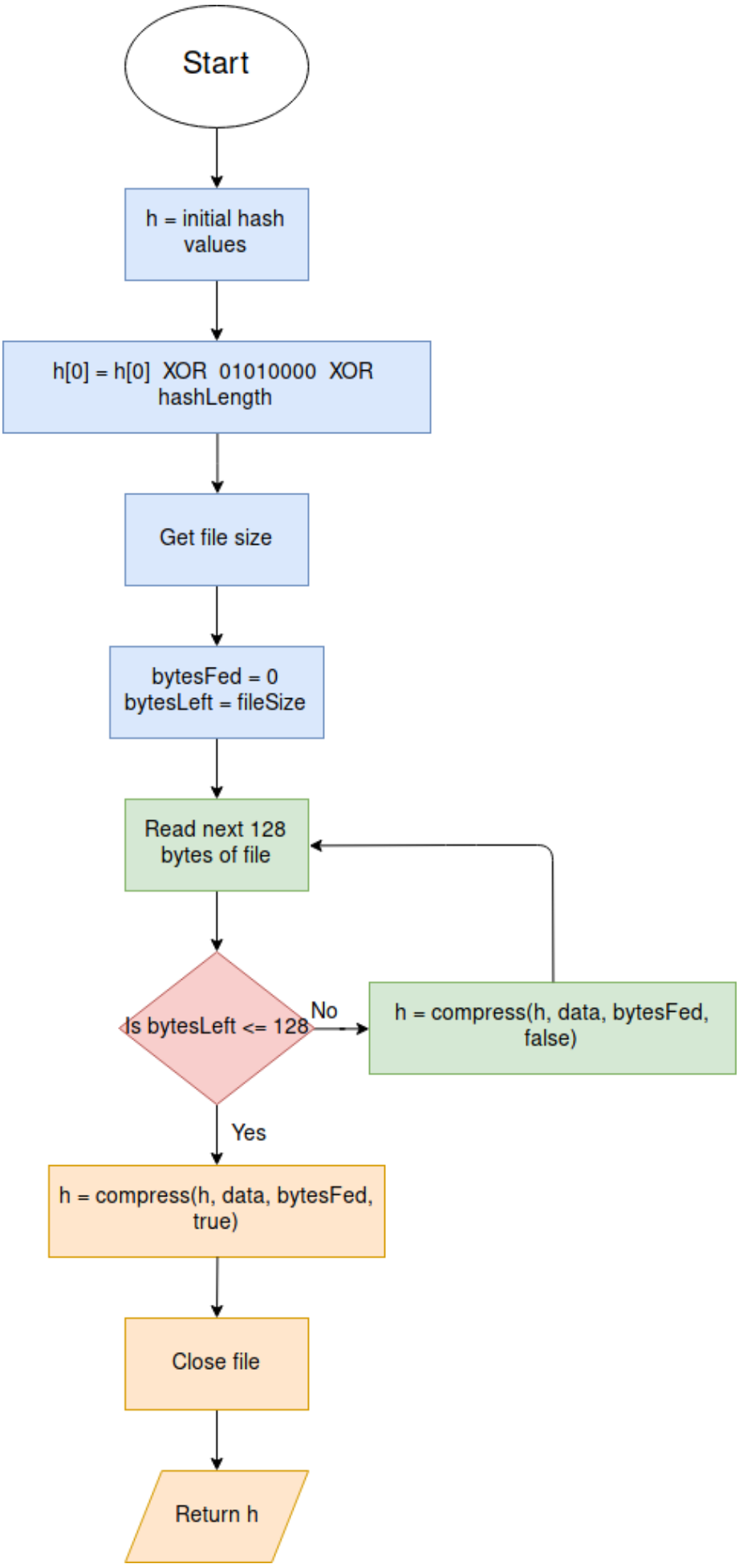
The main mixing function takes the inputs:

$$mix(v,\ a,\ b,\ c,\ d,\ x,\ y)$$

Where v is the current vector (16 64-bit words), a, b, c, d, x, and y are the indices of the working vector you want to work with. Here is the main mixing algorithm:



So all together, this is the BLAKE2b checksum algorithm:


Start
h = initial hash values
h[0] = h[0] XOR 01010000 XOR hashLength
Get file size
bytesFed = 0
bytesLeft = fileSize
Read next 128 bytes of file
Is bytesLeft <= 128
No
h = compress(h, data, bytesFed, false)
Yes
h = compress(h, data, bytesFed, true)
Close file
Return h

The second step ($h[0] = h[0] \oplus 01010000 \oplus hL$) XORs $h[0]$ with $0101kknn$, where kk is the length of the key (which is optional, so I probably will never use it), and nn is the hash length desired.

Quick Sort

My program will need a quick sort for sorting the files by:

- Size
- Name

I have chosen quick sort because it is quicker than most sorts (it's in the name!) with a big-O notation of $O(n \log n)$ on average, with the worst case being $O(n^2)$. Merge sort has a big-O notation of $O(n \log n)$, and worst case of $O(n \log n)$, so why am I not using merge sort? Merge sort is supposed to be quicker mathematically, however merge sort has to access the array of items more often, which puts more strain on the memory of the computer, which is considerably slower in comparison to the CPU in the majority of computers. Here is a good video comparing merge sort and quick sort (along with a few other algorithms): https://youtu.be/ZZuD6iUe3Pc

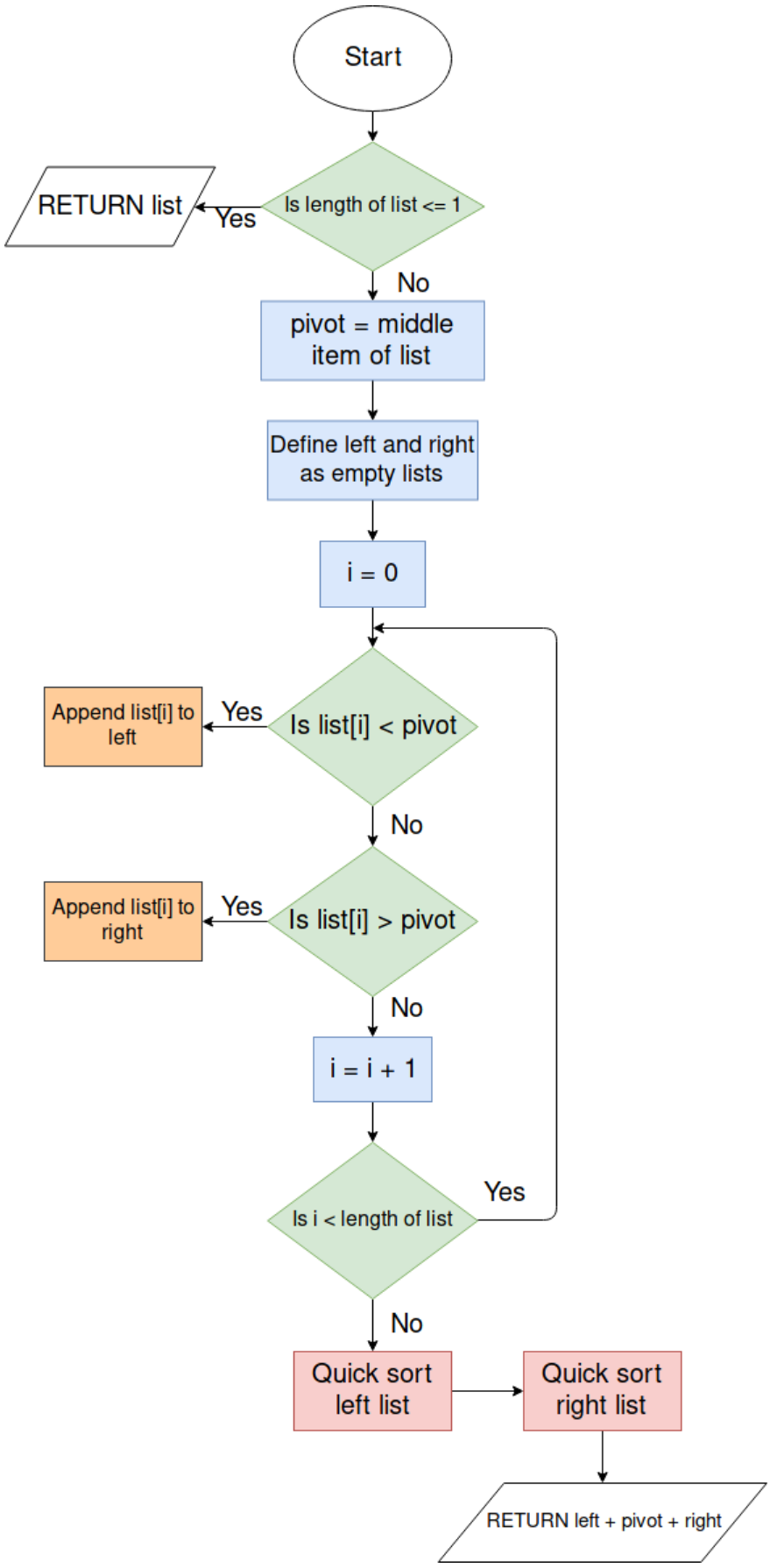
The algorithm goes like this (using a list of items to be sorted):

1. Take the item in the middle of the list. Call this the "pivot".
2. Compare each item either side of the pivot. If the item is bigger than the pivot, add it to a new list called "right", if the item is smaller than the pivot, add the item to a new list called "left".
3. Then repeat this process with the left and right lists (making this algorithm recursive).
4. Once the current left and right lists have been sorted, append the left list and right list with the pivot in the middle.

Here is the pseudocode of the algorithm:

```
function quickSort(list)
    if length(list) <= 1 then
        return list
  end

    left   = []
    middle = []
    right  = []
    pivot  = list[int(length(list)/2)]
    for i = 0 to length(list) do
        if list[i] < pivot then
            left.append(list[i])
        else if list[i] > pivot then
            right.append(list[i])
        else
            middle.append(list[i])
        end
    end

    return quickSort(left)+middle+quickSort(right)
end
```

Here is a flow diagram to represent this:

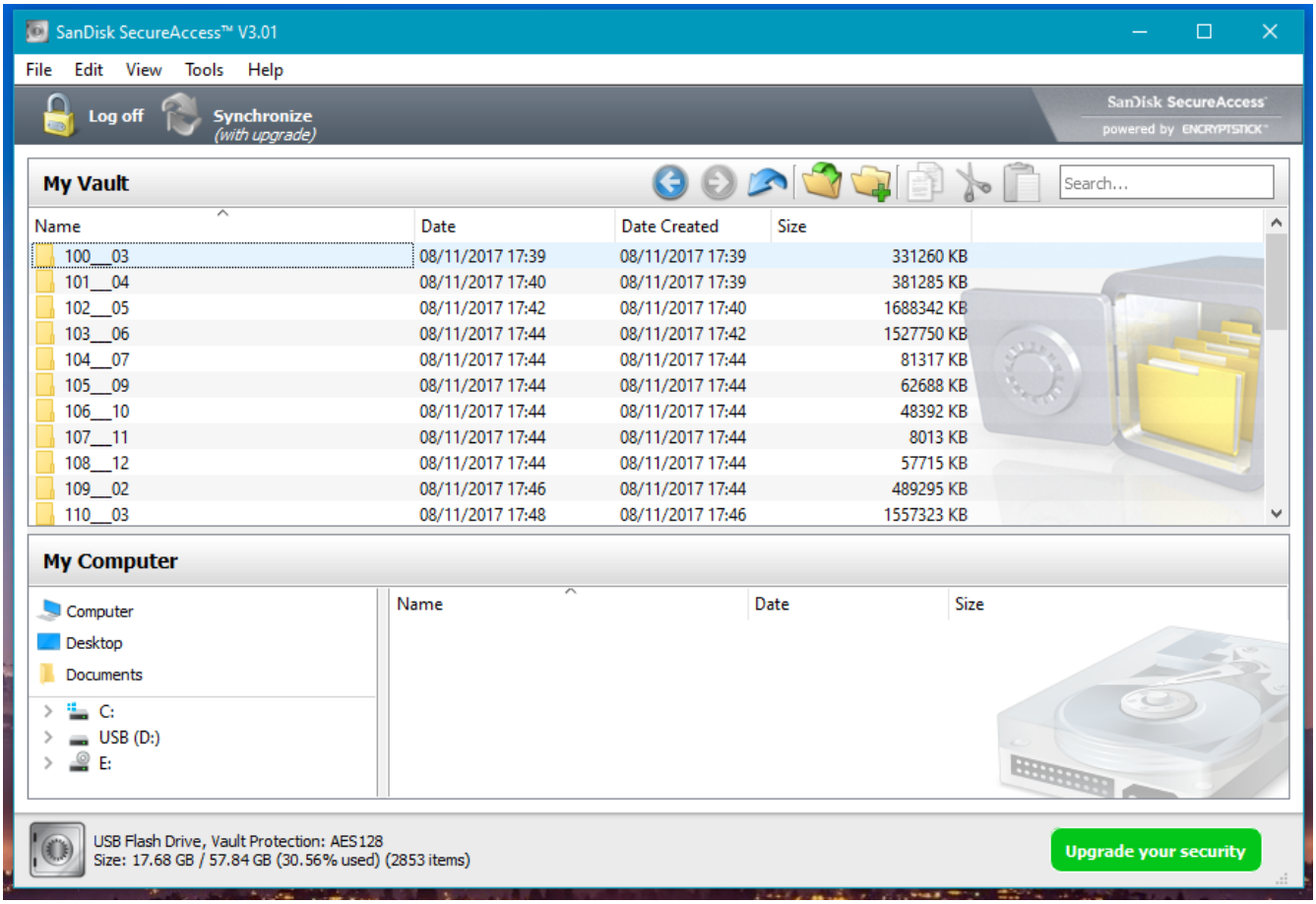

Start
Is length of list <= 1
Yes
RETURN list
No
pivot = middle item of list
Define left and right as empty lists
i = 0
Is list[i] < pivot
Yes
Append list[i] to left
No
Is list[i] > pivot
Yes
Append list[i] to right
No
i = i + 1
Is i < length of list
Yes
No
Quick sort left list
Quick sort right list
RETURN left + pivot + right

UI Research:

For the UI of both apps, I will use Kivy (a Python module) to make both the mobile app and the PC program. I have chosen Kivy because using it on both the app and the main program means that the design will stay consistent, and Kivy does look quite nice "out of the box".

Main Program (on PC):

The main program has to be designed to be easy to use, and actions that are used a lot should be easily accessible. I think I will go for a similar layout to a program that already exists, SanDisk Secure Access:



SanDisk Secure Access did inspire this project, however I do not want to make a carbon copy of it. I will take what SanDisk have done right, and improve the areas they lacked on.

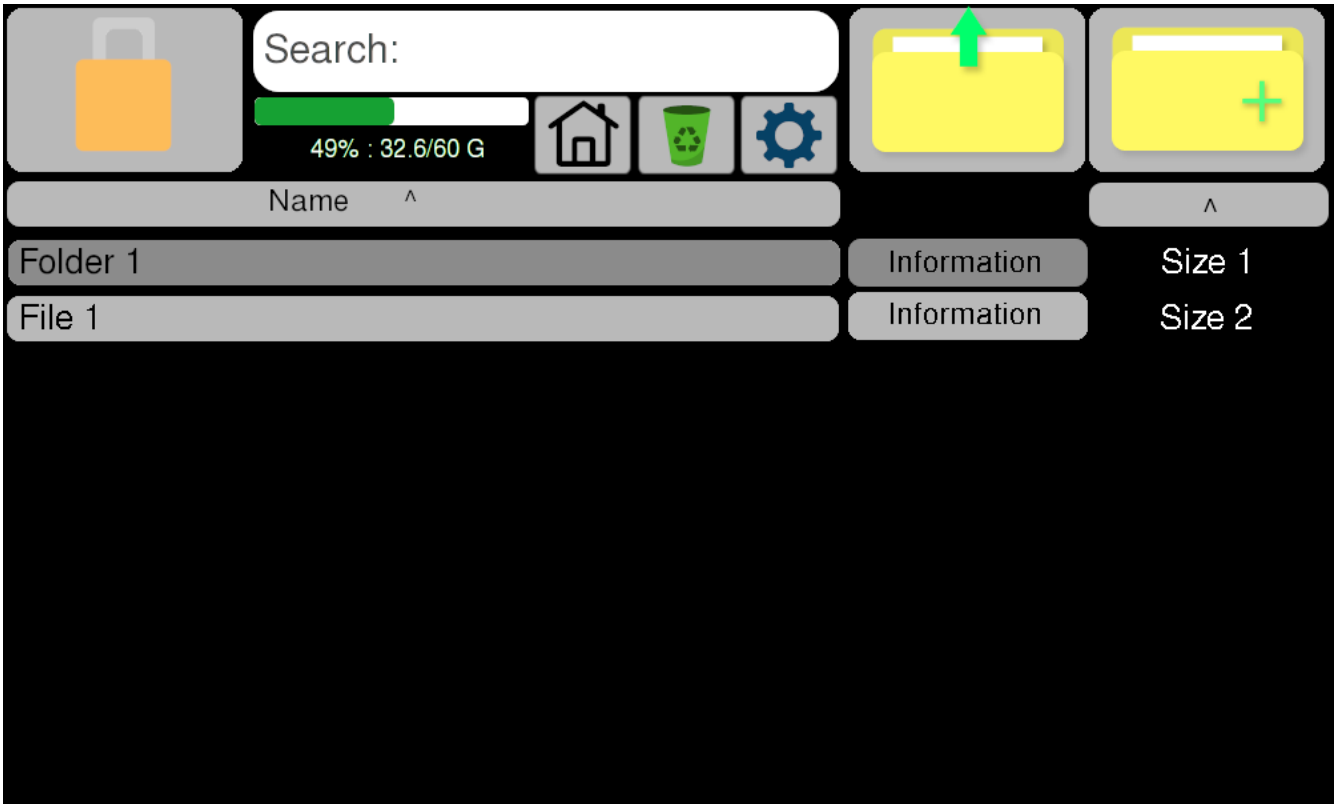
SanDisk did these things right:

- The layout is pretty good because all buttons you would need regularly are available, and it doesn't differ too much in design from the Windows file explorer, so it feels familiar to it's users.
- Shows the user how much space is left on their device.
- Shows useful information about each file.
- The user can easily sort the list of files however they want.
- More options are hidden unless needed regularly.
- Allows the user to search the vault for a file.
- I can easily drag files in and out of the program.

What I think SanDisk did not do too well:

- Looks a bit cluttered with all the extra stuff at the bottom. If I wanted to see other files on my computer I would open my file manager, and if I wanted to add files to the vault I can just drag it in easily.
- Faded pictures in the background are distracting.
- Some buttons are quite small, so may be hard for some users to click.
- Aesthetically alright but could be better.
- Some icons are confusing when first using the program (like the folder with the green arrow inside of it; too much going on).
- Size is displayed in kilobytes, which is alright but is kind of hard to read for files larger than 1 megabyte.

Taking all of these points into consideration, here is a possible design for the UI of my program:



Everything grey is a clickable button. This helps the user distinguish between buttons and information. The most important buttons are large, as they will be used the most. The user can sort by name or size, and can search the entire vault for a search term.

The information button displays more information, such as:

- The time the file (if it is a file) was added to the vault.
- The full directory path from the vault.
- The size of the file/folder.
- The option to delete the file/folder.

The button with the home picture on it takes the user back to the root directory of the vault. The recycling bin button is for the recycling folder, where the files that have been deleted can be either restored or deleted. The cog wheel button is settings, where all the settings are kept. I gave the settings it's separate section to avoid clutter, as most users will probably not need to use it very often.

The user can sort the files by name alphabetically, or they can sort by size. Space remaining on the current device is shown underneath the search bar.

While searching through large folders, the search results should update every so often since it may take a while to search the full file tree.

When using the recycling bin, the program will look exactly the same, but warn the user that they are in the recycling bin "mode", so when they click files, instead of decrypting the file and opening it the file is instead moved back into the vault, recovering it to where it originally came from.

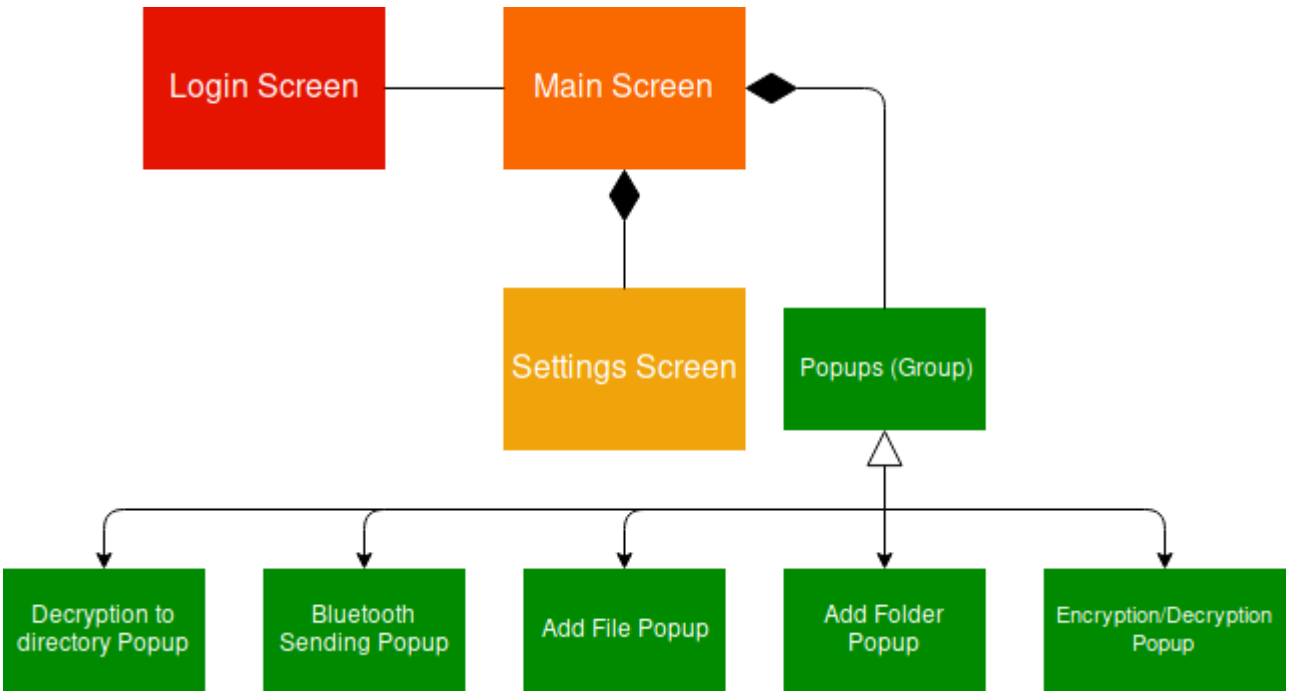
The login screen will have 2 modes:

1. Login without Bluetooth (can't use any Bluetooth functions while logged in).
2. Login with Bluetooth.

I will also make it so that you can easily switch between Bluetooth and non-Bluetooth login, whether that be a button on the login screen, or in the configuration file. Also, when in non-Bluetooth mode, the user will not need to have PyBluez installed, neither will they need Bluetooth on their PC.

When navigating the app, the navigation should be easy and simple so that the user does not get lost. I will have 2 main screens, a login screen and a main screen (to view files and open other functions once logged in), and within the main screen I will have a screen for settings, and a few other popups.

Here is a class diagram to show the relationship between screens and popups:



These are only the custom classes, so regular buttons and labels and such will be left out of this diagram.

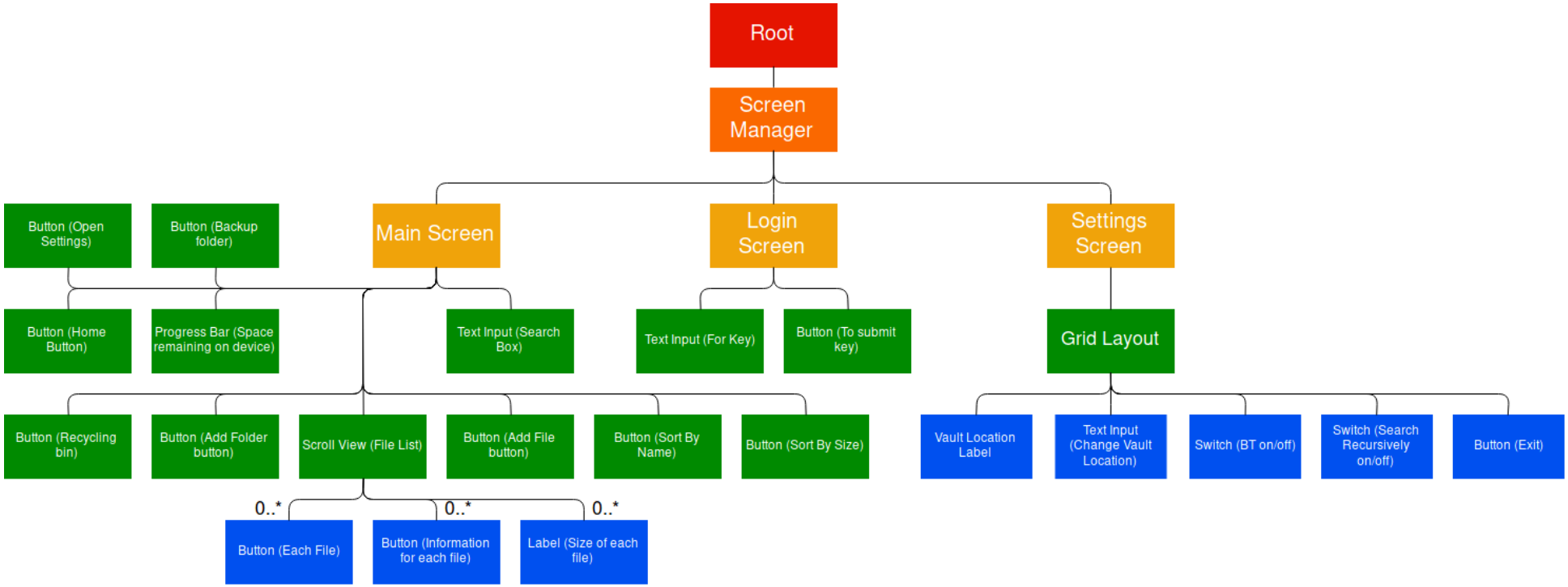
The Encryption/Decryption popup should be opened when the user encrypts/decrypts a file, and should display information including how fast the file is being enc/decrypted (in kb or mb per second), the percentage of the file that has been enc/decrypted so far, and how many items have been done out of the total files to be enc/decrypted. There should also be a progress bar at the bottom, showing the percentage visually.

The Bluetooth sending popup should show the exact same information, but for the current status of the file being sent over Bluetooth.

The add file and add folder popups should both be similar in design, however the add file popup will let the user encrypt a file or folder to the vault, while the add folder popup will allow the user to create a new folder within the vault.

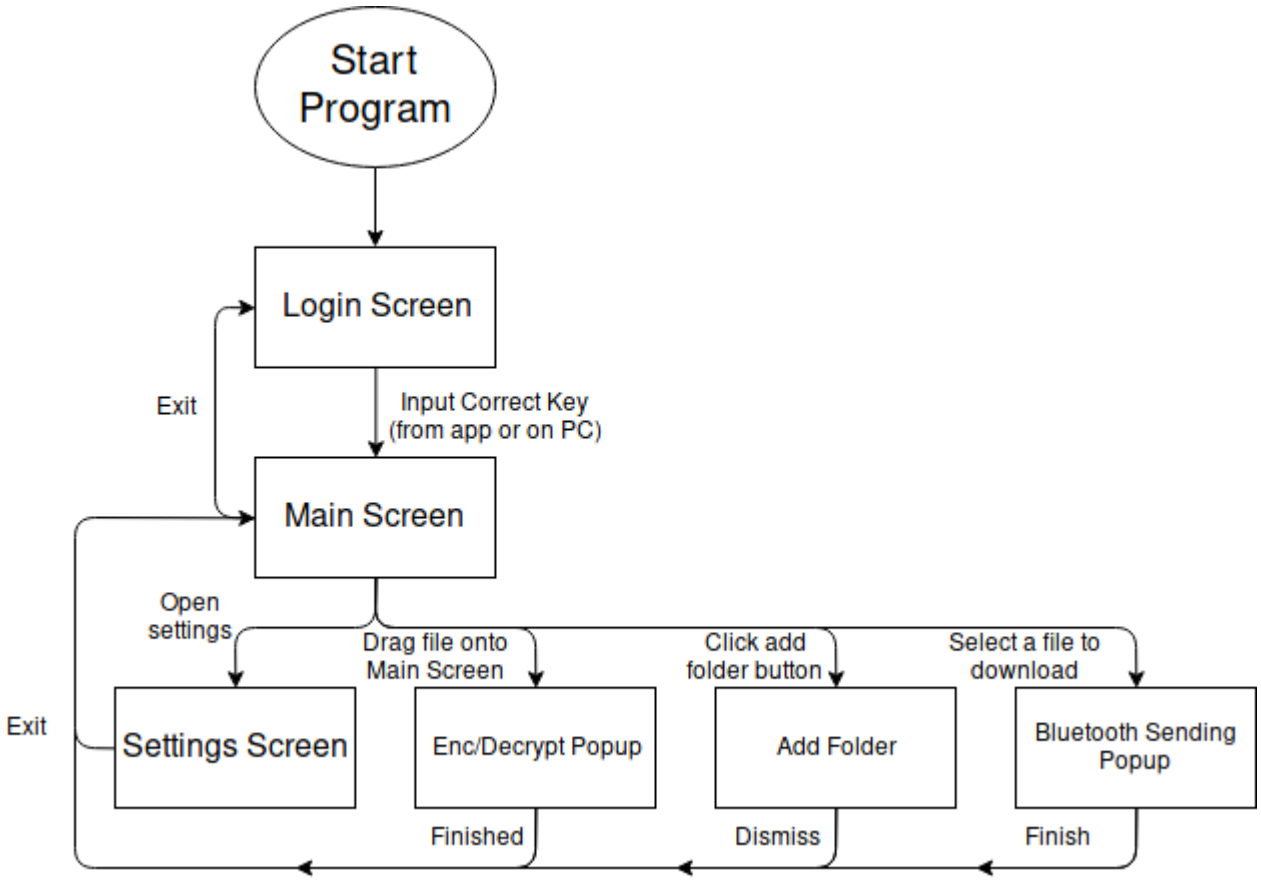
Popups are designed for one purpose only, and are usually used briefly before they are closed again. Screens will be used throughout the program, acting as the base of the GUI, where child widgets can be added to the screen, such as buttons, text inputs and views (such as scroll views). The screens will inherit from Kivy's Screen class, and the popups will inherit from Kivy's Popup class. The screens get managed by a ScreenManager, also a Kivy widget. The ScreenManager is then added to the app's root widget (the base widget of an app).

A hierarchy diagram for the entire GUI would look something like this (since Popups can be added and removed to any widget when needed, I will not include them in this diagram):


Root
Screen Manager
Main Screen
Login Screen
Settings Screen
Button (Open Settings)
Button (Backup folder)
Button (Home Button)
Progress Bar (Space remaining on device)
Text Input (Search Box)
Text Input (For Key)
Button (To submit key)
Grid Layout
Button (Recycling bin)
Button (Add Folder button)
Scroll View (File List)
Button (Add File button)
Button (Sort By Name)
Button (Sort By Size)
Vault Location Label
Text Input (Change Vault Location)
Switch (BT on/off)
Switch (Search Recursively on/off)
Button (Exit)
0..*
0..*
0..*
Button (Each File)
Button (Information for each file)
Label (Size of each file)

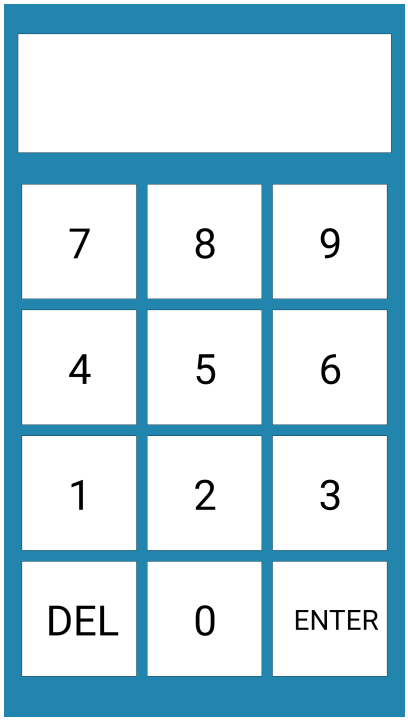
Each layer has it's own colour, since I couldn't think of a better way of making this clear without making the image extremely wide. "0..*" means 0 to many of this widget can exist at any time. This shows all of the widgets that will be on each screen at all times (unless obstructed by a popup) as default.

Here is a top-down view of how the GUI will flow while the user is using the program:



The App:

The app's UI design should be very simple, as I do not need to add much. All it needs to be is a number pad with a display, an enter button and a screen to have open while you are connected to the PC, and a file browser similar to the one on the PC app. Here is a prototype I made in Processing (A java based "software sketchbook):



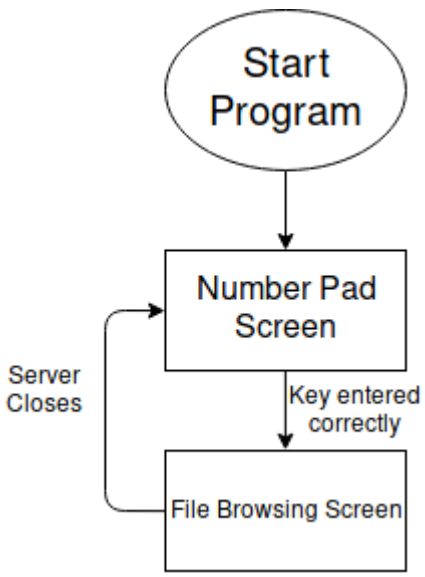
It is very minimal, as I decided to keep it as minimal as possible so that the user doesn't get confused, and to keep clutter at a minimum.

Once the vault is unlocked, the user should be given the option to browse files in the vault from their phone, and select files to download, or instead just minimise the app and continue using their phone. The vault should only close once the user has exited the app, rather than when they minimise the app.

The user should be able to browse the folders independently from the computer program (so both programs can be looking at different folders), browsing the files should be a seamless experience, and when searching for files, the searching work should be done on the computer so that precious phone battery is not wasted, and also because it is quicker in general to just send the search results to the mobile once they are generated.

The app should have a pin-code screen and a file browsing screen. The pin-code screen should only be used when the PC program is logged out.

Here is a top-down diagram of how the GUI will flow while the user is using the program:



The program as a whole:

My program will handle a fair amount of data, so here is a IPSO (Input, Processing, Storage, Output) chart to simplify it a little:

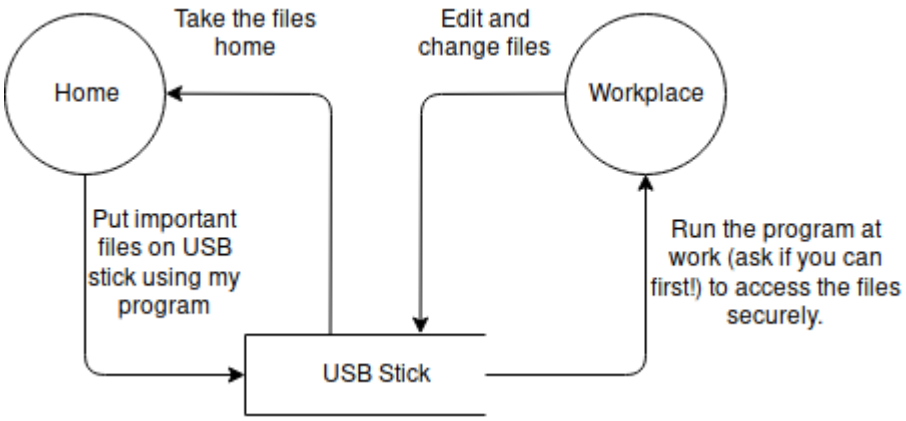
IPSO	Program Section	Item
Input	Login	Key (From user input). Vault directory path. Files in the Vault (for checking the key).
	File Browser (Main Screen)	Vault directory path. Recycling folder path (for when files are deleted). The key (for displaying encrypted file names).
	Search Bar (Main Screen)	Search item entered by user.
	Settings	Configuration file path. Current settings.
	Encryption/Decryption	The file path of the file that is desired to be enc/decrypted. The path to write the new data to. The key.
	Add Folder Popup	The name of the new folder to be created.
	Add File Popup	The path of the file to be encrypted to the vault.
	Recycling bin folder	Recycling folder path. Where each file came from originally.
Processing	Login	Decrypt the first block of the first file you find in the Vault, and check that it is equal to the key entered.
	File Browser (Main Screen)	Getting the sizes of each file. Sorting the files by name or size. Decrypting files when files are clicked. Encrypting files when files/folders are dragged into the window, or if a file/folder is added via the add file popup. Changing directory when a folder is clicked.
	Search Bar (Main Screen)	Search recursively for the file/folder in the Vault, or if recursive search is disabled in settings just search the current directory that the file browser is in.

	Settings	Change settings in the configuration file when changed in the program.
	Encryption/Decryption	Encrypt/Decrypt the file given using the key given.
	Add Folder Popup	Create the new folder in the current directory of the file browser.
	Recycling Bin Folder	Move files selected to original position.
Storage	File Browser (Main Screen)	Read the current files in the current directory that the file path is in.
	Settings	Read from the configuration file, and write to the configuration file when settings are changed.
	Add Folder Popup	Make new directory in the current directory the file browser is in.
	Encryption/Decryption	Read data from the file to be enc/decrypted, and write the enc/decrypted data to the location specified.
	Recycling Bin Folder	Read the file names of the files in the recycling bin.
Output	Login	Change the screen to Main Screen if the key is correct, otherwise create a Popup telling the user that the key is incorrect.
	File Browser (Main Screen)	Display the files in the Vault sorted how the user has specified, along with the size of each file, and a more information button.
	Search Bar	Return the list of closest matches to the search item given.
	Settings	Edit changes to file, and return values of each setting to the main program.
	Add File Popup	Pass the file path of the file to be added to the encryption function, with the path in the Vault where the new data should be written to.

There are many different use cases for my program. Some people may want to travel with the data, some people may just want to use it on one computer. In this section I will outline different ways I intend my program to be used.

Using a USB stick:

People who want to take the data with them to other places, a USB stick is a good idea. All the user has to do is download my program, put it on the USB stick and set the vault directory as a directory on the USB stick. No more setup should be needed. The program should be able to run on Windows, MacOS and Linux so using the USB on most devices should not be an issue. Here is a data flow diagram showing how the user may handle the data:

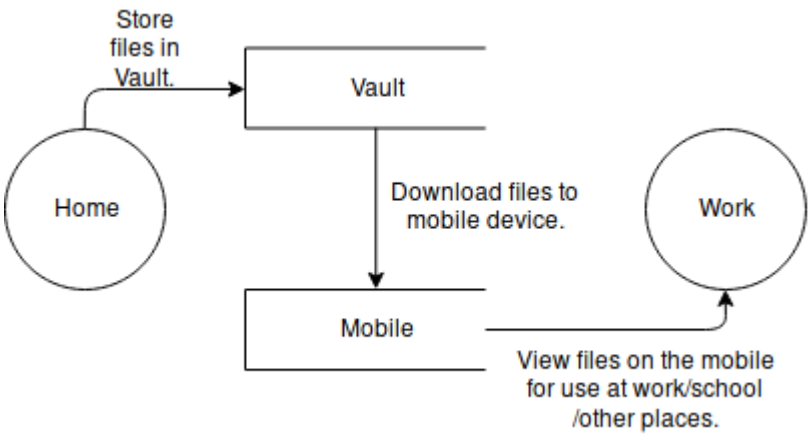


Storing the files at home:

People who may not need to travel as much with their data may just want to store their files at home, however if they want to take files to work/other places I will try to make it as easy as possible to do so.

The user should be able to decrypt the files they need to a folder (possibly on a USB stick), or download files from the Vault to their mobile device. This is worse than just using the whole app on the USB stick as mentioned in the last section, as the files will not be encrypted once they are in the folder or downloaded onto the mobile device. It is not recommended to do this if you want to edit the files while away from home, unless you can edit it on your device, however if not you may as well just put the files onto a USB stick.

A data flow diagram for this use case would look something like this:



If you wanted to edit the files at work without putting the entire program on a USB, you could instead decrypt the file and put it on a USB, take it to work, edit the file, go home and then encrypt it back into the vault, however the file is not encrypted.

Technical Solution

All intensive AES and BLAKE are written in Go, while everything else is written in Python, however the sorts are Cythonized (Python that has been compiled to a C shared object, using a mix of static variables and dynamic variables). Python communicates with Go using stdin and stdout pipes. SHA is written in Python because it is only needed a couple of times during the program, and only ever has to hash small data, so it does not need to be as fast as possible.

File Structure:

Here is the file structure of the code:

```
code
├── mobile
│   ├── btShared.py
│   ├── buildozer.spec
│   ├── fileSelectionScreen.py
│   ├── main.py
│   ├── mainScreen.py
│   ├── pad.kv
│   ├── padScreen.py
│   └── SHA.py
└── python-go
    ├── AES
    │   ├── AES
    │   ├── build.sh
    │   ├── main.go
    │   ├── src
    │   │   ├── AES
    │   │   │   ├── AEScheckKey
    │   │   │   │   └── aesCheckKey.go
    │   │   │   ├── AESfiles
    │   │   │   │   ├── aesFiles.go
    │   │   │   │   └── aesFiles_test.go
    │   │   │   ├── aes.go
    │   │   │   ├── AESstring
    │   │   │   │   └── aesString.go
    │   │   │   └── aes_test.go
    │   │   └── sorts
    │   │       └── sorts.go
    │   ├── testAES.sh
    │   └── testBenchAES.sh
    ├── AESWin.exe
    ├── BLAKE
    │   ├── BLAKE
    │   ├── BLAKE.test
    │   ├── build.sh
    │   ├── main.go
    │   ├── src
    │   │   └── BLAKE
    │   │       ├── blake.go
    │   │       ├── blake_test.go
    │   │       └── checksum.go
    │   ├── testBenchBLAKE.sh
    │   └── testBLAKE.sh
    ├── BLAKEWin.exe
    ├── config.cfg
    ├── configOperations.py
    ├── fileClass.py
    ├── kivyStuff
    │   ├── kvFiles
    │   │   ├── loginScBT.kv
    │   │   ├── loginSc.kv
```

```
    │   │   ├── mainScButtons.kv
    │   │   ├── mainSc.kv
    │   │   ├── mainScLabels.kv
    │   │   ├── mainScPops.kv
    │   │   └── settingsSc.kv
    │   ├── loginClass.py
    │   ├── mainBtnsNew.py
    │   ├── mainBtns.py
    │   ├── mainScClass.py
    │   ├── mainSmallPops.py
    │   ├── settingsScreen.py
    │   └── ui.py
    ├── SHA.py
    └── start.py
```

I have taken out all of the `__pycache__` folders that Python generates.

This is the output of `tree code` in my projects' `code` directory. You can find my project at https://github.com/Lytchett-Minster/nea-12ColcloughJ.

The `code` directory, surprisingly, holds the code for my project. Inside is one folder for the mobile app (`mobile`), and one folder for the PC app (`python-go`). The PC app is started by running `start.py`. `start.py` imports `kivyStuff/ui.py` and runs it. This means that any Python files in `kivyStuff` can import any of the files that are in the same directory as `start.py` (`python-go`), and any Python files in `kivyStuff`. It also makes it easier to find the start script, as it isn't as buried.

The `assets` directory holds all the images needed for the GUI of the PC program (the images on the buttons). Here is a `tree` of the `assets` folder:

```
assets/
├── exports
│   ├── addFile.png
│   ├── backUpFolder.png
│   ├── folder.png
│   ├── home.png
│   ├── info.png
│   ├── padlock.png
│   ├── recycling.png
│   ├── refresh-icon.png
│   ├── remove file.png
│   ├── search.png
│   └── settings.png
└── psd
    ├── add file.psd
    ├── back up folder.psd
    ├── folder.psd
    ├── info.svg
    ├── padlock.psd
    └── remove file.psd

2 directories, 17 files
```

Some images are taken from the internet, so they do not have `.psd` files (photoshop files).

Configuration of the program:

The program can be configured via the configuration file `config.cfg` located at `code/python-go/config.cfg`, or instead if the user is on Linux, then they can copy the configuration file into `~/.config/FileMate/config`, which is the standard area in Linux where configuration files are stored (and by the way, I called the program "File Mate" because it was the first thing that popped into my head).

The configuration file is edited by the settings menu in the main screen of the app, however if something goes horribly wrong, the user can edit it themselves easily.

The layout of the configuration file looks something like this:

```
vaultDir--<file path here>
searchRecursively--<True / False>
bluetooth--<True / False>
```

`vaultDir` is the path to the Vault that you would like to use to store all encrypted files and folders. The file path can be done as an absolute path from the root of the file system (`/home/user/folder/`, or `C:\\Users\\user\\folder\\`), or can instead be done relatively from the folder that the program is in. For example, if the folder the code is stored in is `/home/josh/nea-12ColcloughJ/code/python-go/`, then it would remove `nea12-ColcloughJ/code/python-go/` from the file path to get `/home/josh/`, then adds the file path specified in the config file. If the relative path specified was `folder/vault`, then the full path would become `/home/josh/folder/vault/`.

`searchRecursively` determines if the program should search for items recursively, as this may take a long time if you have a lot of files, and some people may just want to search within the current folder.

`bluetooth` determines the default Login Screen to start when the program starts.

I have used `--` to separate the setting name from it's set value, as it does not appear at the start of file paths, and should not be needed much in any settings that could possibly be added in the future.

To change the configuration of the program from within the program, `configOperations.py` located at `code/python-go/configOperations.py` has a few functions that can get the configured settings, and write new ones.

Here is the content of `configOperations.py`:

```
from os import path as osPath
from os import listdir, makedirs
from sys import platform
from tempfile import gettempdir

def findConfigFile(startDir, fileSep):
    config = None
    if fileSep == "/":
        try:
            home = listdir(osPath.expanduser("~/.config/FileMate/"))
        except:
            print("No config file in .config")
        else:
            if "config" in home:
                config = osPath.expanduser("~/.config/FileMate/config")

    if config == None:
        try:
            configFile = open(startDir+"config.cfg", "r")
        except Exception as e:
            raise FildNotFoundError("No config file found. Refer to the README if you need help.")
        else:
            configFile.close()
            config = startDir+"config.cfg"

    return config


def readConfigFile(configLocation=None, lineNumToRead=None, fSep=None, startDir=None):
    if fSep == None:
        fSep = getFileSep()
    if configLocation == None:
```

```
        fSep = getFileSep()
        configLocation = findConfigFile(getStartDir(fSep)[0], fSep)

    configFile = open(configLocation, "r")
    if lineNumToRead == None:
        for line in configFile:
            lineSplit = line.split("--")
            lineSplit[1] = lineSplit[1].replace("\n", "")
            if lineSplit[0] == "vaultDir":
                path = lineSplit[1]
            elif lineSplit[0] == "searchRecursively":
                if lineSplit[1] == "True":
                    recurse = True
                elif lineSplit[1] == "False":
                    recurse = False
                else:
                    raise ValueError("Recursive search settings not set correctly in config file: Not True or False.")
            elif lineSplit[0] == "bluetooth":
                if lineSplit[1] == "True":
                    bt = True
                elif lineSplit[1] == "False":
                    bt = False
                else:
                    raise ValueError("Bluetooth not configured correctly in config file: Not True or False.")

        configFile.close()

        if path[0] != fSep:  # If vaultDir done relatively, then get path relative to the folder the program is in, rather than searching the folder.
            if startDir == None:
                startDir = osPath.dirname(osPath.realpath(__file__))+fSep
            startDir = startDir.split(fSep)
            path = fSep.join(startDir[:-4])+fSep+path # Removes "" and nea-12ColcloughJ/code/python-go folder names from list, then adds the Vault folder name to the end.
            if path[-1] != fSep:
                path += fSep # End with file separator

        return path, recurse, bt

    else:
        lineSplit = configFile.readlines()[lineNumToRead].split("--")
        lineSplit[1] = lineSplit[1].replace("\n", "")
        return lineSplit[1]

def getFileSep():
    if platform.startswith("win32"): # Find out what operating system is running.
        return "\\"
    else:
        return "/"

def getStartDir(fileSep=None):
    if fileSep == None:
        fileSep = getFileSep()
    startDir = osPath.dirname(osPath.realpath(__file__))+fileSep
    tempDir = startDir.split(fileSep)
    for i in range(2):
        del tempDir[-2]
    return startDir, fileSep.join(tempDir)+fileSep+"assets"+fileSep+"exports"+fileSep


def editConfTerm(term, newContent, config):  # Edits a given term in the config.cfg file.
    with open(config, "r") as conf:
        confContent = conf.readlines()

    for i in range(len(confContent)):
        a = confContent[i].split("--")
        if term == a[0]:
            a[1] = newContent+"\n"
```

```
            confContent[i] = "--".join(a)

    with open(config, "w") as confW:
        confW.writelines(confContent)

def dirInputValid(inp, fileSep):
    valid = bool((inp[0] == fileSep) and ("\n" not in inp))       #If it starts with the file separator and doesn't contain any new lines, then it is valid for now.
    inp = inp.split(fileSep)
    focusIsSlash = False
    for item in inp:            #Checks for multiple file separators next to each other, as that would be an invalid folder name.
        if item == "":
            if focusIsSlash:
                valid = False
            focusIsSlash = True
        else:
            focusIsSlash = False
    return valid

def changeVaultLoc(inp, fileSep, config):      #Sorts out the UI while the vault location is changed.
    if inp != "":
        if dirInputValid(inp, fileSep):
            if osPath.exists(inp) and osPath.isdir(inp):
                editConfTerm("vaultDir", inp, config)
            else:
                makedirs(inp)
                if inp[-1] != fileSep:
                    inp += fileSep
                editConfTerm("vaultDir", inp, config)

            return True

    return False


def runConfigOperations():
    fileSep = getFileSep()
    osTemp = gettempdir()+fileSep #From tempfile module
    # Get config settings.
    startDir, sharedAssets = getStartDir(fileSep)

    configLoc = findConfigFile(startDir, fileSep)
    path, recurse, bt = readConfigFile(configLoc, fSep=fileSep, startDir=startDir)
    return fileSep, osTemp, startDir, sharedAssets, path, recurse, bt, configLoc  # 8 Outputs in total.
```

`findConfigFile` checks for the configuration file in `~/.config/FileMate/`, and if it does not exist, checks for it in `code/python-go/config.cfg`. Once the configuration file has been found, it returns the path to the file.

`readConfigFile` reads the configuration file, and gets each configured option and returns their value. It can also return the value of a specific line in the config file.

`getFileSep` just gets the file separator of the current system. For Windows this is `\\`, but for MacOS and Linux this is `/`.

`getStartDir` gets the path of the current file (located in `code/python-go/`), and the path to the `assets` directory, which is used for the images on the buttons.

`editConfTerm` edits a term in the configuration file. If the term was "bluetooth" then it would find the line that starts with "bluetooth", and change the data after the `--` with the new data specified.

`dirInputValid` checks that a given input is a valid file path (e.g no "/" in a row). This is in here because it is used all over the program, and is used for changing the directory of the Vault.

`changeVaultLoc` changes the location of the Vault using `dirInputValid` to check the input, and `editConfTerm` to update the configuration file.

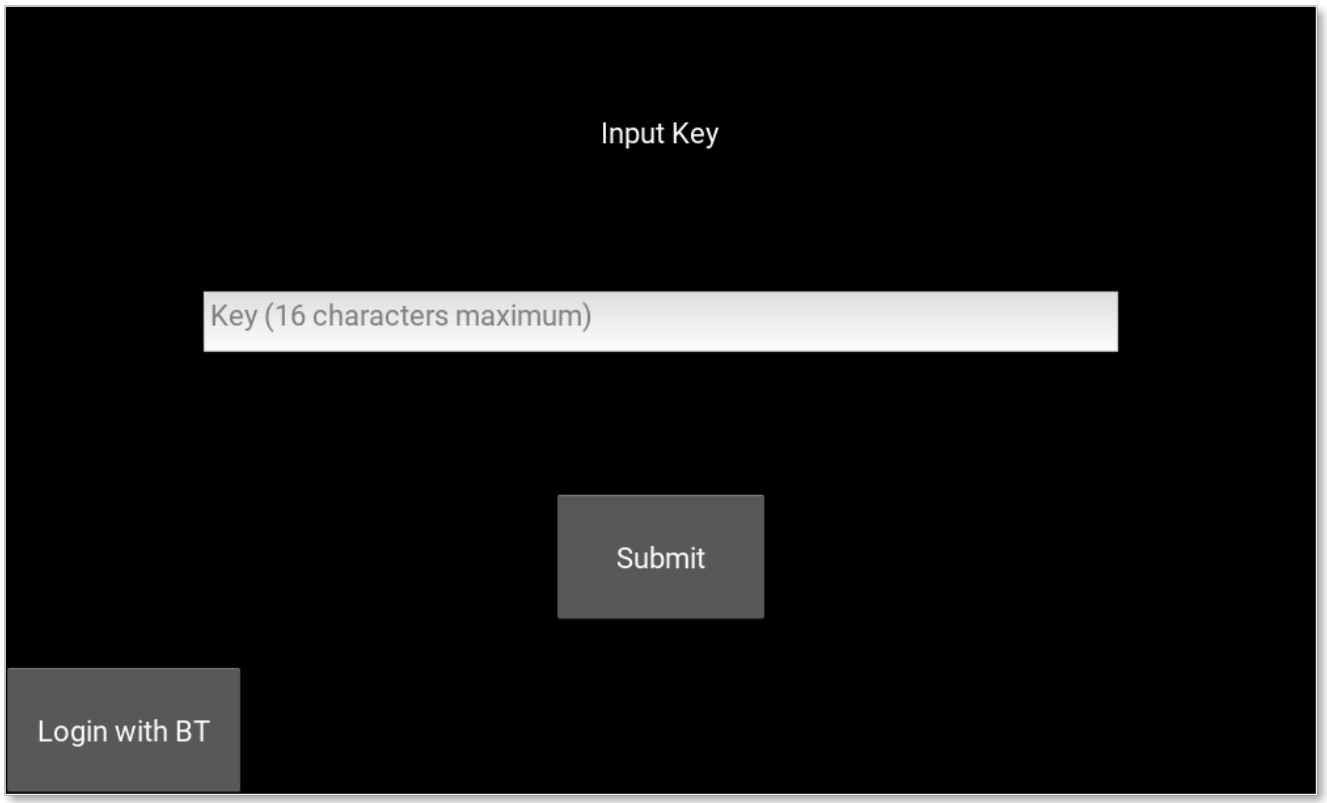
`runConfigOperations` runs all of the operations required for when the program is started, and returns the variables needed by the rest of the program. This is done in `ui.py`, which loads the configuration file, and starts the program.

The PC App GUI:

I will go through the visuals first, and then move onto the code.

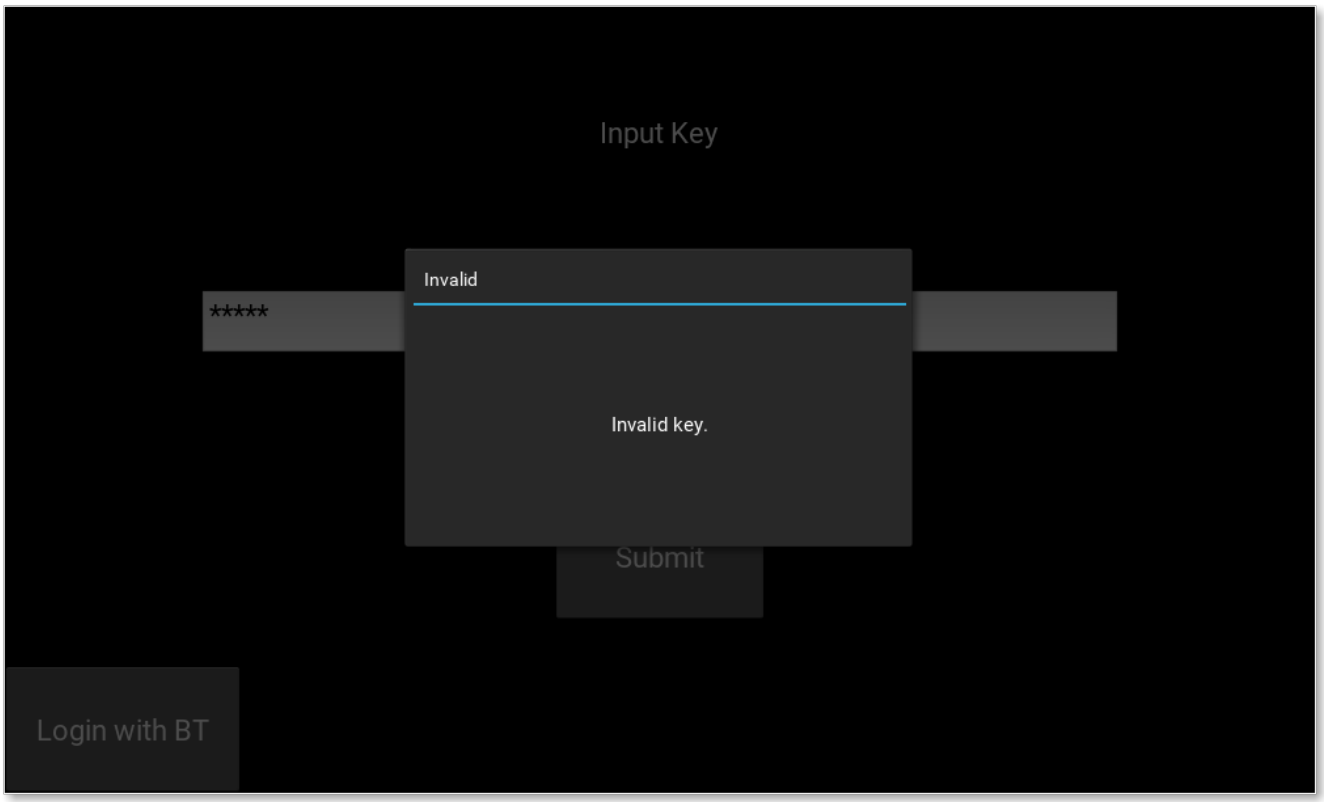
Login Screen

Here is an image of the Login Screen:

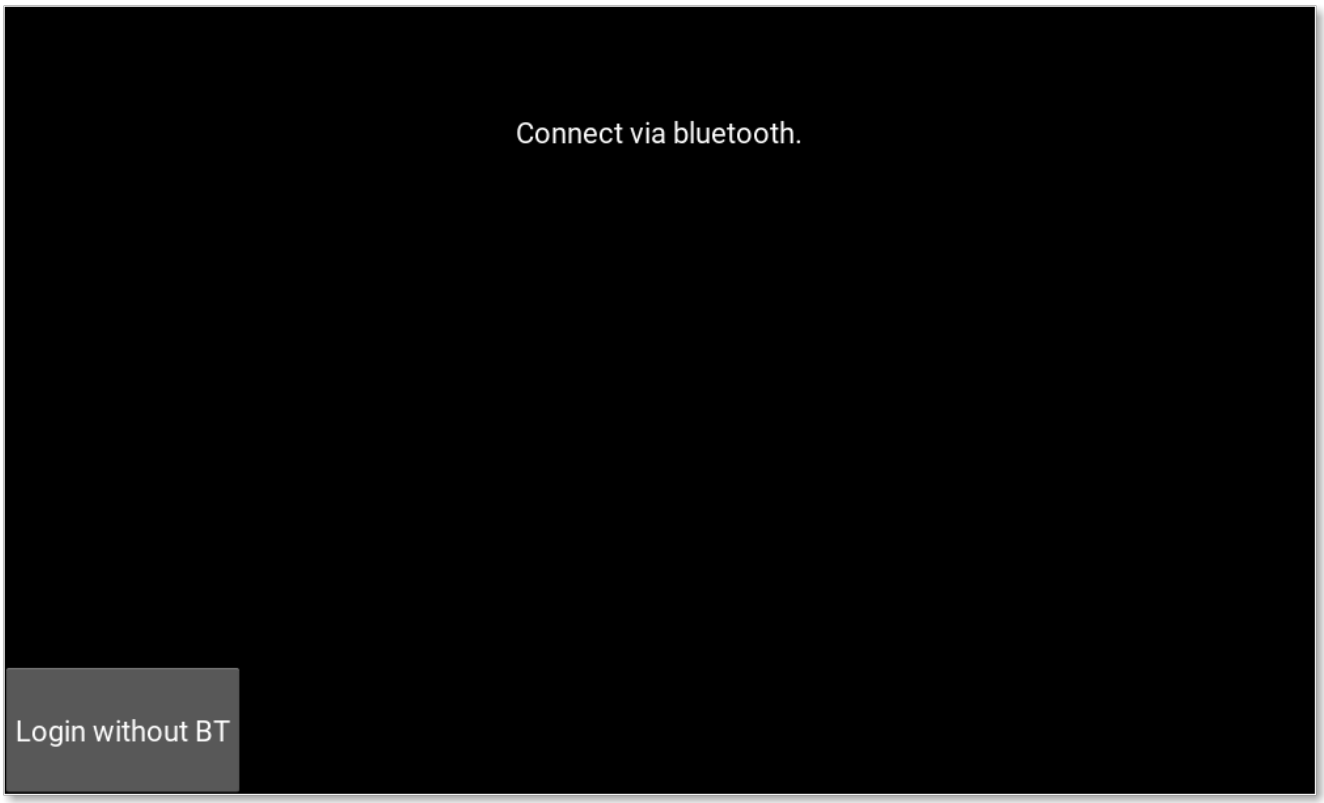


It consists of a key entry text input, a "Submit" button and a button to switch between logging in with Bluetooth and without Bluetooth.

When you enter an incorrect key, a popup tells the user the key is invalid:

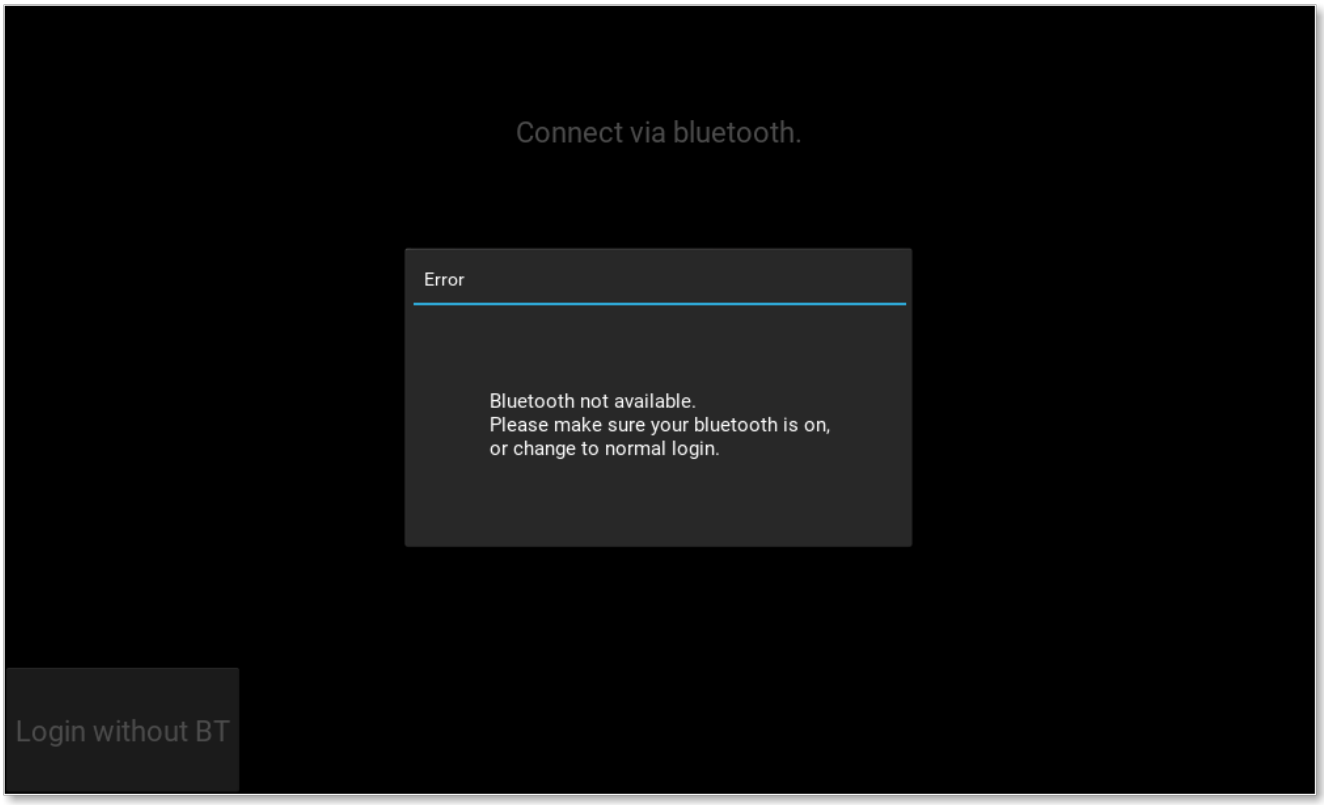


The Bluetooth login screen can be accessed by clicking the "Login with BT" button, changing the configuration file, or changing the settings once logged in. Here is an image of the Login Screen with Bluetooth:



I have tried to keep it as simple and as clutter-free as possible. When a user connects to the BT server, the address of the device connected appears in the middle of the screen, to let the user know that they have connected. The user then proceeds to enter the pin code on the app.

If Bluetooth is not available, or can't start, then a popup appears warning the user that they cannot use the Bluetooth login until Bluetooth becomes available, or they can instead login with regular login:

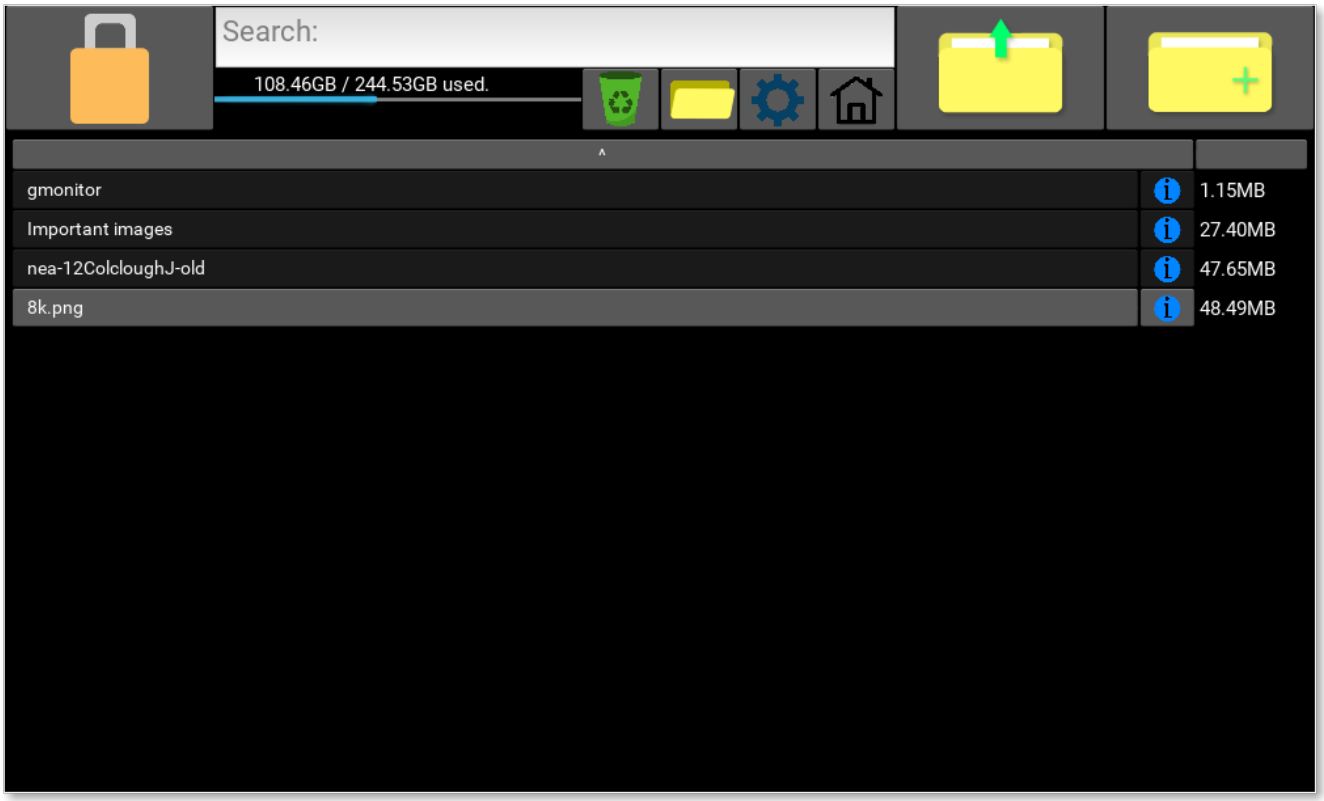


They can then click away from the popup to dismiss it, and do what they want from there.

Once the key has been entered correctly, the screen changes to the Main Screen.

Main Screen

Here is an image of the Main Screen:



I tried to keep it as similar as possible to the design in the **Design** section, however I had to add a button to add a new folder, as I realised that was a necessity. Also, instead of writing "Information" on the information button, I made an image to be put over the button instead, as it looks a bit better. All the buttons in the GUI are darker than in the design, but that is fine.

It is easy to distinguish between files and folders, and doesn't feel cluttered. The progress bar showing the amount of space used on the current storage device, in my opinion looks better than in the design. It is easy to sort by name (click the button above all the files) or to sort by size (click the button above all of the sizes).

When you click a folder, you change directory to that folder, and the contents of that folder are displayed on the screen. If it is a file, it is decrypted to `<systems_temp_folder>/FileMate/<fileName>`, where it is then opened with the system's default application and can be renamed and edited.

When you click to add a new folder, you get the exact same popup as in the **Information Tab** when you decrypt an item to a location.

The Information Tab

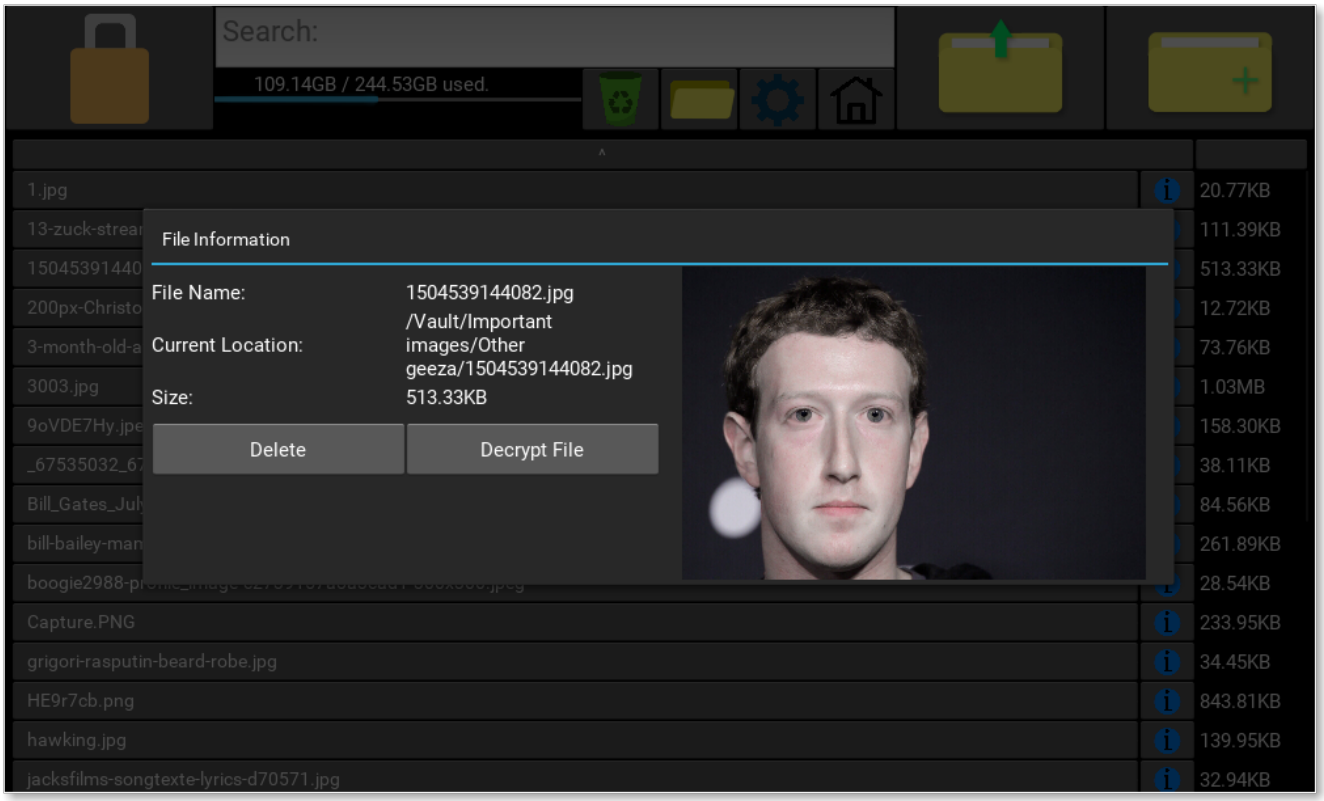
The information tab shows you information about the file:

- The location the file/folder is relative to the Vault.
- The size of the file/folder.
- A thumbnail of the image, if it is a file not a folder, and if the file is an image.

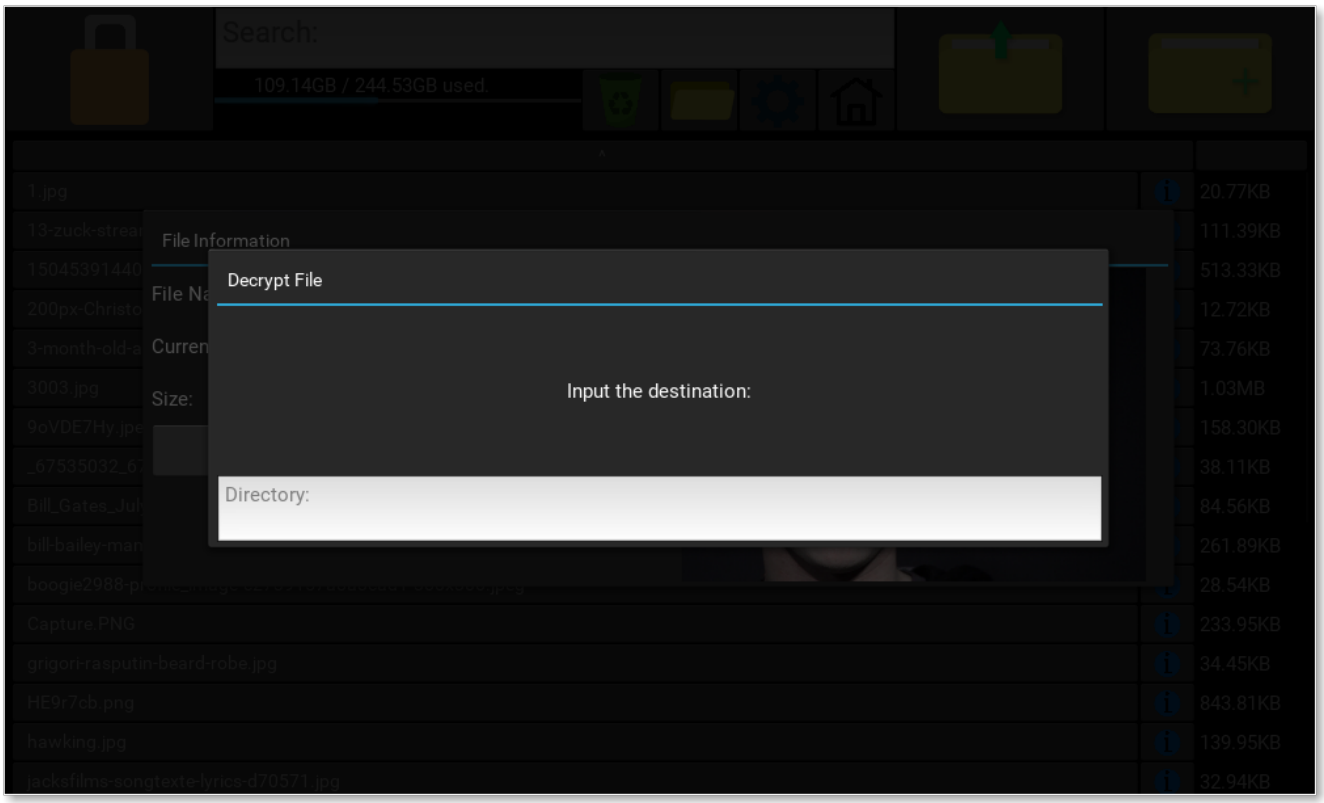
You also have a few options within the information tab to chose from:

- Delete the file/folder.
- Decrypt the file/folder to a specified location.

Here is a screenshot of the information popup:



When you click decrypt file, you are greeted with another popup asking where you would like the file to go:



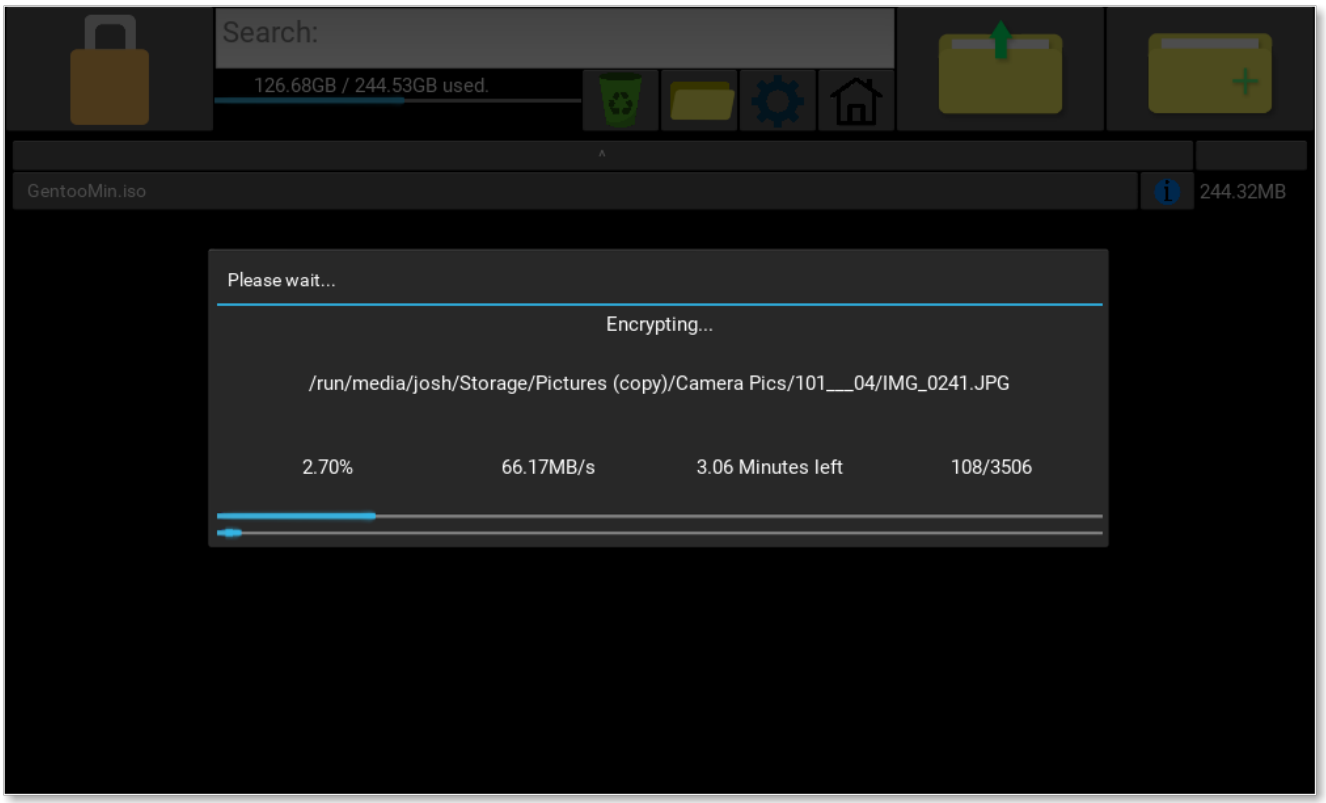
Once you input a correct directory name, it decrypts the file to that directory. If the path ends with the file separator (e.g "/"), then it will be decrypted to that folder with it's original name. If the path does not, then it is saved to that exact location, with that new name. For example, if I wanted to decrypt a file called `Zuckerburg.png`, then I put in `/home/josh/zucc.png`, then it would decrypt the file and would be saved as `zucc.png`. If I instead put in `/home/josh/`, then it would be saved to `/home/josh/Zuckerburg.png`.

When you delete the file, the file moves to the recycling folder located in `Vault/.$recycling` (relative to the vault). To recover the file, you click the recycling bin button, and you get put in the recycling folder (with a popup warning the user they are in the recycling bin). Now when you click items in the recycling folder, instead of opening them and decrypting it, it moves the file back into the vault. You can still view information about the file like usuall, and search for items. To leave the recycling bin, you click the folder up button on the top right, or the home key below the search bar.

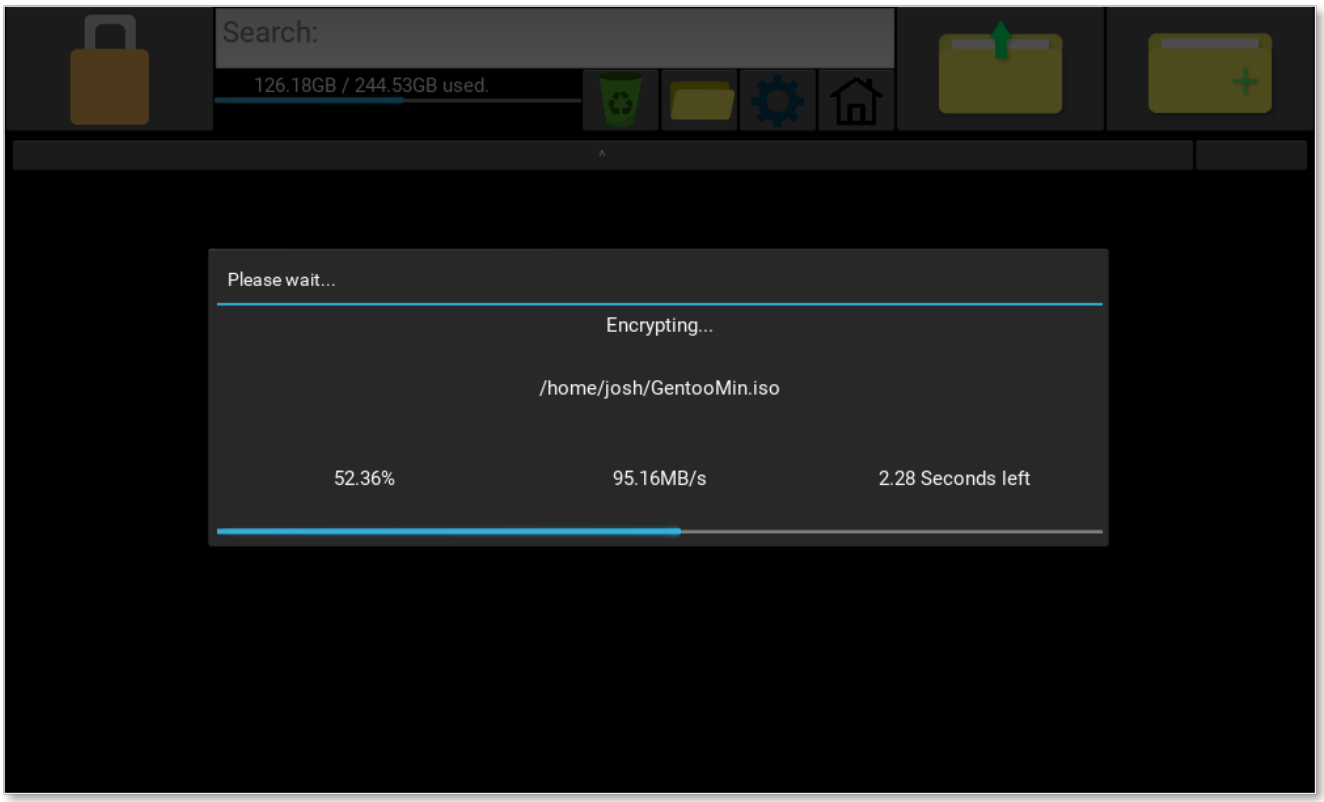
Encryption and Decryption Status

When decrypting a file, a popup opens showing you the percentage of the way through you are in the file and the current speed of decryption. When decrypting a folder, the same information is shown, however there are two progress bars. One for the current file being decrypted, and one for the total progress of decrypting the folder. Also, you are shown how many files in the folder have been encrypted out of the total. This is the exact same for encryption too by the way.

Here is an image of a folder being encrypted (12GB):



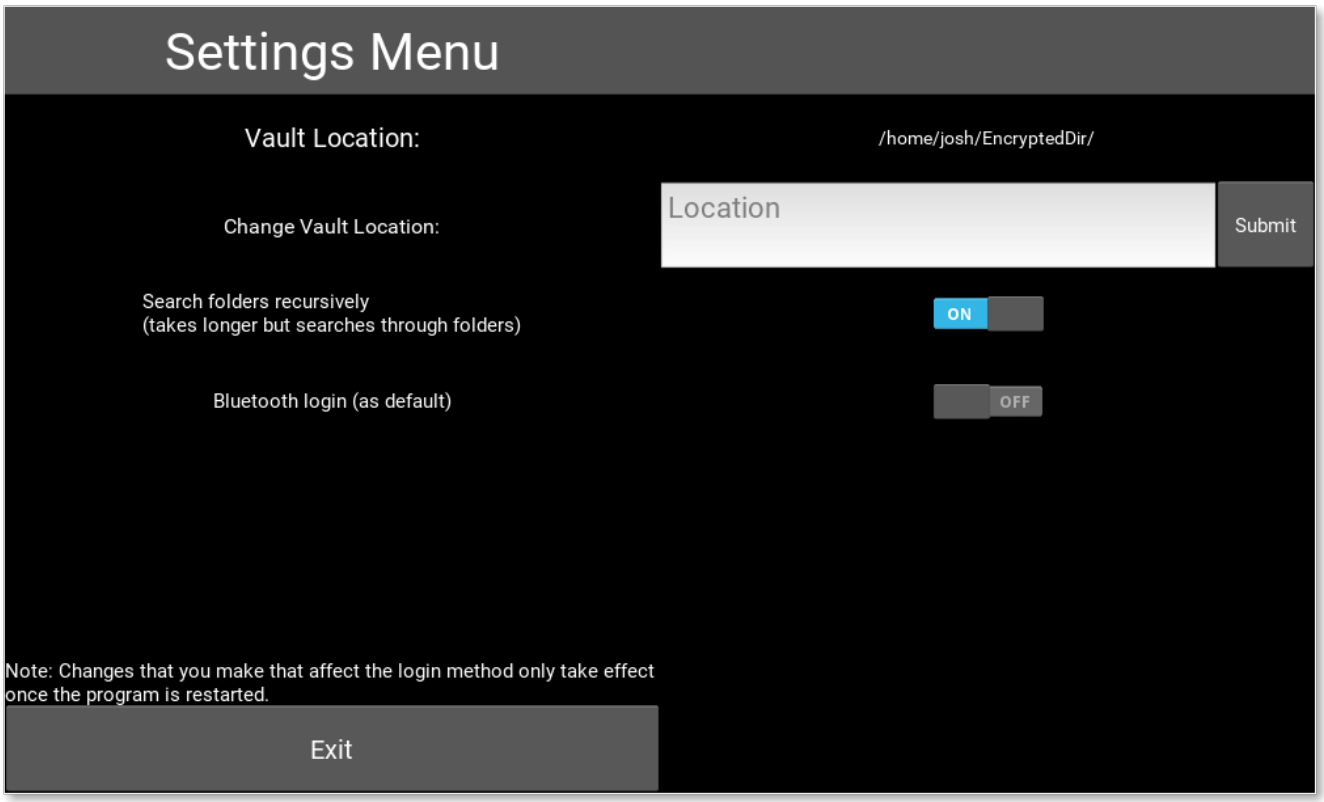
Here is an image of a file being encrypted (244 MB):



As I have said before, when a file is decrypted, it is decrypted to `<systems_temp_folder>/FileMate/<fileName>`, and is then opened using the system's default program for that file type. A checksum is calculated before the file is opened, and after the file is closed using BLAKE2b. The checksum is then compared, and if the checksum is different, then the file is encrypted back into the vault.

Setings Screen

Here is an image of the settings screen:



The current Vault location is displayed at the top of the screen, followed by an input to change the Vault location, followed by a pair of switches to change whever the search is recursive, and which login screen to use as default. When done, the user can click "Exit" to exit to the main screen again.

The Search

The search does a linear search through the unsorted directory, checking if the search term is in the file name, and at what position the item appears in the file name. This data is appended in tuples like this: `(pos, fileName)`. These tuples are then sorted by their `pos` value using a quick sort, and if the search term matched a file in the list exactly, letter for letter, then it will be added to the start of the list.

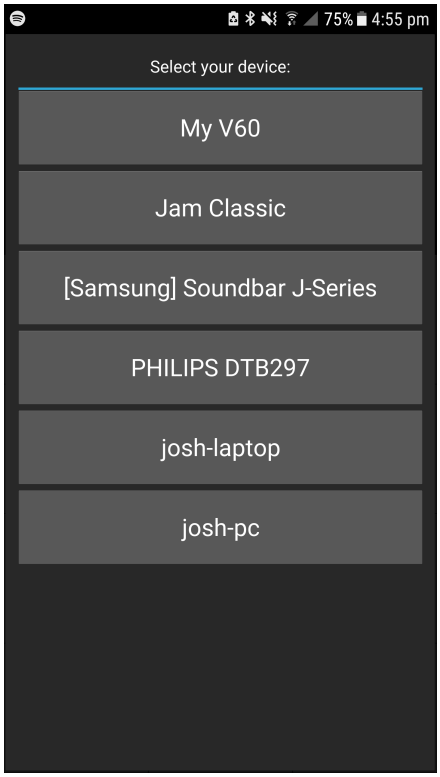
The list of results is then displayed:

If no results are found, a popup opens saying "No results found for: search item".

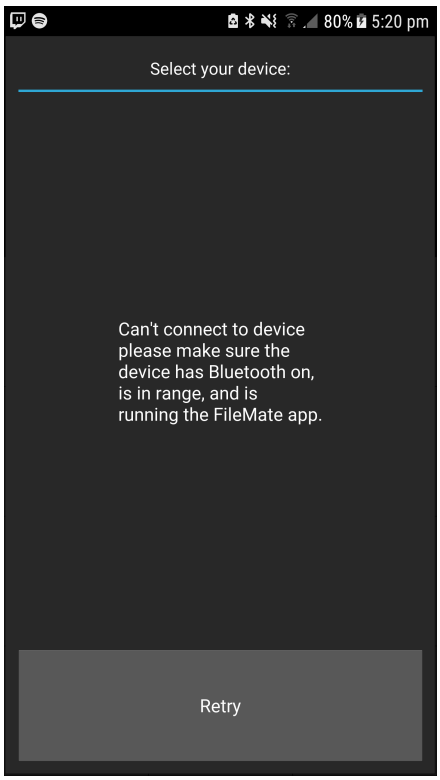
The Mobile App GUI

The mobile app has a basic design, as I wanted to keep it as small as possible, and images were not really needed.

When you first open the app, you are greeted by a scrollable list of devices to connect to (if Bluetooth is on):

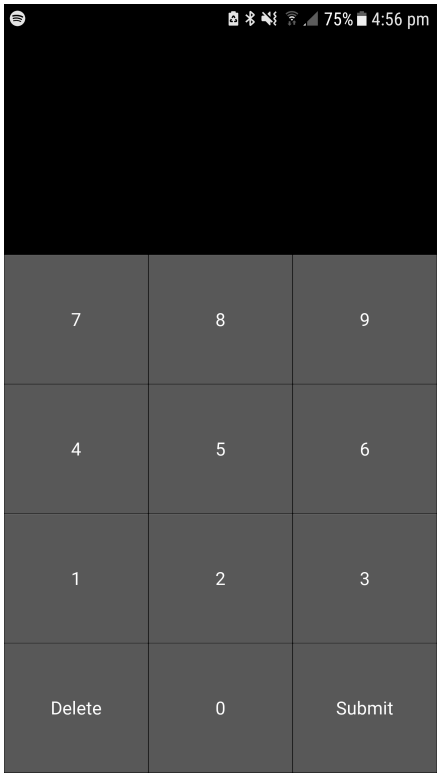


If you can't connect to a device, then you are greeted by this large popup:

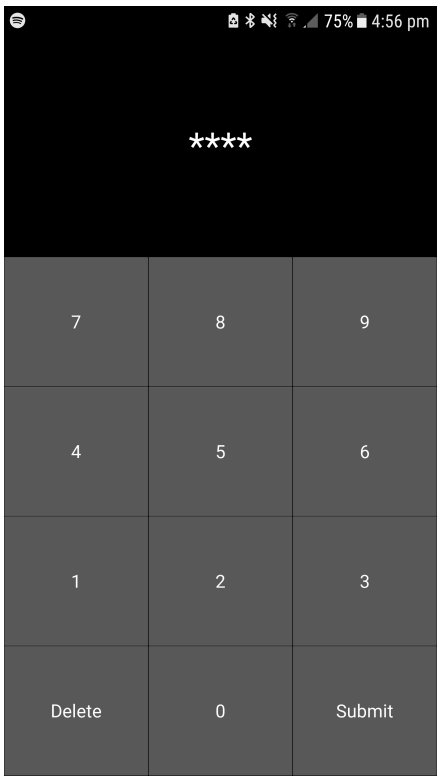


If you click retry, it takes you back to the start screen.

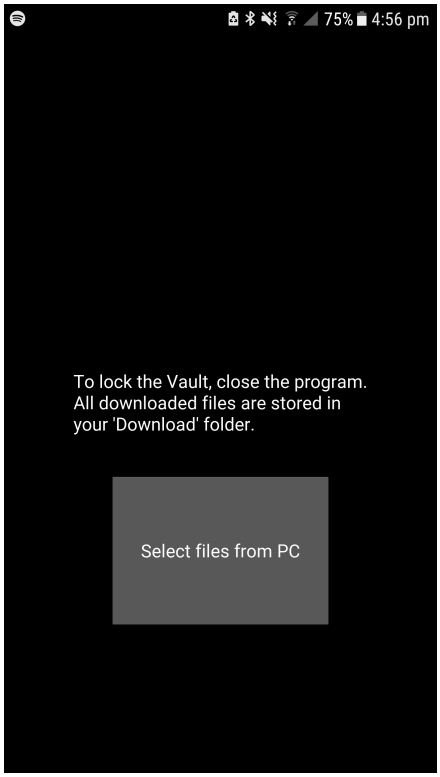
If you connect successfully, you are greeted by this screen:



Where you can then enter your key and submit it. While you are entering it, it looks like this:

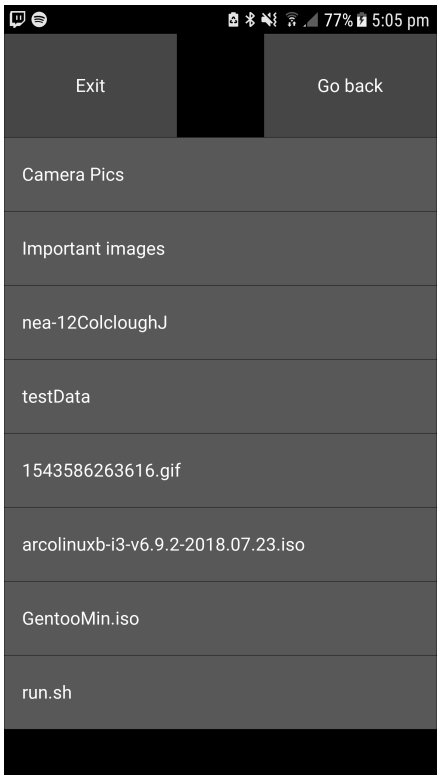


Once you press submit, a popup opens telling you if the key was correct or not, and then you are put into this screen:



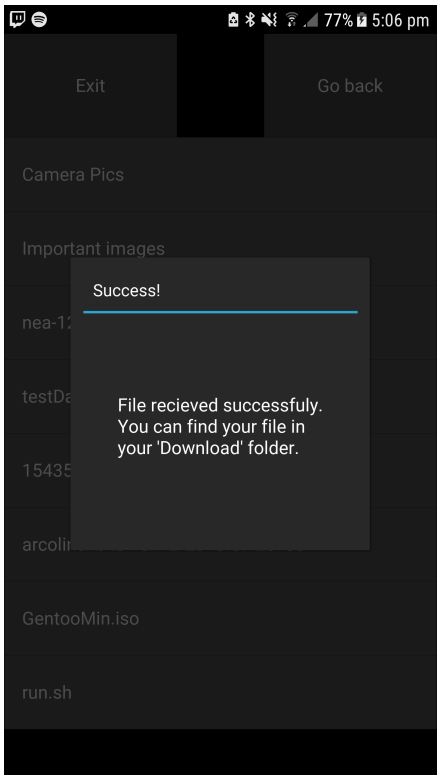
From here you can either close the app and leave it running in the background, or browse files. If you close the app completely, the app on the PC locks.

Here is what the app looks like while you are browsing files:



Here you can navigate folders and download files. Here is an image of a navigated folder:

If you want to download a file, a popup opens on the PC app showing the current status of the file using `btTransferPop` on `MainScreen`, and once the download has finished, a popup opens saying that it has finished, and where you can find it:



Now you can find that file in your devices "Download" folder.

Here is a video of the whole process (type this into your web browser's address bar): https://youtu.be/FNt5Vsaf4UM

Key Algorithms

In this section I will explain each algorithm if the comments in the code are not sufficient, and point out any of the bits that have changed or are different in the **Design** section.

AES:

Go packages are like modules in Python, but are created by grouping Go files of the same package in a folder named the same as the package. Packages have to be stored in a source folder, called `src`, and outside of the `src` folder, a main package (usually stored in `main.go`) handles all of the other packages, and the Go project is built from there.

AES is split into several Go packages. One called AES, which holds all the code needed for the core of AES (encryption and decryption of a single block), AESfiles which handles enc/decryption of files, AESstring which handles with enc/decrypting strings (such as file names) and listing directories containing encrypted files, and finally AEScheckKey which handles key checking. They are all tied together with the `main.go` file in `code/python-go/AES/main.go`, which handles input from Python.

Just to recap, the file structure of the AES folder looks like this:

```
code/python-go/AES/
                  ├── AES
                  ├── build.sh
                  ├── main.go
                  ├── src
                  │   ├── AES
                  │   │   ├── AEScheckKey
                  │   │   │   └── aesCheckKey.go
                  │   │   ├── AESfiles
                  │   │   │   ├── aesFiles.go
                  │   │   │   └── aesFiles_test.go
                  │   │   ├── aes.go
                  │   │   ├── AESstring
                  │   │   │   └── aesString.go
                  │   │   └── aes_test.go
                  │   └── sorts
                  │       └── sorts.go
                  ├── testAES.sh
                  └── testBenchAES.sh

6 directories, 12 files
```

You will notice a few `.sh` files, these are just used to run tests on the code, and also build the code. I will go a bit more into the testing in the **Testing** section.

In the `code/python-go/AES/src/` folder, there is also a folder called `sorts`, which holds the sorts that are used by `AESstring` to sort lists of files. The `sorts` package is used to sort lists of files.

AES package

Here is the `AES` package in `code/python-go/AES/src/AES/aes.go`:

```
package AES

// Global lookup tables.
var sBox = [256]byte {0x63,0x7C,0x77,0x7B,0xF2,0x6B,0x6F,0xC5,0x30,0x01,0x67,0x2B,0xFE,0xD7,0xAB,0x76,
                      0xCA,0x82,0xC9,0x7D,0xFA,0x59,0x47,0xF0,0xAD,0xD4,0xA2,0xAF,0x9C,0xA4,0x72,0xC0,
                      0xB7,0xFD,0x93,0x26,0x36,0x3F,0xF7,0xCC,0x34,0xA5,0xE5,0xF1,0x71,0xD8,0x31,0x15,
```

```
                    0x04,0xC7,0x23,0xC3,0x18,0x96,0x05,0x9A,0x07,0x12,0x80,0xE2,0xEB,0x27,0xB2,0x75,
                    0x09,0x83,0x2C,0x1A,0x1B,0x6E,0x5A,0xA0,0x52,0x3B,0xD6,0xB3,0x29,0xE3,0x2F,0x84,
                    0x53,0xD1,0x00,0xED,0x20,0xFC,0xB1,0x5B,0x6A,0xCB,0xBE,0x39,0x4A,0x4C,0x58,0xCF,
                    0xD0,0xEF,0xAA,0xFB,0x43,0x4D,0x33,0x85,0x45,0xF9,0x02,0x7F,0x50,0x3C,0x9F,0xA8,
                    0x51,0xA3,0x40,0x8F,0x92,0x9D,0x38,0xF5,0xBC,0xB6,0xDA,0x21,0x10,0xFF,0xF3,0xD2,
                    0xCD,0x0C,0x13,0xEC,0x5F,0x97,0x44,0x17,0xC4,0xA7,0x7E,0x3D,0x64,0x5D,0x19,0x73,
                    0x60,0x81,0x4F,0xDC,0x22,0x2A,0x90,0x88,0x46,0xEE,0xB8,0x14,0xDE,0x5E,0x0B,0xDB,
                    0xE0,0x32,0x3A,0x0A,0x49,0x06,0x24,0x5C,0xC2,0xD3,0xAC,0x62,0x91,0x95,0xE4,0x79,
                    0xE7,0xC8,0x37,0x6D,0x8D,0xD5,0x4E,0xA9,0x6C,0x56,0xF4,0xEA,0x65,0x7A,0xAE,0x08,
                    0xBA,0x78,0x25,0x2E,0x1C,0xA6,0xB4,0xC6,0xE8,0xDD,0x74,0x1F,0x4B,0xBD,0x8B,0x8A,
                    0x70,0x3E,0xB5,0x66,0x48,0x03,0xF6,0x0E,0x61,0x35,0x57,0xB9,0x86,0xC1,0x1D,0x9E,
                    0xE1,0xF8,0x98,0x11,0x69,0xD9,0x8E,0x94,0x9B,0x1E,0x87,0xE9,0xCE,0x55,0x28,0xDF,
                    0x8C,0xA1,0x89,0x0D,0xBF,0xE6,0x42,0x68,0x41,0x99,0x2D,0x0F,0xB0,0x54,0xBB,0x16}

var invSBox = [256]byte {0x52,0x09,0x6A,0xD5,0x30,0x36,0xA5,0x38,0xBF,0x40,0xA3,0x9E,0x81,0xF3,0xD7,0xFB,
                         0x7C,0xE3,0x39,0x82,0x9B,0x2F,0xFF,0x87,0x34,0x8E,0x43,0x44,0xC4,0xDE,0xE9,0xCB,
                         0x54,0x7B,0x94,0x32,0xA6,0xC2,0x23,0x3D,0xEE,0x4C,0x95,0x0B,0x42,0xFA,0xC3,0x4E,
                         0x08,0x2E,0xA1,0x66,0x28,0xD9,0x24,0xB2,0x76,0x5B,0xA2,0x49,0x6D,0x8B,0xD1,0x25,
                         0x72,0xF8,0xF6,0x64,0x86,0x68,0x98,0x16,0xD4,0xA4,0x5C,0xCC,0x5D,0x65,0xB6,0x92,
                         0x6C,0x70,0x48,0x50,0xFD,0xED,0xB9,0xDA,0x5E,0x15,0x46,0x57,0xA7,0x8D,0x9D,0x84,
                         0x90,0xD8,0xAB,0x00,0x8C,0xBC,0xD3,0x0A,0xF7,0xE4,0x58,0x05,0xB8,0xB3,0x45,0x06,
                         0xD0,0x2C,0x1E,0x8F,0xCA,0x3F,0x0F,0x02,0xC1,0xAF,0xBD,0x03,0x01,0x13,0x8A,0x6B,
                         0x3A,0x91,0x11,0x41,0x4F,0x67,0xDC,0xEA,0x97,0xF2,0xCF,0xCE,0xF0,0xB4,0xE6,0x73,
                         0x96,0xAC,0x74,0x22,0xE7,0xAD,0x35,0x85,0xE2,0xF9,0x37,0xE8,0x1C,0x75,0xDF,0x6E,
                         0x47,0xF1,0x1A,0x71,0x1D,0x29,0xC5,0x89,0x6F,0xB7,0x62,0x0E,0xAA,0x18,0xBE,0x1B,
                         0xFC,0x56,0x3E,0x4B,0xC6,0xD2,0x79,0x20,0x9A,0xDB,0xC0,0xFE,0x78,0xCD,0x5A,0xF4,
                         0x1F,0xDD,0xA8,0x33,0x88,0x07,0xC7,0x31,0xB1,0x12,0x10,0x59,0x27,0x80,0xEC,0x5F,
                         0x60,0x51,0x7F,0xA9,0x19,0xB5,0x4A,0x0D,0x2D,0xE5,0x7A,0x9F,0x93,0xC9,0x9C,0xEF,
                         0xA0,0xE0,0x3B,0x4D,0xAE,0x2A,0xF5,0xB0,0xC8,0xEB,0xBB,0x3C,0x83,0x53,0x99,0x61,
                         0x17,0x2B,0x04,0x7E,0xBA,0x77,0xD6,0x26,0xE1,0x69,0x14,0x63,0x55,0x21,0x0C,0x7D}

var rcon = [256]byte {0x8d,0x01,0x02,0x04,0x08,0x10,0x20,0x40,0x80,0x1b,0x36,0x6c,0xd8,0xab,0x4d,0x9a,    //
https:// en.wikipedia.org/wiki/Rijndael_key_schedule
                    0x2f,0x5e,0xbc,0x63,0xc6,0x97,0x35,0x6a,0xd4,0xb3,0x7d,0xfa,0xef,0xc5,0x91,0x39,
                    0x72,0xe4,0xd3,0xbd,0x61,0xc2,0x9f,0x25,0x4a,0x94,0x33,0x66,0xcc,0x83,0x1d,0x3a,
                    0x74,0xe8,0xcb,0x8d,0x01,0x02,0x04,0x08,0x10,0x20,0x40,0x80,0x1b,0x36,0x6c,0xd8,
                    0xab,0x4d,0x9a,0x2f,0x5e,0xbc,0x63,0xc6,0x97,0x35,0x6a,0xd4,0xb3,0x7d,0xfa,0xef,
                    0xc5,0x91,0x39,0x72,0xe4,0xd3,0xbd,0x61,0xc2,0x9f,0x25,0x4a,0x94,0x33,0x66,0xcc,
                    0x83,0x1d,0x3a,0x74,0xe8,0xcb,0x8d,0x01,0x02,0x04,0x08,0x10,0x20,0x40,0x80,0x1b,
                    0x36,0x6c,0xd8,0xab,0x4d,0x9a,0x2f,0x5e,0xbc,0x63,0xc6,0x97,0x35,0x6a,0xd4,0xb3,
                    0x7d,0xfa,0xef,0xc5,0x91,0x39,0x72,0xe4,0xd3,0xbd,0x61,0xc2,0x9f,0x25,0x4a,0x94,
                    0x33,0x66,0xcc,0x83,0x1d,0x3a,0x74,0xe8,0xcb,0x8d,0x01,0x02,0x04,0x08,0x10,0x20,
                    0x40,0x80,0x1b,0x36,0x6c,0xd8,0xab,0x4d,0x9a,0x2f,0x5e,0xbc,0x63,0xc6,0x97,0x35,
                    0x6a,0xd4,0xb3,0x7d,0xfa,0xef,0xc5,0x91,0x39,0x72,0xe4,0xd3,0xbd,0x61,0xc2,0x9f,
                    0x25,0x4a,0x94,0x33,0x66,0xcc,0x83,0x1d,0x3a,0x74,0xe8,0xcb,0x8d,0x01,0x02,0x04,
                    0x08,0x10,0x20,0x40,0x80,0x1b,0x36,0x6c,0xd8,0xab,0x4d,0x9a,0x2f,0x5e,0xbc,0x63,
                    0xc6,0x97,0x35,0x6a,0xd4,0xb3,0x7d,0xfa,0xef,0xc5,0x91,0x39,0x72,0xe4,0xd3,0xbd,
                    0x61,0xc2,0x9f,0x25,0x4a,0x94,0x33,0x66,0xcc,0x83,0x1d,0x3a,0x74,0xe8,0xcb,0x8d}

var mul2 = [256]byte {0x00,0x02,0x04,0x06,0x08,0x0a,0x0c,0x0e,0x10,0x12,0x14,0x16,0x18,0x1a,0x1c,0x1e,
                      0x20,0x22,0x24,0x26,0x28,0x2a,0x2c,0x2e,0x30,0x32,0x34,0x36,0x38,0x3a,0x3c,0x3e,
                      0x40,0x42,0x44,0x46,0x48,0x4a,0x4c,0x4e,0x50,0x52,0x54,0x56,0x58,0x5a,0x5c,0x5e,
                      0x60,0x62,0x64,0x66,0x68,0x6a,0x6c,0x6e,0x70,0x72,0x74,0x76,0x78,0x7a,0x7c,0x7e,
                      0x80,0x82,0x84,0x86,0x88,0x8a,0x8c,0x8e,0x90,0x92,0x94,0x96,0x98,0x9a,0x9c,0x9e,
                      0xa0,0xa2,0xa4,0xa6,0xa8,0xaa,0xac,0xae,0xb0,0xb2,0xb4,0xb6,0xb8,0xba,0xbc,0xbe,
                      0xc0,0xc2,0xc4,0xc6,0xc8,0xca,0xcc,0xce,0xd0,0xd2,0xd4,0xd6,0xd8,0xda,0xdc,0xde,
                      0xe0,0xe2,0xe4,0xe6,0xe8,0xea,0xec,0xee,0xf0,0xf2,0xf4,0xf6,0xf8,0xfa,0xfc,0xfe,
                      0x1b,0x19,0x1f,0x1d,0x13,0x11,0x17,0x15,0x0b,0x09,0x0f,0x0d,0x03,0x01,0x07,0x05,
                      0x3b,0x39,0x3f,0x3d,0x33,0x31,0x37,0x35,0x2b,0x29,0x2f,0x2d,0x23,0x21,0x27,0x25,
                      0x5b,0x59,0x5f,0x5d,0x53,0x51,0x57,0x55,0x4b,0x49,0x4f,0x4d,0x43,0x41,0x47,0x45,
                      0x7b,0x79,0x7f,0x7d,0x73,0x71,0x77,0x75,0x6b,0x69,0x6f,0x6d,0x63,0x61,0x67,0x65,
                      0x9b,0x99,0x9f,0x9d,0x93,0x91,0x97,0x95,0x8b,0x89,0x8f,0x8d,0x83,0x81,0x87,0x85,
                      0xbb,0xb9,0xbf,0xbd,0xb3,0xb1,0xb7,0xb5,0xab,0xa9,0xaf,0xad,0xa3,0xa1,0xa7,0xa5,
                      0xdb,0xd9,0xdf,0xdd,0xd3,0xd1,0xd7,0xd5,0xcb,0xc9,0xcf,0xcd,0xc3,0xc1,0xc7,0xc5,
                      0xfb,0xf9,0xff,0xfd,0xf3,0xf1,0xf7,0xf5,0xeb,0xe9,0xef,0xed,0xe3,0xe1,0xe7,0xe5}

var mul3 = [256]byte {0x00,0x03,0x06,0x05,0x0c,0x0f,0x0a,0x09,0x18,0x1b,0x1e,0x1d,0x14,0x17,0x12,0x11,
                      0x30,0x33,0x36,0x35,0x3c,0x3f,0x3a,0x39,0x28,0x2b,0x2e,0x2d,0x24,0x27,0x22,0x21,
                      0x60,0x63,0x66,0x65,0x6c,0x6f,0x6a,0x69,0x78,0x7b,0x7e,0x7d,0x74,0x77,0x72,0x71,
```

```
                    0x50,0x53,0x56,0x55,0x5c,0x5f,0x5a,0x59,0x48,0x4b,0x4e,0x4d,0x44,0x47,0x42,0x41,
                    0xc0,0xc3,0xc6,0xc5,0xcc,0xcf,0xca,0xc9,0xd8,0xdb,0xde,0xdd,0xd4,0xd7,0xd2,0xd1,
                    0xf0,0xf3,0xf6,0xf5,0xfc,0xff,0xfa,0xf9,0xe8,0xeb,0xee,0xed,0xe4,0xe7,0xe2,0xe1,
                    0xa0,0xa3,0xa6,0xa5,0xac,0xaf,0xaa,0xa9,0xb8,0xbb,0xbe,0xbd,0xb4,0xb7,0xb2,0xb1,
                    0x90,0x93,0x96,0x95,0x9c,0x9f,0x9a,0x99,0x88,0x8b,0x8e,0x8d,0x84,0x87,0x82,0x81,
                    0x9b,0x98,0x9d,0x9e,0x97,0x94,0x91,0x92,0x83,0x80,0x85,0x86,0x8f,0x8c,0x89,0x8a,
                    0xab,0xa8,0xad,0xae,0xa7,0xa4,0xa1,0xa2,0xb3,0xb0,0xb5,0xb6,0xbf,0xbc,0xb9,0xba,
                    0xfb,0xf8,0xfd,0xfe,0xf7,0xf4,0xf1,0xf2,0xe3,0xe0,0xe5,0xe6,0xef,0xec,0xe9,0xea,
                    0xcb,0xc8,0xcd,0xce,0xc7,0xc4,0xc1,0xc2,0xd3,0xd0,0xd5,0xd6,0xdf,0xdc,0xd9,0xda,
                    0x5b,0x58,0x5d,0x5e,0x57,0x54,0x51,0x52,0x43,0x40,0x45,0x46,0x4f,0x4c,0x49,0x4a,
                    0x6b,0x68,0x6d,0x6e,0x67,0x64,0x61,0x62,0x73,0x70,0x75,0x76,0x7f,0x7c,0x79,0x7a,
                    0x3b,0x38,0x3d,0x3e,0x37,0x34,0x31,0x32,0x23,0x20,0x25,0x26,0x2f,0x2c,0x29,0x2a,
                    0x0b,0x08,0x0d,0x0e,0x07,0x04,0x01,0x02,0x13,0x10,0x15,0x16,0x1f,0x1c,0x19,0x1a}

var mul9 = [256]byte {0x00,0x09,0x12,0x1b,0x24,0x2d,0x36,0x3f,0x48,0x41,0x5a,0x53,0x6c,0x65,0x7e,0x77,
                      0x90,0x99,0x82,0x8b,0xb4,0xbd,0xa6,0xaf,0xd8,0xd1,0xca,0xc3,0xfc,0xf5,0xee,0xe7,
                      0x3b,0x32,0x29,0x20,0x1f,0x16,0x0d,0x04,0x73,0x7a,0x61,0x68,0x57,0x5e,0x45,0x4c,
                      0xab,0xa2,0xb9,0xb0,0x8f,0x86,0x9d,0x94,0xe3,0xea,0xf1,0xf8,0xc7,0xce,0xd5,0xdc,
                      0x76,0x7f,0x64,0x6d,0x52,0x5b,0x40,0x49,0x3e,0x37,0x2c,0x25,0x1a,0x13,0x08,0x01,
                      0xe6,0xef,0xf4,0xfd,0xc2,0xcb,0xd0,0xd9,0xae,0xa7,0xbc,0xb5,0x8a,0x83,0x98,0x91,
                      0x4d,0x44,0x5f,0x56,0x69,0x60,0x7b,0x72,0x05,0x0c,0x17,0x1e,0x21,0x28,0x33,0x3a,
                      0xdd,0xd4,0xcf,0xc6,0xf9,0xf0,0xeb,0xe2,0x95,0x9c,0x87,0x8e,0xb1,0xb8,0xa3,0xaa,
                      0xec,0xe5,0xfe,0xf7,0xc8,0xc1,0xda,0xd3,0xa4,0xad,0xb6,0xbf,0x80,0x89,0x92,0x9b,
                      0x7c,0x75,0x6e,0x67,0x58,0x51,0x4a,0x43,0x34,0x3d,0x26,0x2f,0x10,0x19,0x02,0x0b,
                      0xd7,0xde,0xc5,0xcc,0xf3,0xfa,0xe1,0xe8,0x9f,0x96,0x8d,0x84,0xbb,0xb2,0xa9,0xa0,
                      0x47,0x4e,0x55,0x5c,0x63,0x6a,0x71,0x78,0x0f,0x06,0x1d,0x14,0x2b,0x22,0x39,0x30,
                      0x9a,0x93,0x88,0x81,0xbe,0xb7,0xac,0xa5,0xd2,0xdb,0xc0,0xc9,0xf6,0xff,0xe4,0xed,
                      0x0a,0x03,0x18,0x11,0x2e,0x27,0x3c,0x35,0x42,0x4b,0x50,0x59,0x66,0x6f,0x74,0x7d,
                      0xa1,0xa8,0xb3,0xba,0x85,0x8c,0x97,0x9e,0xe9,0xe0,0xfb,0xf2,0xcd,0xc4,0xdf,0xd6,
                      0x31,0x38,0x23,0x2a,0x15,0x1c,0x07,0x0e,0x79,0x70,0x6b,0x62,0x5d,0x54,0x4f,0x46}

var mul11 = [256]byte {0x00,0x0b,0x16,0x1d,0x2c,0x27,0x3a,0x31,0x58,0x53,0x4e,0x45,0x74,0x7f,0x62,0x69,
                       0xb0,0xbb,0xa6,0xad,0x9c,0x97,0x8a,0x81,0xe8,0xe3,0xfe,0xf5,0xc4,0xcf,0xd2,0xd9,
                       0x7b,0x70,0x6d,0x66,0x57,0x5c,0x41,0x4a,0x23,0x28,0x35,0x3e,0x0f,0x04,0x19,0x12,
                       0xcb,0xc0,0xdd,0xd6,0xe7,0xec,0xf1,0xfa,0x93,0x98,0x85,0x8e,0xbf,0xb4,0xa9,0xa2,
                       0xf6,0xfd,0xe0,0xeb,0xda,0xd1,0xcc,0xc7,0xae,0xa5,0xb8,0xb3,0x82,0x89,0x94,0x9f,
                       0x46,0x4d,0x50,0x5b,0x6a,0x61,0x7c,0x77,0x1e,0x15,0x08,0x03,0x32,0x39,0x24,0x2f,
                       0x8d,0x86,0x9b,0x90,0xa1,0xaa,0xb7,0xbc,0xd5,0xde,0xc3,0xc8,0xf9,0xf2,0xef,0xe4,
                       0x3d,0x36,0x2b,0x20,0x11,0x1a,0x07,0x0c,0x65,0x6e,0x73,0x78,0x49,0x42,0x5f,0x54,
                       0xf7,0xfc,0xe1,0xea,0xdb,0xd0,0xcd,0xc6,0xaf,0xa4,0xb9,0xb2,0x83,0x88,0x95,0x9e,
                       0x47,0x4c,0x51,0x5a,0x6b,0x60,0x7d,0x76,0x1f,0x14,0x09,0x02,0x33,0x38,0x25,0x2e,
                       0x8c,0x87,0x9a,0x91,0xa0,0xab,0xb6,0xbd,0xd4,0xdf,0xc2,0xc9,0xf8,0xf3,0xee,0xe5,
                       0x3c,0x37,0x2a,0x21,0x10,0x1b,0x06,0x0d,0x64,0x6f,0x72,0x79,0x48,0x43,0x5e,0x55,
                       0x01,0x0a,0x17,0x1c,0x2d,0x26,0x3b,0x30,0x59,0x52,0x4f,0x44,0x75,0x7e,0x63,0x68,
                       0xb1,0xba,0xa7,0xac,0x9d,0x96,0x8b,0x80,0xe9,0xe2,0xff,0xf4,0xc5,0xce,0xd3,0xd8,
                       0x7a,0x71,0x6c,0x67,0x56,0x5d,0x40,0x4b,0x22,0x29,0x34,0x3f,0x0e,0x05,0x18,0x13,
                       0xca,0xc1,0xdc,0xd7,0xe6,0xed,0xf0,0xfb,0x92,0x99,0x84,0x8f,0xbe,0xb5,0xa8,0xa3}

var mul13 = [256]byte {0x00,0x0d,0x1a,0x17,0x34,0x39,0x2e,0x23,0x68,0x65,0x72,0x7f,0x5c,0x51,0x46,0x4b,
                       0xd0,0xdd,0xca,0xc7,0xe4,0xe9,0xfe,0xf3,0xb8,0xb5,0xa2,0xaf,0x8c,0x81,0x96,0x9b,
                       0xbb,0xb6,0xa1,0xac,0x8f,0x82,0x95,0x98,0xd3,0xde,0xc9,0xc4,0xe7,0xea,0xfd,0xf0,
                       0x6b,0x66,0x71,0x7c,0x5f,0x52,0x45,0x48,0x03,0x0e,0x19,0x14,0x37,0x3a,0x2d,0x20,
                       0x6d,0x60,0x77,0x7a,0x59,0x54,0x43,0x4e,0x05,0x08,0x1f,0x12,0x31,0x3c,0x2b,0x26,
                       0xbd,0xb0,0xa7,0xaa,0x89,0x84,0x93,0x9e,0xd5,0xd8,0xcf,0xc2,0xe1,0xec,0xfb,0xf6,
                       0xd6,0xdb,0xcc,0xc1,0xe2,0xef,0xf8,0xf5,0xbe,0xb3,0xa4,0xa9,0x8a,0x87,0x90,0x9d,
                       0x06,0x0b,0x1c,0x11,0x32,0x3f,0x28,0x25,0x6e,0x63,0x74,0x79,0x5a,0x57,0x40,0x4d,
                       0xda,0xd7,0xc0,0xcd,0xee,0xe3,0xf4,0xf9,0xb2,0xbf,0xa8,0xa5,0x86,0x8b,0x9c,0x91,
                       0x0a,0x07,0x10,0x1d,0x3e,0x33,0x24,0x29,0x62,0x6f,0x78,0x75,0x56,0x5b,0x4c,0x41,
                       0x61,0x6c,0x7b,0x76,0x55,0x58,0x4f,0x42,0x09,0x04,0x13,0x1e,0x3d,0x30,0x27,0x2a,
                       0xb1,0xbc,0xab,0xa6,0x85,0x88,0x9f,0x92,0xd9,0xd4,0xc3,0xce,0xed,0xe0,0xf7,0xfa,
                       0xb7,0xba,0xad,0xa0,0x83,0x8e,0x99,0x94,0xdf,0xd2,0xc5,0xc8,0xeb,0xe6,0xf1,0xfc,
                       0x67,0x6a,0x7d,0x70,0x53,0x5e,0x49,0x44,0x0f,0x02,0x15,0x18,0x3b,0x36,0x21,0x2c,
                       0x0c,0x01,0x16,0x1b,0x38,0x35,0x22,0x2f,0x64,0x69,0x7e,0x73,0x50,0x5d,0x4a,0x47,
                       0xdc,0xd1,0xc6,0xcb,0xe8,0xe5,0xf2,0xff,0xb4,0xb9,0xae,0xa3,0x80,0x8d,0x9a,0x97}

var mul14 = [256]byte {0x00,0x0e,0x1c,0x12,0x38,0x36,0x24,0x2a,0x70,0x7e,0x6c,0x62,0x48,0x46,0x54,0x5a,
                       0xe0,0xee,0xfc,0xf2,0xd8,0xd6,0xc4,0xca,0x90,0x9e,0x8c,0x82,0xa8,0xa6,0xb4,0xba,
                       0xdb,0xd5,0xc7,0xc9,0xe3,0xed,0xff,0xf1,0xab,0xa5,0xb7,0xb9,0x93,0x9d,0x8f,0x81,
                       0x3b,0x35,0x27,0x29,0x03,0x0d,0x1f,0x11,0x4b,0x45,0x57,0x59,0x73,0x7d,0x6f,0x61,
```

```
                        0xad,0xa3,0xb1,0xbf,0x95,0x9b,0x89,0x87,0xdd,0xd3,0xc1,0xcf,0xe5,0xeb,0xf9,0xf7,
                        0x4d,0x43,0x51,0x5f,0x75,0x7b,0x69,0x67,0x3d,0x33,0x21,0x2f,0x05,0x0b,0x19,0x17,
                        0x76,0x78,0x6a,0x64,0x4e,0x40,0x52,0x5c,0x06,0x08,0x1a,0x14,0x3e,0x30,0x22,0x2c,
                        0x96,0x98,0x8a,0x84,0xae,0xa0,0xb2,0xbc,0xe6,0xe8,0xfa,0xf4,0xde,0xd0,0xc2,0xcc,
                        0x41,0x4f,0x5d,0x53,0x79,0x77,0x65,0x6b,0x31,0x3f,0x2d,0x23,0x09,0x07,0x15,0x1b,
                        0xa1,0xaf,0xbd,0xb3,0x99,0x97,0x85,0x8b,0xd1,0xdf,0xcd,0xc3,0xe9,0xe7,0xf5,0xfb,
                        0x9a,0x94,0x86,0x88,0xa2,0xac,0xbe,0xb0,0xea,0xe4,0xf6,0xf8,0xd2,0xdc,0xce,0xc0,
                        0x7a,0x74,0x66,0x68,0x42,0x4c,0x5e,0x50,0x0a,0x04,0x16,0x18,0x32,0x3c,0x2e,0x20,
                        0xec,0xe2,0xf0,0xfe,0xd4,0xda,0xc8,0xc6,0x9c,0x92,0x80,0x8e,0xa4,0xaa,0xb8,0xb6,
                        0x0c,0x02,0x10,0x1e,0x34,0x3a,0x28,0x26,0x7c,0x72,0x60,0x6e,0x44,0x4a,0x58,0x56,
                        0x37,0x39,0x2b,0x25,0x0f,0x01,0x13,0x1d,0x47,0x49,0x5b,0x55,0x7f,0x71,0x63,0x6d,
                        0xd7,0xd9,0xcb,0xc5,0xef,0xe1,0xf3,0xfd,0xa7,0xa9,0xbb,0xb5,0x9f,0x91,0x83,0x8d}


func keyExpansionCore(inp [4]byte, i int) [4]byte {
  // Shift the inp left by moving the first byte to the end (rotate).
  inp[0], inp[1], inp[2], inp[3] = inp[1], inp[2], inp[3], inp[0]

  // S-Box the bytes
  inp[0], inp[1], inp[2], inp[3] = sBox[inp[0]], sBox[inp[1]], sBox[inp[2]], sBox[inp[3]]

  // rcon, the round constant
  inp[0] ^= rcon[i]

  return inp
}

func ExpandKey(inputKey []byte) [176]byte {
  var expandedKey [176]byte
  // first 16 bytes of the expandedKey should be the same 16 as the original key
  for i := 0; i < 16; i++ {
    expandedKey[i] = inputKey[i]
  }
  var bytesGenerated int = 16 // needs to get to 176 to fill expandedKey with 11 keys, one for every round.
  var rconIteration int = 1
  var temp [4]byte

  for bytesGenerated < 176{
    // Read 4 bytes for use in keyExpansionCore
    copy(temp[:], expandedKey[bytesGenerated-4:bytesGenerated])

    if bytesGenerated % 16 == 0 {    // Keys are length 16 bytes so every 16 bytes generated, expand.
      temp = keyExpansionCore(temp, rconIteration)
      rconIteration += 1
    }

    for y := 0; y < 4; y++ {
      expandedKey[bytesGenerated] = expandedKey[bytesGenerated - 16] ^ temp[y]  // XOR first 4 bytes of
previous key with the temporary list.
      bytesGenerated += 1
    }
  }

  return expandedKey
}

func addRoundKey(state []byte, roundKey []byte) {       // Add round key is also it's own inverse
  state[ 0], state[ 1], state[ 2], state[ 3],
  state[ 4], state[ 5], state[ 6], state[ 7],
  state[ 8], state[ 9], state[10], state[11],
  state[12], state[13], state[14], state[15] =

  state[ 0]^roundKey[ 0], state[ 1]^roundKey[ 1], state[ 2]^roundKey[ 2], state[ 3]^roundKey[ 3],
  state[ 4]^roundKey[ 4], state[ 5]^roundKey[ 5], state[ 6]^roundKey[ 6], state[ 7]^roundKey[ 7],
  state[ 8]^roundKey[ 8], state[ 9]^roundKey[ 9], state[10]^roundKey[10], state[11]^roundKey[11],
  state[12]^roundKey[12], state[13]^roundKey[13], state[14]^roundKey[14], state[15]^roundKey[15]
}

func subBytes(state []byte) {
```

```
  state[ 0], state[ 1], state[ 2], state[ 3],
  state[ 4], state[ 5], state[ 6], state[ 7],
  state[ 8], state[ 9], state[10], state[11],
  state[12], state[13], state[14], state[15] =

  sBox[state[ 0]], sBox[state[ 1]], sBox[state[ 2]], sBox[state[ 3]],
  sBox[state[ 4]], sBox[state[ 5]], sBox[state[ 6]], sBox[state[ 7]],
  sBox[state[ 8]], sBox[state[ 9]], sBox[state[10]], sBox[state[11]],
  sBox[state[12]], sBox[state[13]], sBox[state[14]], sBox[state[15]]
}

func invSubBytes(state []byte) {
  state[ 0], state[ 1], state[ 2], state[ 3],
  state[ 4], state[ 5], state[ 6], state[ 7],
  state[ 8], state[ 9], state[10], state[11],
  state[12], state[13], state[14], state[15] =

  invSBox[state[ 0]], invSBox[state[ 1]], invSBox[state[ 2]], invSBox[state[ 3]],
  invSBox[state[ 4]], invSBox[state[ 5]], invSBox[state[ 6]], invSBox[state[ 7]],
  invSBox[state[ 8]], invSBox[state[ 9]], invSBox[state[10]], invSBox[state[11]],
  invSBox[state[12]], invSBox[state[13]], invSBox[state[14]], invSBox[state[15]]
}

func shiftRows(state []byte) {
  state[ 0], state[ 1], state[ 2], state[ 3],
  state[ 4], state[ 5], state[ 6], state[ 7],
  state[ 8], state[ 9], state[10], state[11],
  state[12], state[13], state[14], state[15] =

  state[ 0], state[ 5], state[10], state[15],
  state[ 4], state[ 9], state[14], state[ 3],
  state[ 8], state[13], state[ 2], state[ 7],
  state[12], state[ 1], state[ 6], state[11]
}
  //  Shifts it like this:
  //
  //  0  4  8 12         0  4  8 12   Shifted left by 0
  //  1  5  9 13  ---->  5  9 13  1   Shifted left by 1
  //  2  6 10 14  ----> 10 14  2  6   Shifted left by 2
  //  3  7 11 15        15  3  7 11   Shifted left by 3

func invShiftRows(state []byte) {
  state[ 0], state[ 1], state[ 2], state[ 3],
  state[ 4], state[ 5], state[ 6], state[ 7],
  state[ 8], state[ 9], state[10], state[11],
  state[12], state[13], state[14], state[15] =

  state[ 0], state[13], state[10], state[ 7],
  state[ 4], state[ 1], state[14], state[11],
  state[ 8], state[ 5], state[ 2], state[15],
  state[12], state[ 9], state[ 6], state[ 3]
}
  //   0  4  8 12         0  4  8 12   Shifted right by 0
  //   5  9 13  1  ---->  1  5  9 13   Shifted right by 1
  //  10 14  2  6  ---->  2  6 10 14   Shifted right by 2
  //  15  3  7 11         3  7 11 15   Shifted right by 3

func mixColumns(state []byte) {
  state[ 0], state[ 1], state[ 2], state[ 3],
  state[ 4], state[ 5], state[ 6], state[ 7],
  state[ 8], state[ 9], state[10], state[11],
  state[12], state[13], state[14], state[15] =

  mul2[state[ 0]] ^ mul3[state[ 1]] ^ state[ 2] ^ state[ 3],
  state[ 0] ^ mul2[state[ 1]] ^ mul3[state[ 2]] ^ state[ 3],
  state[ 0] ^ state[ 1] ^ mul2[state[ 2]] ^ mul3[state[ 3]],
  mul3[state[ 0]] ^ state[ 1] ^ state[ 2] ^ mul2[state[ 3]],

  mul2[state[ 4]] ^ mul3[state[ 5]] ^ state[ 6] ^ state[ 7],
```

```
  state[ 4] ^ mul2[state [5]] ^ mul3[state[ 6]] ^ state[ 7],
  state[ 4] ^ state[ 5] ^ mul2[state[ 6]] ^ mul3[state[ 7]],
  mul3[state[ 4]] ^ state[ 5] ^ state[ 6] ^ mul2[state[ 7]],

  mul2[state[ 8]] ^ mul3[state[ 9]] ^ state[10] ^ state[11],
  state[ 8] ^ mul2[state[ 9]] ^ mul3[state[10]] ^ state[11],
  state[ 8] ^ state[ 9] ^ mul2[state[10]] ^ mul3[state[11]],
  mul3[state[ 8]] ^ state[ 9] ^ state[10] ^ mul2[state[11]],

  mul2[state[12]] ^ mul3[state[13]] ^ state[14] ^ state[15],
  state[12] ^ mul2[state[13]] ^ mul3[state[14]] ^ state[15],
  state[12] ^ state[13] ^ mul2[state[14]] ^ mul3[state[15]],
  mul3[state[12]] ^ state[13] ^ state[14] ^ mul2[state[15]]
}

func invMixColumns(state []byte) {
  state[ 0], state[ 1], state[ 2], state[ 3],
  state[ 4], state[ 5], state[ 6], state[ 7],
  state[ 8], state[ 9], state[10], state[11],
  state[12], state[13], state[14], state[15] =

  mul14[state[ 0]] ^ mul11[state[ 1]] ^ mul13[state[ 2]] ^ mul9[state[ 3]],
  mul9[state[ 0]] ^ mul14[state[ 1]] ^ mul11[state[ 2]] ^ mul13[state[ 3]],
  mul13[state[ 0]] ^ mul9[state[ 1]] ^ mul14[state[ 2]] ^ mul11[state[ 3]],
  mul11[state[ 0]] ^ mul13[state[ 1]] ^ mul9[state[ 2]] ^ mul14[state[ 3]],

  mul14[state[ 4]] ^ mul11[state[ 5]] ^ mul13[state[ 6]] ^ mul9[state[ 7]],
  mul9[state[ 4]] ^ mul14[state[ 5]] ^ mul11[state[ 6]] ^ mul13[state[ 7]],
  mul13[state[ 4]] ^ mul9[state[ 5]] ^ mul14[state[ 6]] ^ mul11[state[ 7]],
  mul11[state[ 4]] ^ mul13[state[ 5]] ^ mul9[state[ 6]] ^ mul14[state[ 7]],

  mul14[state[ 8]] ^ mul11[state[ 9]] ^ mul13[state[10]] ^ mul9[state[11]],
  mul9[state[ 8]] ^ mul14[state[ 9]] ^ mul11[state[10]] ^ mul13[state[11]],
  mul13[state[ 8]] ^ mul9[state[ 9]] ^ mul14[state[10]] ^ mul11[state[11]],
  mul11[state[ 8]] ^ mul13[state[ 9]] ^ mul9[state[10]] ^ mul14[state[11]],

  mul14[state[12]] ^ mul11[state[13]] ^ mul13[state[14]] ^ mul9[state[15]],
  mul9[state[12]] ^ mul14[state[13]] ^ mul11[state[14]] ^ mul13[state[15]],
  mul13[state[12]] ^ mul9[state[13]] ^ mul14[state[14]] ^ mul11[state[15]],
  mul11[state[12]] ^ mul13[state[13]] ^ mul9[state[14]] ^ mul14[state[15]]
}

func Encrypt(state []byte, expandedKey *[176]byte) {
  addRoundKey(state, expandedKey[:16])

  for i := 0; i < 144; i += 16 {    // 9 regular rounds * 16 = 144
    subBytes(state)
    shiftRows(state)
    mixColumns(state)
    addRoundKey(state, expandedKey[i+16:i+32])
  }
  // Last round
  subBytes(state)
  shiftRows(state)
  addRoundKey(state, expandedKey[160:])
}

func Decrypt(state []byte, expandedKey *[176]byte) {
  addRoundKey(state, expandedKey[160:])
  invShiftRows(state)
  invSubBytes(state)

  for i := 144; i != 0; i -= 16 {
    addRoundKey(state, expandedKey[i:i+16])
    invMixColumns(state)
    invShiftRows(state)
    invSubBytes(state)
  }
  // Last round
```

```
  addRoundKey(state, expandedKey[:16])
}
```

MixColumns is the same as in **Design**, where I explain how lookup tables can be used towards the end of the **Mix Columns** section.

In Go, names of functions and global variables starting with a capital letter are exported in the package, hence why Encrypt, Decrypt and ExpandKey all start with a capital letter, while other names in the file begin with a lower case letter. These names can be accessed when the package is imported like this:

```
package main

import (
  "package"
)

func main() {
  package.Name()
}
```

The expanded key is passed by reference to Encrypt and Decrypt so it does not keep being copied by functions. This increases speed slightly. The state is passed to each function as a slice, which is an array that can change size. In Go, slices are always passed by reference, so I do not need to worry about dereferencing it or anything, and hence why none of the functions in the `AES` package return any values (apart from for key expansion).

AESfiles package

Here is the `AESfiles` package in `code/python-go/AES/src/AES/AESfiles/aesFiles.go`:

```
package AESfiles

import (
  "os"        // For opening files
  "io"        // For reading files
  "runtime"   // For getting CPU core count
  "AES"
  "AES/AEScheckKey"
)

const DEFAULT_BUFFER_SIZE = 65536  // Define the default buffer size for enc/decrypt (is 2^16)

func check(e error) {  // Checks error given
  if e != nil { panic(e) }
}

func getNumOfCores() int {  // Gets the number of cores so the number of workers can be determined.
  maxProcs := runtime.GOMAXPROCS(0)
  numCPU := runtime.NumCPU()
  if maxProcs < numCPU {
    return maxProcs
  }
  return numCPU
}

// For holding the buffer to be worked on and the offset together, so it can be written to the file in the
correct place at the end.
type work struct {
  buff []byte
  offset int64
}
```

```
31
32  func workerEnc(jobs <-chan work, results chan<- work, expandedKey *[176]byte) {    // Encrypts a chunk when
    given (a chunk of length bufferSize)
33    for job := range jobs {
34      for i := 0; i < len(job.buff); i += 16 {
35        AES.Encrypt(job.buff[i:i+16], expandedKey)
36      }
37      results<- job // Return result with encrypted job
38    }
39  }
40
41  func workerDec(jobs <-chan work, results chan<- work, expandedKey *[176]byte, fileSize int) {
42    for job := range jobs {
43      for i := 0; i < len(job.buff); i += 16 {
44        AES.Decrypt(job.buff[i:i+16], expandedKey)
45      }
46      results<- job  // Return job with decrypted buffer
47    }
48  }
49
50  func EncryptFile(expandedKey *[176]byte, f, w string) {
51    a, err := os.Open(f)    // Open original file to get statistics and read data.
52    check(err)
53    aInfo, err := a.Stat()  // Get statistics
54    check(err)
55
56    fileSize := int(aInfo.Size()) // Get size of original file
57
58    if _, err := os.Stat(w); err == nil { // If file already exists, delete it
59      os.Remove(w)
60    }
61
62    var workingWorkers int = 0
63    var workerNum int = getNumOfCores()*2
64
65    jobs := make(chan work, workerNum)     // Make two channels for go routines to communicate over.
66    results := make(chan work, workerNum)  // Each has a buffer of length workerNum
67
68    for i := 0; i < workerNum; i++ {
69      go workerEnc(jobs, results, expandedKey)   // Create the workers
70    }
71    /*
72    Each go routine will be given access to the job channel, where each worker then waits to complete the job.
73    Once the job is completed, the go routine pushes the result onto the result channel, where the result can be
74    recieved by the main routine. The results are read once all of the go routines are busy, or if the file
75    is completed, then the remaining workers still working are asked for their results.
76    */
77    var bufferSize int = DEFAULT_BUFFER_SIZE
78
79    if fileSize < bufferSize {    // If the buffer size is larger than the file size, just read the whole file.
80      bufferSize = fileSize
81    }
82
83    var buffCount int = 0   // Keeps track of how far through the file we are
84
85    e, err := os.OpenFile(w, os.O_CREATE|os.O_WRONLY, 0644) // Open file for writing.
86    check(err)  // Check it opened correctly
87
88    // Append key so that when decrypting, the key can be checked before decrypting the whole file.
89    originalKey := make([]byte, 16)
90    for i := 0; i < 16; i++ {
91      originalKey[i] = expandedKey[i]
92    }
93    AES.Encrypt(originalKey, expandedKey)
94    e.Write(originalKey)
95    offset := 16
96
97    for buffCount < fileSize {    // Same as a while buffCount < fileSize: in python3
98      if bufferSize > (fileSize - buffCount) {
```

```
      bufferSize = fileSize - buffCount    // If this is the last block, read the amount of data left in the file.
    }

    buff := make([]byte, bufferSize)  // Make a slice the size of the buffer
    _, err := io.ReadFull(a, buff) // Read the contents of the original file, but only enough to fill the buff array.
                                   // The "_" tells go to ignore the value returned by io.ReadFull, which in this case is the number of bytes read.
    check(err)

    if len(buff) % 16 != 0 {  // If the buffer is not divisable by 16 (usually the end of a file), then padding needs to be added.
      var extraNeeded int
      var l int = len(buff)
      for l % 16 != 0 {       // extraNeeded holds the value for how much padding the block needs.
        l++
        extraNeeded++
      }

      for i := 0; i < extraNeeded; i++ {                  // Add the number of extra bytes needed to the end of the block, if the block is not long enough.
        buff = append(buff, byte(extraNeeded))  // For example, the array [1, 1, 1, 1, 1, 1, 1, 1] would have the number 8 appended to then end 8 times to make the array 16 in length.
      } // This is so that when the block is decrypted, the pattern can be recognised, and the correct amount of padding can be removed.
    }

    jobs <- work{buff: buff, offset: int64(offset)} // Input new work into the jobs channel.
    workingWorkers++

    if workingWorkers == workerNum {  // Once all workers are working, wait for results.
      workingWorkers = 0
      for i := 0; i < workerNum; i++ {
        wk := <-results
        e.WriteAt(wk.buff, wk.offset)   // Write the buffer at the offset specified.
      }
    }

    offset += bufferSize
    buffCount += bufferSize
  }

  if workingWorkers != 0 { // If there are still workers working, then accept the results.
    for i := 0; i < workingWorkers; i++ {
      wk := <-results
      e.WriteAt(wk.buff, wk.offset)
    }
  }

  close(jobs)   // Close the channels since the file has been finished.
  close(results)

  a.Close()  // Close the files used.
  e.Close()
}


func DecryptFile(expandedKey *[176]byte, f, w string) {
  a, err := os.Open(f)
  check(err)
  aInfo, err := a.Stat()
  check(err)

  fileSize := int(aInfo.Size())-16 // Take away length of added key for checksum

  if _, err := os.Stat(w); err == nil { // If file exists, delete it
    os.Remove(w)
  }
```

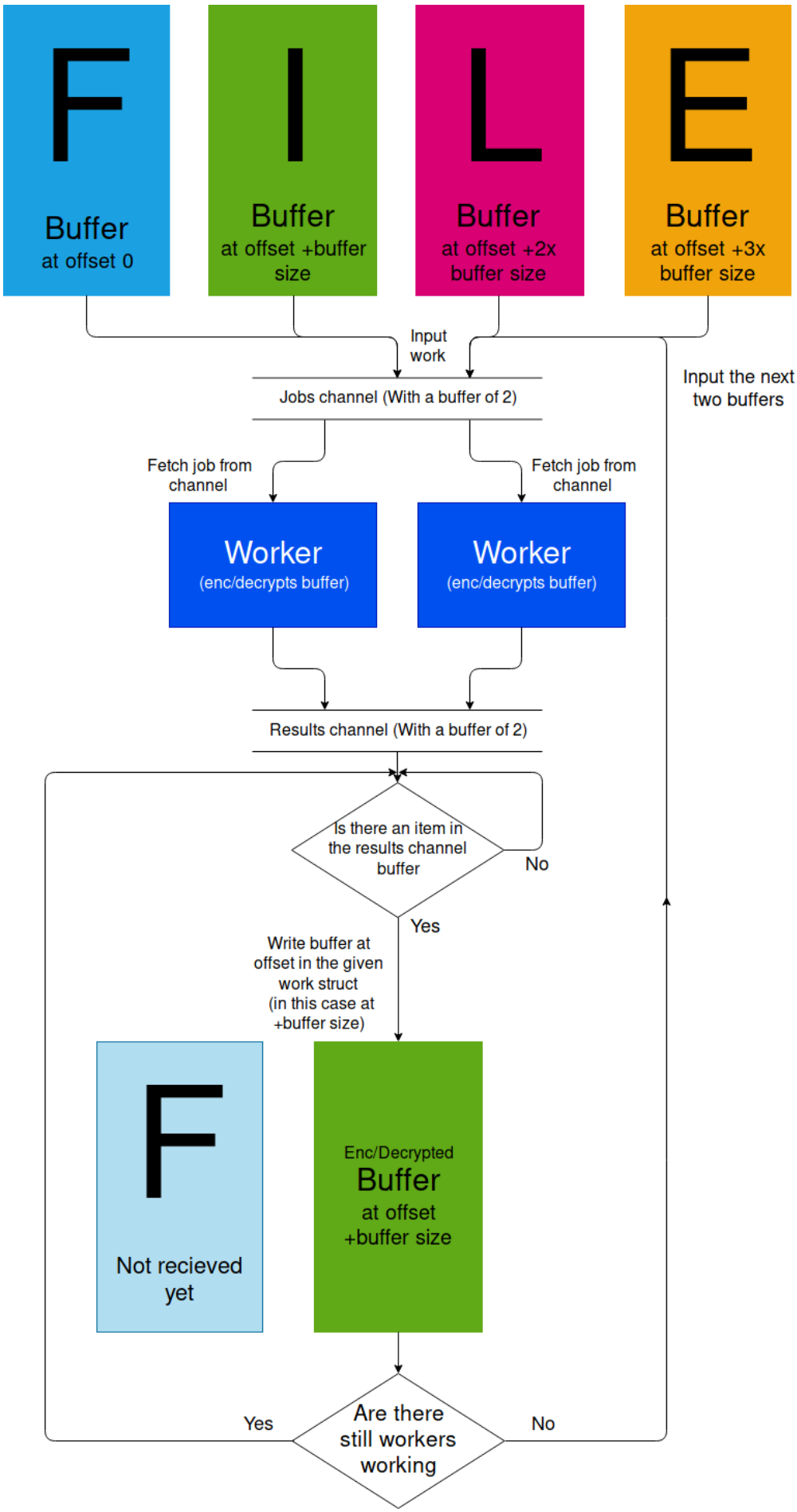
```
161
162   var bufferSize int = DEFAULT_BUFFER_SIZE
163
164   var workingWorkers int = 0
165   var workerNum int = getNumOfCores()*2
166
167   jobs := make(chan work, workerNum)     // Make two channels for go routines to communicate over.
168   results := make(chan work, workerNum)  // Each has a buffer of length workerNum
169
170   for i := 0; i < workerNum; i++ {
171     go workerDec(jobs, results, expandedKey, fileSize)
172   }
173
174   if fileSize < bufferSize {
175     bufferSize = fileSize
176   }
177
178   var buffCount int = 0
179
180   e, err := os.OpenFile(w, os.O_CREATE|os.O_WRONLY, 0644) // Open file
181   check(err)
182
183   // Check first block is key
184   firstBlock := make([]byte, 16)
185   _, er := io.ReadFull(a, firstBlock)
186   check(er)
187
188   if AEScheckKey.CheckKey(expandedKey, firstBlock) { // If key is valid
189     offset := 0
190     a.Seek(16, 0) // Move past key in encrypted file
191     for buffCount < fileSize{   // While the data done is less than the fileSize
192       if bufferSize > (fileSize - buffCount) {
193         bufferSize = fileSize - buffCount
194       }
195
196       buff := make([]byte, bufferSize)
197       _, err := io.ReadFull(a, buff)  // Ignore the number of bytes read (_)
198       check(err)
199
200       jobs<- work{buff: buff, offset: int64(offset)}
201       workingWorkers++
202
203       if workingWorkers == workerNum {
204         workingWorkers = 0
205         for i := 0; i < workerNum; i++ {
206           wk := <-results
207           e.WriteAt(wk.buff, wk.offset)
208         }
209       }
210
211       offset += bufferSize
212       buffCount += bufferSize
213     }
214
215     if workingWorkers != 0 {
216       for i := 0; i < workingWorkers; i++ {  // Collect all but last block
217         wk := <-results
218         if int(wk.offset)+bufferSize >= fileSize {    // If the offset is the last block in file
219           wk.buff = checkForPadding(wk.buff)
220         }
221         e.WriteAt(wk.buff, wk.offset)
222       }
223     }
224     close(jobs)
225     close(results)
226
227   } else {
228     panic("Invalid Key")  // If first block is not equal to the key, then do not bother trying to decrypt the
    file.
```

```
  }
  a.Close()
  e.Close()
}

func checkForPadding(buffer []byte) []byte {  // Checks a block for padding
  var focus byte = buffer[len(buffer)-1]
  var focusCount byte = 0
  if focus < 16 {
    for j := 1; (buffer[len(buffer)-j] == focus) && (j <= 16); j++ {
      if buffer[len(buffer)-j] == focus { focusCount++ }
    }
    if focus == focusCount {
      buffer = buffer[:len(buffer)-int(focusCount)]  // If the number of bytes at the end is equal to the value of each byte, then remove them, as it is padding.
    }
  }
  return buffer
}

// For dealing with directories
func EncryptList(expandedKey *[176]byte, fileList []string, targetList []string) {  // Encrypts list of files given to the corresponding targets.
  if len(fileList) != len(targetList) { panic("fileList and targList are different in length") }
  for i := range fileList {
    EncryptFile(expandedKey, fileList[i], targetList[i])
  }
}

func DecryptList(expandedKey *[176]byte, fileList []string, targetList []string) {  // Decrypts list of files given to the corresponding targets.
  if len(fileList) != len(targetList) { panic("fileList and targList are different in length") }
  for i := range fileList {
    DecryptFile(expandedKey, fileList[i], targetList[i])
  }
}
```

Enc/decryption of files is done in parallel (using multiple processes/CPU cores) by having 'workers' that accept jobs from a work channel, do work on each job given and return them in a results channel. The workers are really just a function that is run in a **g**oroutine (coroutines that are designed to be easy to use and low on memory), and each worker waits for a job on the job channel while the job channel is open. The job channel allows for the transfer of a `work` struct to the goroutine, containing a full buffer of the original file, and what offset in the file that buffer was read from. The offset is important because each goroutine may finish at a different time, and the data has to be in the correct order, however it does not need to be written to the new file at the same time. As long as it is in order it is fine.

If on the last block of decryption, then the program checks for padding, which works the same as specified in the **Design** section. If the last element of the last block has a value less than 16, it counts how many of that number occur going back through the block, and if the number of occurrences matches the value itself, then the occurrences

Here is a visual representation of this process:


F
Buffer
at offset 0
I
Buffer
at offset +buffer size
L
Buffer
at offset +2x buffer size
E
Buffer
at offset +3x buffer size
Input work
Input the next two buffers
Jobs channel (With a buffer of 2)
Fetch job from channel
Fetch job from channel
Worker
(enc/decrypts buffer)
Worker
(enc/decrypts buffer)
Results channel (With a buffer of 2)
Is there an item in the results channel buffer
No
Yes
Write buffer at offset in the given work struct (in this case at +buffer size)
F
Not recieved yet
Enc/Decrypted
Buffer
at offset +buffer size
Yes
Are there still workers working
No

The number of workers is determined by the number of cores, and is then multiplied by 2 because I wanted the CPU usage to be about 85-90%, using a lot of cpu usage but also leaving room for other processes. The `DEFAULT_BUFFER_SIZE` is set to a power of 2 (2^x) as this is a very divisable number.

I did play with the `DEFAULT_BUFFER_SIZE` value on multiple machines, and ended up settling on 2^16, as it seemed to perform best on several computers.

`EncryptList` and `DecryptList` take a list of files to enc/decrypt, and a list of targets to decrypt each file in the list to. This is used when enc/decrypting folders. Separating this function from the generation of the lists is a good idea because it makes programming additional features more flexible, as the list does not necessarily need to be created in Go.

The lists are generated in the `AESstring` package, which we will look at next.

AESstring package

The AESstring package contains functions for enc/decrypting strings, and generating lists of directories that need enc/decrypting.

All file names are encoded in base 64 to allow for larger file names to be encrypted (since with hex encoding, the name's size would increase by 2x, since each charachter is 1 byte). The maximum file name length on most operating systems is 255 in length, and the maximum length for a string to be encoded into base 64 to be within the 255 byte limit is 176 bytes.

Here is the package (`code/python-go/AES/src/AES/AESstring/aesString.go`):

```go
package AESstring

import (
  "os"                  // For making new folders
  "log"                 // For debugging
  "io/ioutil"           // For listing contents of directories
  b64 "encoding/base64" // For enc/decoding encrypted string
  "AES"
  "sorts" // QuickSortAlph made in sorts.go
)

func EncryptFileName(expandedKey *[176]byte, name string) string {
  var byteName = []byte(name)

  for len(byteName) % 16 != 0 {   // Pad with 0's
    byteName = append(byteName, 0)
  }

  for i := 0; i < len(byteName); i += 16 {
    AES.Encrypt(byteName[i:i+16], expandedKey)  // Done by reference so does not need to be assigned
  }
  return b64.URLEncoding.EncodeToString(byteName) // URL encoding used so it is safe for file systems ("/")
}

func DecryptFileName(expandedKey *[176]byte, hexName string) string {
  byteName, err := b64.URLEncoding.DecodeString(hexName)
  if err != nil { panic(err) }

  for i := 0; i < len(byteName); i += 16 {
    AES.Decrypt(byteName[i:i+16], expandedKey)
  }
  byteName = checkForPadding(byteName)
  return string(byteName[:])
}

func checkForPadding(input []byte) []byte {
```

```
  var newBytes []byte
  for _, element := range input {
    if (element > 31) && (element < 127) {    //If a character
      newBytes = append(newBytes, element)
    }
  }
  return newBytes
}

func EncryptListOfString(expandedKey *[176]byte, l []string) []string {
  for i := range l {
    l[i] = EncryptFileName(expandedKey, l[i])
  }
  return l
}

func DecryptListOfString(expandedKey *[176]byte, l []string) []string {
  var out []string
  for i := range l {
    out = append(out, DecryptFileName(expandedKey, l[i]))
  }
  return out
}

func GetListsEnc(expandedKey *[176]byte, fileList, targetList []string, folder, target string) ([]string,
[]string) { // Also makes the folders required
  os.Mkdir(target, os.ModePerm)
  list, err := ioutil.ReadDir(folder)
  if err != nil { panic(err) }        // Go has weird error handling
  for i := range list {
    if len(list[i].Name()) <= 176 {
      if list[i].IsDir() {
        fileList, targetList = GetListsEnc(expandedKey, fileList, targetList, folder+list[i].Name()+"/",
target+EncryptFileName(expandedKey, list[i].Name())+"/")  // Recursively go through folders
      } else {
        fileList   = append(fileList, folder+list[i].Name())
        targetList = append(targetList, target+EncryptFileName(expandedKey, list[i].Name()))
      }
    } else {
      log.Output(0, "File name too long: "+list[i].Name())
    }
  }
  return fileList, targetList
}

func GetListsDec(expandedKey *[176]byte, fileList, targetList []string, folder, target string) ([]string,
[]string) {
  os.Mkdir(target, os.ModePerm)
  list, err := ioutil.ReadDir(folder)
  if err != nil { panic(err) }
  for i := range list {
    if list[i].IsDir() {
      fileList, targetList = GetListsDec(expandedKey, fileList, targetList, folder+list[i].Name()+"/",
target+DecryptFileName(expandedKey, list[i].Name())+"/")
    } else {
      fileList   = append(fileList, folder+list[i].Name())
      targetList = append(targetList, target+DecryptFileName(expandedKey, list[i].Name()))
    }
  }
  return fileList, targetList
}

func getSortedFoldersAndFiles(inp []sorts.Tuple) ([]string, []string) {
  var files []sorts.Tuple
  var folders []sorts.Tuple
  for i := 0; i < len(inp); i++ {
    if inp[i].A.IsDir() {
      folders = append(folders, inp[i])
    } else {
```

```
      files = append(files, inp[i])
    }
  }
  foldersSort, filesSort := sorts.QuickSortAlph(folders), sorts.QuickSortAlph(files)  // Sort the folders and files.
  var (
    encOut []string
    decOut []string
  )
  for x := range foldersSort { // Append folder names to each list.
    encOut = append(encOut, foldersSort[x].A.Name())
    decOut = append(decOut, foldersSort[x].B)
  }
  for y := range filesSort {   // Append file names to each list.
    encOut = append(encOut, filesSort[y].A.Name())
    decOut = append(decOut, filesSort[y].B)
  }
  return encOut, decOut
}

func GetListOfFiles(expandedKey *[176]byte, dir string) ([]string, []string) {  // Decrypts a list of files at the directory specified, also returning original list
  list, err := ioutil.ReadDir(dir)
  if err != nil { panic(err) }
  l := make([]sorts.Tuple, 0)
  var listOfNames []string
  for x := range list {
    listOfNames = append(listOfNames, list[x].Name())
  }
  dec := DecryptListOfString(expandedKey, listOfNames)

  for i := range list {
    l = append(l, sorts.Tuple{A: list[i], B: dec[i]})  // Make a tuple containing the encrypted name and the decrypted name.
  }                                                    // These need to be paired so the encrypted names can be returned in order.
  return getSortedFoldersAndFiles(l)
}
```

In `GetListOfFiles`, the directory given is listed, decrypted, and then tuples containing the file info object and decrypted name are sorted.

AEScheckKey package

This package handles key checking. It takes the first 16 byte block of a file, or a block given, and decrypts the block then compares it against the key given to decrypt it with. This is because in encryption, the key is encrypted and written to the first 16 bytes of the file so that it can be checked when decrypting it.

This system works well, and is better than decrypting the whole file just to try and open it and realising that the key was incorrect.

Here is the code for the AEScheckKey package (`code/python-go/AES/src/AES/AEScheckKey/aesCheckKey.go`):

```
package AEScheckKey

import (
  "os"
  "io"
  "AES"
)

func compareSlices(slice1, slice2 []byte) bool {    // Function used for checking first block of a file with the key when decrypting.
  if len(slice1) != len(slice2) {
```

```
    return false
  } else {
    for i := 0; i < len(slice1); i++ {
      if slice1[i] != slice2[i] {
        return false
      }
    }
  }
  return true
}

func CheckKey(expandedKey *[176]byte, block []byte) bool {
  AES.Decrypt(block, expandedKey)    // Decrypt first block
  return compareSlices(expandedKey[:16], block) // Compare decrypted first block with the key.
}

func CheckKeyOfFile(key []byte, f string) bool {
  a, err := os.Open(f)    // Open an encrypted file to check first block against key
  if err != nil { panic(err) }

  firstBlock := make([]byte, 16)
  _, er := io.ReadFull(a, firstBlock)   // Fill a slice of length 16 with the first block of 16 bytes in the file.
  if er != nil { panic(er) }
  a.Close()
  expKey := AES.ExpandKey(key)
  return CheckKey(&expKey, firstBlock)
}
```

The expanded key `expKey` is passed by reference, so on line `36`, the "&" gets the memory address (pointer) to the `expKey` array.

`CheckKeyOfFile` decrypts the first block of a file and compares it to the key. If the decrypted block is the same as the key, then the key is valid. `CheckKey` does the same, however it takes a 16 byte block and checks the key against it. `compareSlices` is used internally to check the key against the decrypted block, so it does not need to be exported so the first letter of the function is lower case.

The main package

Every Go program that runs by itself requires a main package, with a main function.

Here is the main package (`code/python-go/AES/main.go`):

```
package main

import (
  "AES"
  "AES/AEScheckKey"
  "AES/AESfiles"
  "AES/AESstring"
  "fmt"       // For sending output on stout
  "io/ioutil" // For reading from stdin
  "log"
  "os" // Gets stdin
  "sorts"
  "strconv" // ^
  "strings" // For converting string key to an array of bytes
)

func strToInt(str string) (int, error) { // Used for converting string to integer, as go doesn't have that built in for some reason
  n := strings.Split(str, ".") // Splits by decimal point
  return strconv.Atoi(n[0])    // Returns integer of whole number
}
```

```
21
22  func main() {
23    bytes, err := ioutil.ReadAll(os.Stdin)
24    if err != nil {
25      panic(err)
26    }
27    fields := strings.Split(string(bytes), ", ")
28    request := string(fields[0])
29    var expandedKey [176]byte
30    var key []byte
31
32    keyString := strings.Split(string(fields[3]), " ")
33    for i := 0; i < len(keyString); i++ {
34      a, err := strToInt(keyString[i])
35      if err != nil {
36        panic(err)
37      }
38      key = append(key, byte(a))
39    }
40    expandedKey = AES.ExpandKey(key)
41
42    if request == "y" {
43      AESfiles.EncryptFile(&expandedKey, string(fields[1]), string(fields[2]))
44    } else if request == "n" {
45      AESfiles.DecryptFile(&expandedKey, string(fields[1]), string(fields[2]))
46    } else if request == "yDir" {
47      AESfiles.EncryptList(&expandedKey, strings.Split(string(fields[1]), "\n"), strings.Split(string(fields[2]),
"\n"))
48    } else if request == "nDir" {
49      AESfiles.DecryptList(&expandedKey, strings.Split(string(fields[1]), "\n"), strings.Split(string(fields[2]),
"\n"))
50    } else if request == "encString" {
51      fmt.Print(AESstring.EncryptFileName(&expandedKey, string(fields[1])))
52    } else if request == "decString" {
53      fmt.Print(AESstring.DecryptFileName(&expandedKey, string(fields[1])))
54    } else if request == "encList" {
55      fmt.Print(strings.Join(AESstring.EncryptListOfString(&expandedKey, strings.Split(string(fields[1]), "\n")),
",,"))
56    } else if request == "decList" {
57      fmt.Print(strings.Join(AESstring.DecryptListOfString(&expandedKey, strings.Split(string(fields[1]), "\n")),
",,"))
58    } else if request == "getListsy" {
59      fileList, targList := AESstring.GetListsEnc(&expandedKey, []string{}, []string{}, string(fields[1]),
string(fields[2]))
60      fmt.Print(strings.Join(fileList, ",,") + "--!--")
61      fmt.Print(strings.Join(targList, ",,"))
62    } else if request == "getListsn" {
63      fileList, targList := AESstring.GetListsDec(&expandedKey, []string{}, []string{}, string(fields[1]),
string(fields[2]))
64      fmt.Print(strings.Join(fileList, ",,") + "--!--")
65      fmt.Print(strings.Join(targList, ",,"))
66    } else if request == "listDir" {
67      log.Output(0, "Getting List")
68      fs, fsDec := AESstring.GetListOfFiles(&expandedKey, string(fields[1]))
69      fmt.Print(strings.Join(fs, ",,") + "--!--")
70      fmt.Print(strings.Join(fsDec, ",,"))
71    } else if request == "sortSize" {
72      fmt.Print(strings.Join(sorts.UseQuickSortSize(strings.Split(string(fields[1]), "\n")), ",,"))
73    } else if request == "sortAlph" {
74      fmt.Print(strings.Join(sorts.UseQuickSortAlph(strings.Split(string(fields[1]), "\n")), ",,"))
75      log.Output(0, "Sorting alph")
76    } else if request == "sortSearch" {
77      fmt.Print(strings.Join(sorts.UseQuickSortSearch(strings.Split(string(fields[1]), "\n"),
strings.Split(string(fields[2]), "\n")), ",,"))
78    } else if request == "test" {
79      valid := AEScheckKey.CheckKeyOfFile(key, string(fields[1]))
80      if valid {
81        fmt.Print("-Valid-")
82      } else {
```

```
      fmt.Print("-NotValid-")
    }
  } else {
    panic("Invalid options.")
  }
}
```

The `main` function is run when the executable, `code/python-go/AES/AES` or `code/python-go/AESWin.exe` for Windows, is started. My `main` function accepts input from `stdin` (system's way of comunicating between programs), which stands for standard input. The results are returned on `stdout` (standard output), which are then recieved by Python.

The program accepts the fields `<encryptionType>, <field1>, <field2>, <key>`, where `<field1>` is the first argument of the function you want to execute, and `<field2>` is the second argument. If there is no `<field2>` argument, then this can just be set to `0`. The key is input like this: `1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16` (it is hashed first though), where it is then split by the space in-between each number, and each number is converted to a byte, where it can be used in the functions that need it.

If an array is needed to be passed through `field1` or `field2`, then it is joined with a new line `"\n"`, as the fields are separated with `,`. If an array is returned by the program, it is joined with `",,"`, and if multiple arrays are to be returned then they are separated with `--!--`.

A full command to AES would look like this:

```
'y', '/home/josh/file.png', '/home/josh/temp', '1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16'
```

This string would get passed to the standard input of the program.

`aes.go` is compiled to `AES` for Linux/MacOS, and `AESWin.exe` for Windows.

`build.sh` just compiles the main code. Here it is:

```
#!/bin/bash
export GOPATH="/home/josh/nea-12ColcloughJ/code/python-go/AES/"
go build
```

It exists because I am too lazy to paste the GOPATH environment variable into the terminal whenever I want to build it. Go requires that you set the GOPATH environment variable saying where the source code is to compile it. This bash script made it easier to go from building AES to building BLAKE.

SHA256:

Here is the code for SHA256 (`code/python-go/SHA.py`, `code/mobile/SHA.py`):

```
k = [0x428a2f98, 0x71374491, 0xb5c0fbcf, 0xe9b5dba5,    #Round constants
     0x3956c25b, 0x59f111f1, 0x923f82a4, 0xab1c5ed5,
     0xd807aa98, 0x12835b01, 0x243185be, 0x550c7dc3,
     0x72be5d74, 0x80deb1fe, 0x9bdc06a7, 0xc19bf174,
     0xe49b69c1, 0xefbe4786, 0x0fc19dc6, 0x240ca1cc,
     0x2de92c6f, 0x4a7484aa, 0x5cb0a9dc, 0x76f988da,
     0x983e5152, 0xa831c66d, 0xb00327c8, 0xbf597fc7,
     0xc6e00bf3, 0xd5a79147, 0x06ca6351, 0x14292967,
     0x27b70a85, 0x2e1b2138, 0x4d2c6dfc, 0x53380d13,
     0x650a7354, 0x766a0abb, 0x81c2c92e, 0x92722c85,
     0xa2bfe8a1, 0xa81a664b, 0xc24b8b70, 0xc76c51a3,
     0xd192e819, 0xd6990624, 0xf40e3585, 0x106aa070,
     0x19a4c116, 0x1e376c08, 0x2748774c, 0x34b0bcb5,
```

```
     0x391c0cb3, 0x4ed8aa4a, 0x5b9cca4f, 0x682e6ff3,
     0x748f82ee, 0x78a5636f, 0x84c87814, 0x8cc70208,
     0x90befffa, 0xa4506ceb, 0xbef9a3f7, 0xc67178f2]

def makeBitArray(inp):
    bitArray = []
    for element in inp:
        tempByte = intToBits(element)
        for bit in tempByte:
            bitArray.append(bit)
    return bitArray

def intToBits(inp, bitLength=8):
    tempByte = []
    for x in range(bitLength):
        tempByte.append(0)  #Initialize
    for i in range(bitLength):
        tempByte[(bitLength-1)-i] = (inp >> i) & 1 #Goes through bits backwards so append backwards.
    return tempByte

def bitsToInt(inp):
    return int("".join(str(i) for i in inp), 2)


def pad(inpBits):   #https://csrc.nist.gov/csrc/media/publications/fips/180/4/archive/2012-03-06/documents/fips180-4.pdf section 5.1
    l = len(inpBits)
    if (l % 512 == 0) and l != 0:
        return inpBits
    else:
        inpBits.append(1) #Add one to the end of the message
        # 448%512 = k + l + 1
        #k = 448-(l+1)
        k = 448-(l+1)
        for i in range(k):
            inpBits.append(0)
        #Pad with message length expessed as 64 bit binary number
        lengthBits = intToBits(l, 64)
        for x in lengthBits:
            inpBits.append(x)
        return inpBits


def checkLessThan32(num):  # Used for getting the index to move the element in an array in RotR
    if num < 32:
        return num
    else:
        return num - 32

def checkShiftInBounds(word, num): # Similar to checkLessThan32, however it is for shifting.
    if (num < 0) or (num >= 32):
        return 0
    else:
        return word[num]


def notArray(array, l=32):
    temp = []
    for x in range(l):
        temp.append(0)
    for i in range(l):
        if array[i] == 1:
            temp[i] = 0
        else:
            temp[i] = 1
    return temp

def xorArrays(array1, array2):  # XORs two arrays
    temp = [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
```

```
    for i in range(32):
        temp[i] = array1[i] ^ array2[i]
    return temp

def andBitArrays(array1, array2):  # Does AND on two arrays
    temp = [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]
    for i in range(32):
        temp[i] = array1[i] & array2[i]
    return temp

def RotR(word, amount):
    temp = [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] #32Bits

    for i in range(32):
        temp[i] = word[checkLessThan32(i-amount)]
    return temp

def addMod2W(array1, array2, W=32):    # Adds % 2^W two arrays, so that the word does not overflow it's word length
    if len(array1) != len(array2):
        raise IndexError("Arrays not same size - ", array1, array2)
    return intToBits((bitsToInt(array1) + bitsToInt(array2)) % 2**W, 32)

def ShR(x, n):
    temp = [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0]

    for i in range(32):
        temp[i] = checkShiftInBounds(x, i-n)
    return temp

def SigExpansion0(x):
    return xorArrays(xorArrays(RotR(x, 7), RotR(x, 18)), ShR(x, 3))

def SigExpansion1(x):
    return xorArrays(xorArrays(RotR(x, 17), RotR(x, 19)), ShR(x, 10))

def Sig0(x):
    return xorArrays(xorArrays(RotR(x, 2), RotR(x, 13)), RotR(x, 22))

def Sig1(x):
    return xorArrays(xorArrays(RotR(x, 6), RotR(x, 11)), RotR(x, 25))

def Ch(x, y, z):
    return xorArrays(andBitArrays(x, y), andBitArrays(notArray(x), z))

def Maj(x, y, z):
    return xorArrays(xorArrays(andBitArrays(x, y), andBitArrays(x, z)), andBitArrays(y, z))

def sha256(inp):
    #Initial hash values - https://csrc.nist.gov/csrc/media/publications/fips/180/4/archive/2012-03-06/documents/fips180-4.pdf section 5.3.3
    hList = [0x6a09e667,    # H0
             0xbb67ae85,    # H1
             0x3c6ef372,    # H2
             0xa54ff53a,    # H3
             0x510e527f,    # H4
             0x9b05688c,    # H5
             0x1f83d9ab,    # H6
             0x5be0cd19]    # H7

    bits = makeBitArray(inp)
    bits = pad(bits)
    bits = [bits[x:x+32] for x in range(0, len(bits), 32)]  #Split padded message into 32 bit words
    bits = bits+[[0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0] for y in range(48)]
    #Main part

    for x in range(16, 64): #Expand current bits to be 64 words
```

```
        bits[x] = addMod2W(addMod2W(addMod2W(bits[x-16], SigExpansion0(bits[x-15])), bits[x-7]), SigExpansion1(bits[x-2]))

    a = intToBits(hList[0], 32)
    b = intToBits(hList[1], 32)
    c = intToBits(hList[2], 32)
    d = intToBits(hList[3], 32)
    e = intToBits(hList[4], 32)
    f = intToBits(hList[5], 32)
    g = intToBits(hList[6], 32)
    h = intToBits(hList[7], 32)

    for i in range(64):
        temp1 = addMod2W(addMod2W(addMod2W(addMod2W(h, Sig1(e)), Ch(e, f, g)), intToBits(k[i], 32)), bits[i])
        S0 = Sig0(a)
        maj = Maj(a, b, c)

        h = g
        g = f
        f = e
        e = addMod2W(d, temp1)
        d = c
        c = b
        b = a
        a = addMod2W(temp1, addMod2W(S0, maj))

    resultBits = addMod2W(intToBits(hList[0], 32), a)+addMod2W(intToBits(hList[1], 32), b)+addMod2W(intToBits(hList[2], 32), c)+addMod2W(intToBits(hList[3], 32), d)+addMod2W(intToBits(hList[4], 32), e)+addMod2W(intToBits(hList[5], 32), f)+addMod2W(intToBits(hList[6], 32), g)+addMod2W(intToBits(hList[7], 32), h)
    # Looks really ugly but works better (otherwise I would have to store each in variables)

    resultBytes = [resultBits[x:x+8] for x in range(0, len(resultBits), 8)] # Makes 2D array of bytes
    result = []
    for byte in resultBytes:
        result.append(bitsToInt(byte))  # Converts each byte into an integer
    return result

def getSHA128of16(data):
    out = sha256(data)
    return [out[i]^out[i+16] for i in range(16)]
```

Each byte is made into an array of bits. Doing it this way made it easier to debug, however probably made the algorithm much slower than it needed to be. However, I don't really care too much about how fast SHA is, as it is only used a few times in the program, and only ever works on very small amounts of data, so it will probably be unnoticeable for the user.

The file is called SHA.py, and is imported by LoginScreen (default login without Bluetooth), which is in `code/kivyStuff/loginClass.py`, for use when the key is entered.

BLAKE2b:

Unlike AES, BLAKE does not have any sub-packages (like `AESfiles`). Here is the file structure of BLAKE:

```
code/python-go/BLAKE/
                    ├── BLAKE
                    ├── BLAKE.test
                    ├── build.sh
                    ├── main.go
                    ├── src
                    │   └── BLAKE
                    │       ├── blake.go
```

```
9                     │       ├── blake_test.go
10                    │       └── checksum.go
11                    ├── testBenchBLAKE.sh
12                    └── testBLAKE.sh
13
14                    2 directories, 9 files
```

It consists of two packages, `BLAKE` and `main`. `main` just communicates between Go and Python (like in AES). Here is the content of `code/python-go/BLAKE/main.go`:

```
1  package main
2
3  import (
4    "fmt"
5    "os"
6    "io/ioutil"
7    "BLAKE"
8  )
9
10 func main() {
11   bytes, err := ioutil.ReadAll(os.Stdin)  // Read file to hash from stdin
12   if err != nil { panic(err) }
13   f := string(bytes)
14
15   fmt.Printf("%x", BLAKE.GetChecksum(f, 64))
16 }
```

It is a small package, as BLAKE only accepts a file location, then returns the checksum of that file. Line 15 `fmt.Printf("%x", BLAKE.GetChecksum(f, 64))` gets the hex representation of the bytes returned by GetChecksum, and returns it on `stdout`, back to Python.

Here is the main part of the `BLAKE` package (`code/python-go/BLAKE/src/BLAKE/blake.go`):

```
1  package BLAKE
2
3  // Inital constants.
4  var k = [8]uint64 {0x6A09E667F3BCC908,
5                     0xBB67AE8584CAA73B,
6                     0x3C6EF372FE94F82B,
7                     0xA54FF53A5F1D36F1,
8                     0x510E527FADE682D1,
9                     0x9B05688C2B3E6C1F,
10                    0x1F83D9ABFB41BD6B,
11                    0x5BE0CD19137E2179}
12
13 var sigma = [12][16]uint64 {{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15},
14                            {14, 10, 4, 8, 9, 15, 13, 6, 1, 12, 0, 2, 11, 7, 5, 3},
15                            {11, 8, 12, 0, 5, 2, 15, 13, 10, 14, 3, 6, 7, 1, 9, 4},
16                            {7, 9, 3, 1, 13, 12, 11, 14, 2, 6, 5, 10, 4, 0, 15, 8},
17                            {9, 0, 5, 7, 2, 4, 10, 15, 14, 1, 11, 12, 6, 8, 3, 13},
18                            {2, 12, 6, 10, 0, 11, 8, 3, 4, 13, 7, 5, 15, 14, 1, 9},
19                            {12, 5, 1, 15, 14, 13, 4, 10, 0, 7, 6, 3, 9, 2, 8, 11},
20                            {13, 11, 7, 14, 12, 1, 3, 9, 5, 0, 15, 4, 8, 6, 2, 10},
21                            {6, 15, 14, 9, 11, 3, 0, 8, 12, 2, 13, 7, 1, 4, 10, 5},
22                            {10, 2, 8, 4, 7, 6, 1, 5, 15, 11, 9, 14, 3, 12, 13, 0},
23                            {0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15}, // Same as first line
24                            {14, 10, 4, 8, 9, 15, 13, 6, 1, 12, 0, 2, 11, 7, 5, 3}} // Same as second line
25
26
27 func rotR64(in uint64, n int) uint64 {  // For 64 bit words
28   return (in >> uint(n)) ^ (in << (64 - uint(n)))
29 }
30
31 func get64(in []uint64) uint64 {  // Gets a full 64-bit word from a list of 8 64-bit bytes.
```

```
  return uint64(in[0] ^ (in[1] << 8) ^ (in[2] << 16) ^ (in[3] << 24) ^ (in[4] << 32) ^ (in[5] << 40) ^ (in[6] << 48) ^ (in[7] << 56))
}

func blakeMix(v []uint64, a, b, c, d int, x, y *uint64) {
  v[a] = v[a] + v[b] + *x
  v[d] = rotR64((v[d] ^ v[a]), 32)

  v[c] = v[c] + v[d]
  v[b] = rotR64((v[b] ^ v[c]), 24)

  v[a] = v[a] + v[b] + *y
  v[d] = rotR64((v[d] ^ v[a]), 16)

  v[c] = v[c] + v[d]
  v[b] = rotR64((v[b] ^ v[c]), 63)
}

func BlakeCompress(h *[8]uint64, block []uint64, t int, lastBlock bool) {  // Compressing function. Takes a block of 128 uint64s
  v := make([]uint64, 16) // Current vector as a slice. This allows you to pass by reference

  v[ 0], v[ 1], v[ 2], v[ 3],     // Doing this instead of for loop allows for marginal performance increase.
  v[ 4], v[ 5], v[ 6], v[ 7],
  v[ 8], v[ 9], v[10], v[11],
  v[12], v[13], v[14], v[15] =

  h[ 0], h[ 1], h[ 2], h[ 3],
  h[ 4], h[ 5], h[ 6], h[ 7],
  k[ 0], k[ 1], k[ 2], k[ 3],
  k[ 4], k[ 5], k[ 6], k[ 7]

  v[12] ^= uint64(t)
  v[13] ^= (uint64(t) >> 64)

  if lastBlock {
    v[14] = ^v[14] // NOT
  }

  var m [16]uint64
  for i, z := 0, 0; i < 121; i, z = i+8, z+1 { // Having z prevents having to divide by 8
    m[z] = get64(block[i:i+8])
  }

  for i := 0; i < 12; i++ {
    blakeMix(v, 0, 4,  8, 12, &m[sigma[i][0]], &m[sigma[i][1]])
    blakeMix(v, 1, 5,  9, 13, &m[sigma[i][2]], &m[sigma[i][3]])
    blakeMix(v, 2, 6, 10, 14, &m[sigma[i][4]], &m[sigma[i][5]])
    blakeMix(v, 3, 7, 11, 15, &m[sigma[i][6]], &m[sigma[i][7]])

    blakeMix(v, 0, 5, 10, 15, &m[sigma[i][ 8]], &m[sigma[i][ 9]])   // Rows have been shifted
    blakeMix(v, 1, 6, 11, 12, &m[sigma[i][10]], &m[sigma[i][11]])
    blakeMix(v, 2, 7,  8, 13, &m[sigma[i][12]], &m[sigma[i][13]])
    blakeMix(v, 3, 4,  9, 14, &m[sigma[i][14]], &m[sigma[i][15]])
  }

  for i := 0; i < 8; i++ {
    h[i] ^= v[i]
    h[i] ^= v[i+8]
  }
}
```

`get64` takes 8 bytes, and sticks them together to return a single 64-bit word. I know `get64` takes an array of 64-bit words `[]uint64`, however these are read from the file as bytes, and are changed into 64-bit words, but they are bytes so none of them are bigger than 255. Here is a small example:

```
8 bytes: 0xaa 0xbb 0xcc 0xdd 0xee 0xff 0x1e 0x9d
get64: 0xaabbccddeeff1e9d
```

`blakeMix` accepts the reference to the current working vector `v` (since it is a slice it is automatically passed by reference), the elements in `v` to change, and also a reference to tow elements from the message `m`, which is the block that has been converted using the `get64` method explained above.

`h` is the current hash that is being worked on, and is also passed by reference to the compression function. Passing by reference increases speed about twofold compared to not passing by reference, as the function is called a lot it is more efficient to change one copy of the variable, rather than copying it and returning it every time the function is called.

Here is the part of the `BLAKE` package that handles getting the checksum of a file (`code/python-go/BLAKE/src/BLAKE/checksum.go`):

```
package BLAKE

import (
  "os"
  "io"
)

func check(e error) {     //Used for checking errors when reading/writing to files.
  if e != nil {
    panic(e)
  }
}

func GetChecksum(f string, hashL int) [64]byte {
  h := k  // Initialize h0-7 with initial values.
  h[0] = h[0] ^ (0x01010000 ^ uint64(hashL)) // Not using a key

  a, err := os.Open(f)    // Open file
  check(err)
  aInfo, err := a.Stat()  // Get statistics of file
  check(err)

  fileSize := int(aInfo.Size()) // Get size of original file

  var bufferSize int = 65536

  if fileSize < bufferSize {    // If the buffer size is larger than the file size, just read the whole file.
    bufferSize = fileSize
  }

  var buffCount int = 0   // Keeps track of how far through the file we are
  var bytesFed int = 0
  var bytesLeft int = fileSize

  for buffCount < fileSize {
    if bufferSize > (fileSize - buffCount) {
      bufferSize = fileSize - buffCount
    }
    buff := make([]uint64, bufferSize)
    tempBuff := make([]byte, bufferSize)  // Make a slice the size of the buffer
    _, err := io.ReadFull(a, tempBuff) // Read the contents of the original file, but only enough to fill the
buff array.
                                  // The "_" tells go to ignore the value returned by io.ReadFull, which in
this case is the number of bytes read.
    check(err)
    for i := range tempBuff {
      buff[i] = uint64(tempBuff[i])
    }
    tempBuff = nil // Delete array
```

```
48
49      for len(buff) % 128 != 0 {
50        buff = append(buff, 0)  // Append 0s when buffer is not long enough
51      }
52
53      for i := 0; i < bufferSize; i += 128 {
54        if bytesLeft <= 128 {
55          BlakeCompress(&h, buff[i:i+128], bytesFed+bytesLeft, true)
56        } else {
57          bytesFed += 128
58          BlakeCompress(&h, buff[i:i+128], bytesFed, false)
59        }
60        bytesLeft -= 128
61      }
62
63      buffCount += bufferSize
64    }
65    a.Close()
66
67    return getLittleEndian(h)
68  }
69
70  func getLittleEndian(h [8]uint64) [64]byte {
71    var out [64]byte
72    for i := 0; i < 8; i++ {
73      for j := 8; j != 0; j-- {
74        out[i*8+(j-1)] = byte(((h[i] << uint64(64 - uint64((j)*8))) & 0xFFFFFFFFFFFFFFFF) >> 56)
75      }
76    }
77    return out
78  }
```

The way that the `GetChecksum` function goes through the file is very similar to AES, however it cannot be easily parallelised like AES, as the checksum takes into account the order of the data. There is a way to make BLAKE parallel but I didn't really have the time to look into it.

`getLittleEndian` turns the array `h`, which contains 8 64-bit words, into an array of 64 bytes, that can then be turned into a hex output that is a bit more readable. The way it works is it generates a little-endian interpretation of the 64-bit words as bytes. So if I had the word $0D4D1C983FA580BA$, the output of the function would return $BA80A53F981C4D0D$. The function `getLittleEndian` uses bit masking (shifting the bits in the word around to leave the bits you want to change exposed) to get each byte of the 64-bit word, then appends the byte to the list in reverse order (since it is little-endian). Little-endian is just a way to store a number larger than a byte. Little-endian and big-endian are needed in computer systems because in memory, each address can only store a single byte, so if a number is bigger than that then the number needs to be split into separate bytes. For example, if I had the number `354`, then I would first convert that into binary:
$2 + 32 + 64 + 256 = 354$, = 101100010, however this is larger than 8 bits, so split it into two:

00000001 and 01100010, where the first byte starts at 2^8. Little-endian arranges these bytes in memory like this:

Address1: 01100010, Address2: 0000001

It is called little-endian because the smaller part of the number (little) number is stored in the first address (the end). Big-endian is just the opposite way around.

`build.sh` just compiles the main code. Here it is:

```
1  #!/bin/bash
2  export GOPATH="/home/josh/nea-12ColcloughJ/code/python-go/BLAKE/"
3  go build
```

The Sorts:

The `sorts` package is in the AES folder, as it is used a lot by AES, and the sorts are managed from AES. Here is the code (`code/python-go/AES/src/sorts/sorts.go`):

```go
package sorts

import (
  "fmt"
  "os"
  "strconv"
)

// For keeping the decrypted name with their encrypted name
type Tuple struct {
  A os.FileInfo
  B string
}

type SearchTuple struct {
  pos int
  name string
}

func UseQuickSortSize(inp []string) []string {  // Converts inputs so that QuickSortSize can be used.
  var nums []int64
  var out []string
  for i := 0; i < len(inp); i++ {
    int, err := strconv.ParseInt(inp[i], 10, 64)
    if err != nil { panic(err) }
    nums = append(nums, int)
  }
  nums = quickSort(nums)
  for i := 0; i < len(nums); i++ {
    out = append(out, strconv.FormatInt(nums[i], 10))
  }
  return out
}

func UseQuickSortAlph(inp []string) []string { // For sorting a list that has no encrypted name
  var inpToAlph []Tuple
  var out []string
  for i := 0; i < len(inp); i++ {
    inpToAlph = append(inpToAlph, Tuple{A: nil, B: inp[i]})
  }

  inpToAlph = QuickSortAlph(inpToAlph)
  for i := 0; i < len(inpToAlph); i++ {
    out = append(out, inpToAlph[i].B)
  }
  return out
}

func UseQuickSortSearch(posList, nameList []string) []string { // Returns names in order.
  var inpToSort []SearchTuple
  var out []string
  if len(posList) != len(nameList) {
    panic("Search result lists are different sizes.")
  }
  for i := 0; i < len(posList); i++ {
    intPos, err := strconv.Atoi(posList[i])
    if err != nil { panic(err) }
    inpToSort = append(inpToSort, SearchTuple{pos: intPos, name: nameList[i]})
  }
  inpToSort = quickSortSearch(inpToSort)
  for i := 0; i < len(inpToSort); i++ {
```

```
    out = append(out, inpToSort[i].name)
  }
  return out
}

func quickSort(inp []int64) []int64 {
  if len(inp) < 2 {
    return inp
  }
  var pivot int64 = inp[int(len(inp)/2)]
  var left []int64
  var middle []int64
  var right []int64
  for i := 0; i < len(inp); i++ {
    if inp[i] < pivot {
      left = append(left, inp[i])
    } else if inp[i] > pivot {
      right = append(right, inp[i])
    } else {
      middle = append(middle, inp[i])
    }
  }
  left = quickSort(left)
  right = quickSort(right)
  return append(append(left, middle...), right...)
}

func getLower(inp []byte) []byte { // .lower() in python
  var out []byte
  for i := range inp {
    out = append(out, inp[i])
    if out[i] >= 65 && out[i] <= 90 {
      out[i] += 32 // Using ASCII table
    }
  }
  return out
}

func QuickSortAlph(inp []Tuple) []Tuple {  // Only used internally by AES
  if len(inp) < 2 {
    return inp
  }
  var pivot Tuple = inp[int(len(inp)/2)]
  var left []Tuple
  var middle []Tuple
  var right []Tuple
  for i := 0; i < len(inp); i++ {
    result := compareStrings(pivot.B, inp[i].B)
    if result == 0 {
      right = append(right, inp[i])
    } else if result == 1 {
      left = append(left, inp[i])
    } else if result == 2 {
      middle = append(middle, inp[i])
    }
  }
  left = QuickSortAlph(left)
  right = QuickSortAlph(right)
  return append(append(left, middle...), right...)
}

func quickSortSearch(inp []SearchTuple) []SearchTuple { // Sorts search results
  if len(inp) < 2 {
    return inp
  }
  var pivot int = inp[int(len(inp)/2)].pos
  var left []SearchTuple
  var middle []SearchTuple
  var right []SearchTuple
```

```
  for i := 0; i < len(inp); i++ {
    if inp[i].pos < pivot {
      left = append(left, inp[i])
    } else if inp[i].pos > pivot {
      right = append(right, inp[i])
    } else {
      middle = append(middle, inp[i])
    }
  }
  left = quickSortSearch(left)
  right = quickSortSearch(right)
  return append(append(left, middle...), right...)
}

func compareStrings(string1, string2 string) int {
  if string1 == string2 {
    return 2
  }
  string1b, string2b := []byte(string1), []byte(string2) // Get the ascii values in bytes
  string1bLower, string2bLower := getLower(string1b), getLower(string2b) // Get each string as lower case

  for i := 0; i < len(string1) && i < len(string2); i++ {
    if string2bLower[i] < string1bLower[i] {
      return 1
    } else if string2bLower[i] > string1bLower[i] {
      return 0
    } else {                                        // If the characters are both the same, then compare if they
are lower case or upper case.
      if string2b[i] < string1b[i] {
        return 1
      } else if string2b[i] > string1b[i] {
        return 0
      }
    }
  }
  if len(string1) > len(string2) {      // If they are the exact same to a certain point, then compare their
lengths
    return 1
  } else if len(string1) < len(string2) {
    return 0
  } else {
    panic("Strings are the exact same!")
  }
}

func main() {
  fmt.Println("a")
}
```

The `UseQuickSort___` functions are used for formatting input from `stdin` that Python has given us.

`QuickSortAlph` is used by `AESstring`

`quickSortSearch` is used for sorting search results, as search results are collected along with the position that the search item was found in the word. For example, if I searched for "b" in a folder, and there was a file called "brian.png", then the search result would be (0, "brian.png"). `quickSortSearch` then sorts these results by the number. I need to use a tuple so that I know what string belongs to which number.

`compareStrings` starts at the first character of each string, compares the characters using `ord()` to get their ASCII value, if character1 has a bigger ASCII value than character2, then the function will return `1`, of character1 is less than character2, then the function will return `0`. If they are both the same, then the function moves onto the next pair of characters. If both strings turn out to be exactly the same, then the function returns `2`. `QuickSortAlph` uses this output to determine which side of the pivot the item should be added to. If the output of the function was `2`, then the item is the search item, so add it to the middle. If the output of the function

was `1` then append it to the left side of the list, and if the returned value was `0` then append it to the right. All of the quick sorts allways sort in ascending order, and then if the program wants it in descending order, then all you have to do is reverse the list (`list = list[::-1]`).

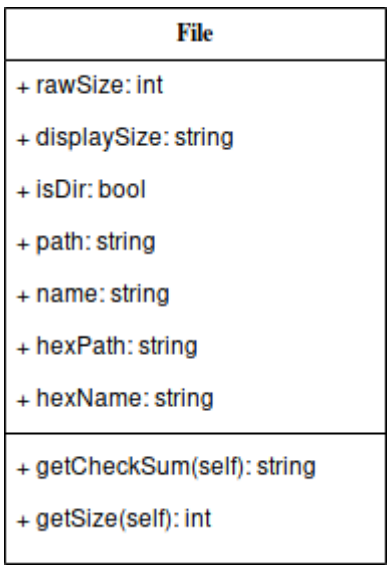
The File class:

Here is the code for the File class (`code/python-go/fileClass.py`), often assigned the variable name `fileObj` in the rest of the program:

```
from os import path as osPath
from os import listdir
from subprocess import Popen, PIPE

class File:

    def __init__(self, screen, hexPath, hexName, fileSep, extension=None, isDir=False, name=None, path=None):
        self.outerScreen = screen
        self._totalSize = 0
        self.hexPath, self.hexName, self.isDir, self.fileSep, self.extension = hexPath, hexName, isDir,
fileSep, extension
        self.thumbDir = ""
        self.checkSum = None
        self.rawSize = self.__getFileSize()
        self.size = self.outerScreen.getGoodUnit(self.rawSize)
        self.isDir = isDir
        if name == None:
            self.name = self.outerScreen.decString(self.hexName)
        else:
            self.name = name
        if path == None:
            self.path = self.__getNormDir(self.hexPath)
        else:
            self.path = path
        if extension == None:
            extension = self.path.split(".")
            self.extension = extension[-1].lower()
        else:
            extension = extension.lower()

        if self.isDir:
            self.hexPath += self.fileSep
            self.path += self.fileSep

        self.relPath = self.hexPath.replace(self.outerScreen.path, "")   # Encrypted path relative to root
folder of Vault

    def __getNormDir(self, hexDir):          # Private functions as they are usually only needed once and
should only be callable from within the class
        dir = self.fileSep.join(self.outerScreen.decListString(hexDir.replace(self.outerScreen.path,
"").split(self.fileSep)[:-1]))+self.name
        if self.isDir:
            dir += self.fileSep
        return dir

    def __getFileSize(self, recurse=True):
        if self.isDir:
            if recurse:
                self._totalSize = 0
                self.__recursiveSize(self.hexPath)
                size = self._totalSize
                return size
            else:
                return " -"
```

```
        else:
            try:
                size = osPath.getsize(self.hexPath) # Imported from os module
                return size
            except Exception as e:
                print(e, "couldn't get size.")
                return " -"

    def __recursiveSize(self, f):  #Get size of folders.
        fs = listdir(f)
        for item in fs:
            if osPath.isdir(f+self.fileSep+item):
                try:
                    self.__recursiveSize(f+self.fileSep+item)
                except OSError:
                    pass
            else:
                try:
                    self._totalSize += osPath.getsize(f+self.fileSep+item)
                except PermissionError: #Thrown when the file is owned by another user/administrator.
                    pass

    def decryptRelPath(self):       # Gets relative path from root of Vault in human form
        splitPath = self.relPath.split(self.fileSep)
        return self.fileSep.join(self.outerScreen.decListString(splitPath))
```

This is the File class talked about in the **File Storage** section of the design. As a recap, here is the class diagram I made for this class:



Most of the variables have been kept the same, however `extension` was added for when I get the thumbnail of the file, as if the file is not a png or a jpg, then a thumbnail cannot be shown (since it isn't an image). I also have the variable `outerScreen` that holds a reference to the Kivy Screen object that created it, so it can access functions and variables from the Screen if it needs to.

There are a few new functions too. `__getNormDir` gets the normal file path if path is `None` (it is also a private funtion (`__`), as it is only needed once by the object, and shouldn't be used again by anything else). `__getFileSize` gets the total size of the File object. If it is a folder (isDir) then `__recursiveSize` is called to handle it. If the size can not be read, then the function returns " -", which will display nicely in the GUI. `decryptRelPath` decrypts the path of the file relative to the Vault's root directory.

`decryptRelPath` decrypts the relative path from the Vault so it can be read by humans.

PC app GUI Code

In this section, I will go through the code for the entire GUI (basically anything in the `code/python-go/kivyStuff` folder).

The root of the GUI

The GUI is started once `code/python-go/kivyStuff/ui.py`'s runUI() function is called from `code/python-go/start.py`. Here is the code for `ui.py`:

```
from tempfile import gettempdir
from shutil import rmtree

from kivy.config import Config
Config.set("graphics", "resizable", True)
Config.set("graphics", "width", "1000") # Set default window size
Config.set("graphics", "height", "600")
Config.set("input", "mouse", "mouse,disable_multitouch") # Disable multitouch features used on mobile apps.
Config.write()

from kivy.app import App
from kivy.uix.screenmanager import ScreenManager, Screen, FadeTransition
from kivy.lang import Builder

######Import personal classes######
from mainScClass import MainScreen
from loginClass import LoginScreen, LoginScreenBT
from settingsScreen import SettingsScreen

#########Import config functions########
import configOperations


def runUI():
    ui = uiApp(title="FileMate")
    ui.run()

    # When program closes:
    print("Deleting temp files.")
    try:
        fSep = configOperations.getFileSep()
        rmtree(gettempdir()+fSep+"FileMate"+fSep) # Remove all temporary files.
    except FileNotFoundError:
        print("No temp files.")
    print("App closed.")

class uiApp(App):

    def build(self):
        sm = ScreenManager()

        sm.transition = FadeTransition() # Set transition animation when changing screens.
        fileSep, osTemp, startDir, assetsPath, path, recurseSearch, useBT, configLoc =
configOperations.runConfigOperations()
        # Load kv files for each screen.
        Builder.load_file(startDir+"kivyStuff/kvFiles/mainSc.kv")     # MainScreen styling.
        Builder.load_file(startDir+"kivyStuff/kvFiles/settingsSc.kv") # SettingsScreen styling.

        if useBT:
            Builder.load_file(startDir+"kivyStuff/kvFiles/loginScBT.kv")
            sm.add_widget(LoginScreenBT(fileSep, path, startDir, name="Login"))
        else:
            Builder.load_file(startDir+"kivyStuff/kvFiles/loginSc.kv")
            sm.add_widget(LoginScreen(fileSep, path, startDir, name="Login"))
```

```
54
55          sm.add_widget(MainScreen(fileSep, osTemp, startDir, assetsPath, path, recurseSearch, useBT, configLoc,
    name="Main")) # fileSep, osTemp, startDir, assetsPath, path, recurseSearch, useBT, **kwargs
56          sm.add_widget(SettingsScreen(sm.get_screen("Main"), configLoc, name="Settings"))
57          sm.current = "Login"
58
59          return sm
```

This is the program that runs the app itself. All it does is create the root App, and add the ScreenManager as the root widget, where then child widgets (in this case screens) can be added.

This program is called from `code/python-go/start.py`, which is used to start the program. This file is also handy because it means that when I call `import <module>` in the `code/python-go/kivyStuff/` folder, the Python programs can import Python programs from `code/python-go/`, which is where everything non-gui related is kept.

Login classes

Here is the code for both the regular login (LoginScreen), and the Bluetooth login screen (LoginScreenBT) (at `code/python-go/kivyStuff/loginClass.py`):

```
1   from os import listdir
2   from os.path import isdir as osIsDir
3   from subprocess import Popen, PIPE
4
5   from kivy.uix.screenmanager import Screen
6   from kivy.lang.builder import Builder
7   from kivy.uix.popup import Popup
8   from kivy.uix.label import Label
9
10  from kivy.clock import Clock
11  from threading import Thread
12
13  import SHA
14
15  # Try importing the BT module, if it isn't available then they just can't use BT. Imported in case the user
    wants to switch from normal login to Bluetooth login.
16  try:
17      from bluetooth import *
18  except:
19      pass
20
21  class LoginScreen(Screen):
22
23      def __init__(self, fileSep, path, startDir, **kwargs):
24          self.fileSep, self.path, self.startDir = fileSep, path, startDir  # Start dir is location of running
    program, path is path of vault
25          super(Screen, self).__init__(**kwargs)  # Run kivy's Screen.__init__ function with the key word
    arguments (such as size or position)
26          self.key = ""
27
28      def cancel(self):
29          self.manager.get_screen("Main").useBT = True                    # Am now using BT
30          Builder.load_file(self.startDir+"kivyStuff/kvFiles/loginScBT.kv") # Load the styling file for BT login
    screen
31          self.manager.add_widget(LoginScreenBT(self.fileSep, self.path, self.startDir, name="Login")) # Create
    the new screen
32          self.name = "Dead"  # To prevent clash with new login screen.
33          self.manager.current = "Login"   # Change to Login
34          self.manager.remove_widget(self) # Remove self from the app
35          self = None                      # Kill self
36
37      def findFile(self, dir):    # For finding a file to decrypt first block and compare it with key given.
```

```
        fs = listdir(dir)
        for item in fs:
            if osIsDir(dir+item+"/"):
                if self.count == 0:
                    self.findFile(dir+item+"/")
                else:
                    return
            else:
                self.decryptTestFile = dir+item
                self.count += 1
                return

    def passToTerm(self, key, d):           # Makes a pipe to communicate with AES
        if self.fileSep == "\\":
            progname = "AESWin"
        else:
            progname = "AES/AES"
        goproc = Popen(self.startDir+progname, stdin=PIPE, stdout=PIPE)
        out, err = goproc.communicate(("test, "+d+", 0, ").encode()+key.encode())
        return out

    def getIfValidKey(self, inputKey):              # Gets the output of the AES key checker.
        if len(listdir(self.path)) > 1:
            self.decryptTestFile = ""
            self.count = 0
            self.findFile(self.path)
            diditwork = self.passToTerm(inputKey, self.decryptTestFile)
            if diditwork == b"-Valid-": #The go program prints "-Valid-" or "-Invalid-" once it is done
checking the key.
                return True
            else:
                return False
        else:
            return True

    def checkKey(self, inputKey):   # Handles the GUI while the key is checked, and passes key to functions to
check it.
        if len(inputKey) < 1:
            Popup(title="Invalid", content=Label(text="Invalid key, valid key\ncontains at least 1 digit."),
pos_hint={"x_center": .5, "y_center": .5}, size_hint=(.4, .4)).open()
            return "Login"
        try:
            int(inputKey)
        except:
            Popup(title="Invalid", content=Label(text="Invalid key, valid key\ncontains no letters."),
pos_hint={"x_center": .5, "y_center": .5}, size_hint=(.4, .4)).open()
            return "Login"
        else:
            if len(str(inputKey)) > 16:
                Popup(title="Invalid", content=Label(text="Invalid key, longer than\n 16 characters."),
pos_hint={"x_center": .5, "y_center": .5}, size_hint=(.4, .4)).open()
                return "Login"
            else:
                inputKeyTemp = []
                for i in range(len(inputKey)):
                    inputKeyTemp.append(int(inputKey[i]))
                inputKey = inputKeyTemp
                inputKey = SHA.getSHA128of16(inputKey)
                key = " ".join(str(i) for i in inputKey)
                valid = self.getIfValidKey(key)
                if valid:
                    self.ids.keyInput.text = "" #reset key input if valid
                    self.key = key
                    return "Main"
                else:
                    Popup(title="Invalid", content=Label(text="Invalid key."), pos_hint={"x_center": .5,
"y_center": .5}, size_hint=(.4, .4)).open()
                    return "Login"

```

```
    def needToSetKey(self):      # Gets text to tell the user if they need to set a key.
        if len(listdir(self.path)) == 0:   # If there are no files in the vault, then the key hasn't been set yet.
            return "Input New Key (Write this down if you have to)"
        else:
            return "Input Key"


class LoginScreenBT(LoginScreen, Screen):      #Has the same methods as LoginScreen, but some overwritten with bluetooth.

    def __init__(self, fileSep, path, startDir, **kwargs):
        self.fileSep, self.path, self.startDir = fileSep, path, startDir
        super(Screen, self).__init__(**kwargs)
        self.key = ""

    def on_enter(self):
        self.serv = None
        self.startServ = Clock.schedule_once(self.startSrv, 0.5) # Use the clock to allow the screen to be rendered. (Waits 0.5 seconds for screen to be loaded.)

    def checkKey(self, inputKey):
        inputKey = inputKey.split(",")
        inputKey = inputKey[:-1]
        key = " ".join(str(i) for i in inputKey)    #Formatting for AES
        valid = self.getIfValidKey(key)
        if valid:
            self.key = key
            self.manager.get_screen("Main").key = key
            return True
        else:
            return False

    def cancel(self):
        if self.serv != None:
            self.manager.get_screen("Main").serverSock.close()  # Close the BT server
            self.serv.join()  # Close the thread that runs the server (in LoginScreenBT)
            try:
                self.manager.get_screen("Main").clientSock.close()
            except AttributeError:  # clientSock will not be initilized if there are no clients.
                pass
        else:
            self.startServ.cancel()   # Cancels scheduled task to start server, as we are switching screens anyway.

        print("Server closed.")
        self.manager.get_screen("Main").useBT = False
        Builder.load_file(self.startDir+"kivyStuff/kvFiles/loginSc.kv")
        self.manager.add_widget(LoginScreen(self.fileSep, self.path, self.startDir, name="Login"))
        self.name = "Dead"      # To prevent name clash with other login screen.
        self.manager.current = "Login"
        self.manager.remove_widget(self)
        self = None

    def startSrv(self, dt=None):
        self.serv = Thread(target=self.manager.get_screen("Main").startBT, daemon=True)  # Runs the function in MainScreen, which prevents segmentation, so I don't have to shutdown server when screen is switched
        self.serv.start()
```

`LoginScreenBT.startSrv` starts the Bluetooth server, however the server is run inside of the `MainScreen` class, which displays the files. This is important because when you change screen and have a thread running, the thread gets cut off and a `Segmentation Fault` is thrown. Running the server in `MainScreen` also means that the server does not need to be closed and opened again (which is what I was doing before I did this).

The function `cancel` is called when the user wants to switch between login screens. What it does is rename the kivy Screen to something other than "Login", load the `.kv` file for the new login screen, then create the new Login screen, and change screen to that one.

`.kv` files are for Kivy's styling language, layed out similar to css. `.kv` files work like this:

```
RootWidget:                 # Example: ScreenManager:
  ChildWidget:
    key_word_argument: value

<CustomClass@KivyClass>:    # Example: <LoginScreen@Screen>
  ...
```

For custom classes, you do not always have to specify a `KivyClass`.

Here is the style sheet `kv` file for both login screens:

LoginScreen (`code/python-go/kivyStuff/kvFiles/loginSc.kv`):

```
<LoginScreen>:
    RelativeLayout:                 #Adds background in case fade transition breaks.
        canvas.before:
            Color:
                rgba: 0,0,0,1
            Rectangle:
                pos: self.pos
                size: self.size

    Label:
        id: labelLogin
        size_hint: .46, .08
        text: root.needToSetKey()
        font_size: 22
        pos_hint: {"center_x": 0.5, "y": 0.8}

    TextInput:
        id: keyInput
        size_hint: .7, .08
        font_size: 22
        hint_text: "Key (16 characters maximum)"
        pos_hint: {"center_x": 0.5, "center_y": 0.6}
        password: True
        multiline: False
        on_text_validate: root.manager.current = root.checkKey(keyInput.text)

    Button:
        id: submitKey
        size_hint: .16, .16
        font_size: 22
        text: "Submit"
        pos_hint: {"center_x": 0.5, "center_y": 0.3}
        on_release: root.manager.current = root.checkKey(keyInput.text)

    Button:
        size_hint: .18, .16
        pos_hint: {"x": 0, "bottom": 1}
        text: "Login with BT"
        font_size: 22
        on_release: root.cancel()
```

The syntax highligting on this document may be a bit off, as the closest highlighting language is `cs`. Comments are done using `#`, however in `cs` they are `//`.

LoginScreenBT:

```
<LoginScreenBT>:
    RelativeLayout:                 #Adds background in case fade transition breaks.
        canvas.before:
            Color:
                rgba: 0,0,0,1
            Rectangle:
                pos: self.pos
                size: self.size

    Button:
        size_hint: .18, .16
        pos_hint: {"x": 0, "bottom": 1}
        text: "Login without BT"
        font_size: 22
        on_release: root.cancel()

    Label:
        id: labelLogin
        size_hint: .46, .08
        text: "Connect via bluetooth."
        font_size: 22
        pos_hint: {"center_x": 0.5, "y": 0.8}

    Label:
        id: clientLabel
        pos_hint: {"center_x": 0.5, "center_y": 0.5}
```

The `id` field of some of the widgets is used to access that widget from within the Python code. For example, to access the Label with the text "Connect via bluetooth." in LoginScreenBT, you would have to do

```
class LoginScreenBT:
  ...
  self.ids.labelLogin
  ...
```

and then from there you can change any attribute of that Label, such as the text (`self.ids.labelLogin.text = "blah"`).

The `RelativeLayout` at the top of each class is only for setting the background to black for both screens. None of the other widgets are children of the `RelativeLayout`. Just thought I should clarify that before moving onto the different types of positioning.

Positioning widgets in Kivy can work using relative positioning, or exact positioning, where exact positioning requires that you put the exact pixel coordinates as the position, while relative positioning takes the width and height of the window and translates it onto a 0 to 1 scale. `x` goes from left to right, 0 to 1, and `y` goes from bottom to top 0 to 1. When setting the `pos_hint` of each widget, there are a few other options than `"x"` and `"y"`, such as `"center_(x/y)"`, which sets the position of the widget relative to it's centre, `"top/bottom"` which sets the position relative to the top or bottom of the screen, `"left/right"` which sets the position relative to the left or right of the screen.

`size_hint` also uses the relative layout system (not actual `RelativeLayout`, there are others like `FloatLayout`) to set the size of a widget depending on the size of the screen.

Also, when I reference `root.something`, `root` is the root widget of this child widget, so in this case either `LoginScreen` or `LoginScreenBT`. `self` refers to the widget itself.

Main Screen

Here is the code for the MainScreen class (`code/python-go/kivyStuff/mainScClass.py`):

```
import os
from shutil import move, disk_usage, rmtree
from threading import Thread
from functools import partial   # For passing in functions with multiple arguments to widgets/threads
from subprocess import Popen, PIPE
from time import sleep

from kivy.uix.scrollview import ScrollView
from kivy.uix.gridlayout import GridLayout
from kivy.uix.boxlayout import BoxLayout
from kivy.uix.label import Label
from kivy.clock import Clock
from kivy.clock import mainthread
from kivy.core.window import Window
from kivy.uix.button import Button
from kivy.uix.progressbar import ProgressBar
from kivy.uix.popup import Popup
from kivy.uix.image import Image
from kivy.uix.screenmanager import Screen

from fileClass import File
# Own kivy classes
import mainBtns
from settingsScreen import SettingsScreen
import mainSmallPops as mainSPops

try:
    from bluetooth import *
except:
    pass

class MainScreen(Screen):

    class infoLabel(Label):   # Not a popup or button so only suitable place.
        pass

    def __init__(self, fileSep, osTemp, startDir, assetsPath, path, recurseSearch, useBT, configLoc, **kwargs):
        self.fileSep, self.osTemp, self.startDir, self.assetsPath, self.path, self.searchRecursively, self.useBT, self.configLoc = fileSep, osTemp, startDir, assetsPath, path, recurseSearch, useBT, configLoc
        super(Screen, self).__init__(**kwargs)
        self.ascending = True       # Sort order
        self.key = ""
        self.encPop = None
        self.entered = False
        self.validBTKey = False
        self.useBTTemp = self.useBT
        self.previousDir = None
        self.lastPathSent = ""
        self.recycleFolder = ""
        self.recycleName = ""
        self.thumbsName = ""

        Window.bind(on_dropfile=self.onFileDrop)    #Binding the function to execute when a file is dropped into the window.
        self.currentDir = self.path


    def on_enter(self): # When the screen is started.
        self.key = self.manager.get_screen("Login").key  # Fetch the key from the Login Screen.
        if not self.entered:
            self.setupSortButtons() #Put sort buttons in place.
```

```
60              [self.recycleName, self.thumbsName] = self.encListString([".$recycling", ".$thumbs"])    # Prepare
recycling and thumbnail folder names for use in the program.
61              self.recycleFolder = self.path+self.recycleName+self.fileSep
62
63              if not os.path.exists(self.recycleFolder):
64                  print("Recycling folder not found in directory, making one now.")
65                  os.makedirs(self.recycleFolder)
66
67              self.entered = True
68
69          if self.recycleFolder in self.currentDir:
70              self.createButtons(self.List(self.path), sort=False)     # Don't want to log into the recycling
bin, as the user might get confused.
71          else:
72              self.createButtons(self.List(self.currentDir), sort=False) # Loads previous directory.
73
74      def on_leave(self):     # Kept separate from lock because i may want to add more screens that need the
key, and do not log the user out.
75          if self.useBT:      # Popups that are open block the lock button, but if BT is lost, the popups stay
open.
76              try:                            # Try to close any popups that may be open.
77                  self.largePop.dismiss()
78                  self.remove_widget(self.largePop)
79              except Exception as e:
80                  print(e, "Already closed?")
81              try:
82                  self.smallPop.dismiss()
83                  self.remove_widget(self.smallPop)
84              except Exception as e:
85                  print(e, "Already closed?")
86              try:
87                  self.encPop.dismiss()
88                  self.remove_widget(self.encPop)
89              except Exception as e:
90                  print(e, "Already closed?")
91
92          self.removeButtons()
93
94      def lock(self, fromRunServ=False):  # Procedure for when the program is locked. If it has been called from
runServMain, then we might still be on login screen, so don't change screen to login, and restart the server.
95          self.clearUpTempFiles() # Delete all temporary files (decrypted files ready for use).
96          if self.useBT:
97              self.manager.get_screen("Login").ids.clientLabel.text = ""
98
99          if fromRunServ and self.validBTKey == False:
100             self.runServMain()
101         else:
102             self.validBTKey = False
103             return mainthread(self.changeToLogin())      #Change screen to the login screen. Ran on mainthread
in case it was called in
104
105     def runServMain(self):
106         self.serverSock = BluetoothSocket( RFCOMM )
107         self.serverSock.bind(("",PORT_ANY))
108         self.serverSock.listen(1)
109
110         uuid = "80677070-a2f5-11e8-b568-0800200c9a66"
111
112         try:
113             advertise_service(self.serverSock, "FileMateServer",
114                               service_id = uuid,
115                               service_classes = [ uuid, SERIAL_PORT_CLASS ],
116                               profiles = [ SERIAL_PORT_PROFILE ],)
117         except BluetoothError as e:
118             Popup(title="Error", content=Label(text="Bluetooth not available.\nPlease make sure your bluetooth
is on,\nor change to normal login.\n\nReason: "+str(e)), size_hint=(.4, .4), auto_dismiss=True).open()
119             return
120
121         print("[BT]: Waiting for connection on RFCOMM channel", self.serverSock.getsockname()[1])
```

```
122
123         self.clientSock, self.clientInfo = self.serverSock.accept()  # Wait for a connection
124         print("[BT]: Accepted connection from ", self.clientInfo)
125         self.manager.get_screen("Login").ids.clientLabel.text = "Connected to: "+str(self.clientInfo[0])
126
127         numbers = []
128         data = ""
129         buff = []
130         backCommand = [33, 66, 65, 67, 75, 33]                                  # !BACK!
131         fileSelectCommand = [33, 70, 73, 76, 69, 83, 69, 76, 69, 67, 84, 33]  # !FILESELECT!
132         endHeader =  [126, 33, 69, 78, 68, 83, 69, 76, 69, 67, 84, 33]        # ~!ENDSELECT!
133
134         try:
135             while len(data) > -1:
136                 data = self.clientSock.recv(1024) # Recieve 1kb of data
137                 print("[BT]: Received data.")
138                 if not self.validBTKey:                 # If the key is not valid yet, BT server has to wait
    for key
139                     numbers.append(str(data, "utf-8"))
140                     if b"~" in data:    # End of key message
141                         append = False
142                         tempNums = "".join(numbers)
143                         tempNums = tempNums.replace("#", "")
144                         tempNums = tempNums.replace("~", "")
145                         if self.manager.get_screen("Login").checkKey(tempNums):   # Check the key in login.
146                             numbers = []
147                             self.clientSock.send("1")
148                             print("[BT]: Send true.")
149                             self.validBTKey = True
150                             [self.recycleName, self.thumbsName] = self.encListString([".$recycling",
    ".$thumbs"])  # Set so that file list can be sent
151                             self.sendFileList(self.getListForSend(self.path))
152                             mainthread(self.changeToMain())   # Exit thread and change screen to main.
153                         else:
154                             numbers = []
155                             self.clientSock.send("0")
156                             print("[BT]: Send false.")
157                             self.validBTKey = False
158
159                 else:
160                     for i in data:
161                         buff.append(i)
162
163                     if buff[:6] == backCommand:   # Buffer is reset every time a header is found
164                         pathBack = self.getPathBack(self.lastPathSent)
165                         if (not pathBack) or (pathBack.replace(self.path, "") == pathBack):    # If you can't
    go further back (if pathBack has less than path, then remove returns the original string).
166                             print("[BT]: Can't go further back.")
167                             self.clientSock.send("!ENDOFTREE!")
168                         else:
169                             self.sendFileList(self.getListForSend(pathBack))
170                         buff = []
171
172                     elif buff[:12] == fileSelectCommand:  # If the command is fileSelect
173                         commandParams = buff[12:]         # Get parameters (buffer will not be reset)
174                         if commandParams[-12:] == endHeader:  # If end of the buffer is the endHeader, then
    proceed.
175                             fileWantedList = commandParams[:-12]
176                             fileWanted = ""
177                             for letter in fileWantedList:
178                                 fileWanted += chr(letter)
179
180                             print("[BT]:", fileWanted, "fileWanted")
181                             buff = []
182                             filesInPath = self.List(self.lastPathSent)  # Get list of files at directory
    requested.
183
184                             f = 0
185                             fileObj = None
```

```
                            while (f < len(filesInPath)) and (fileObj == None): # Searches for the file in the
path
                                if filesInPath[f].name == fileWanted:
                                    fileObj = filesInPath[f]
                                f += 1

                            if fileObj != None:    # If the file was found, then send it
                                if fileObj.isDir:  # If it was a directory then send the list of files in that
directory.
                                    self.sendFileList(self.getListForSend(fileObj.hexPath))
                                else:
                                    self.makeSendFile(fileObj) # Otherwise send the file.

                            else:
                                print("[BT]: Couldn't find that file :/")
                                self.clientSock.send("!NOTFOUND!")


                    elif len(buff) > 12: # Clear buffer and wait for next command.
                        buff = []


        except IOError as e:
            print(e)        # Will be caused when app on mobile closes.

        print("[BT]: Closed.")

        self.clientSock.close()
        self.serverSock.close()
        self.lock(fromRunServ=True)

    def sendFileList(self, fileList):
        # File list sent like: !FILELIST!--fileName1--filename2~!!ENDLIST!
        self.clientSock.send("!FILELIST!")
        print("[BT]: Sent !FILELIST!")

        for i in fileList:
            self.clientSock.send("--{}".format(i))

        print("[BT]: Sent full list, now sent end.")
        self.clientSock.send("~!!ENDLIST!")


    def getListForSend(self, path):
        if not path:
            return False
        else:
            _, fsDec = self.listDir(path)
            self.lastPathSent = path
            return [i for i in fsDec if i != ".$thumbs" and i != ".$recycling"]
            # Cheeky bit of list comprehension so that these two folders are not sent.


##Functions for changing screen within threads (used to prevent segmentation faults)
    @mainthread
    def changeToMain(self):   # Has to be defined in a function because threads need a target function.
        self.manager.current = "Main"

    @mainthread
    def changeToLogin(self):    # Only used for checkServerStatus because you can only return a function or
variable, and if i execute this within the thread then it causes a segmentation fault.
        self.manager.current = "Login"
###############################################

    def startBT(self):
        self.serverThread = Thread(target=self.runServMain, daemon=True)      #Start BT server as thread so
the screen still renders.
        self.serverThread.start()

```

```
    def setupSortButtons(self):
        self.sortsGrid = GridLayout(cols=2, size_hint=(.99, .04), pos_hint={"x": .005, "y": .79})    #Make a grid of 1 row (colums=2 and i am only adding 2 widgets) to hold sort buttons.
        self.nameSort = mainBtns.nameSortButton(self, text="^")  # Default starts with Alphabetical sort ascending.
        self.sizeSort = mainBtns.sizeSortButton(self)
        self.sortsGrid.add_widget(self.nameSort)
        self.sortsGrid.add_widget(self.sizeSort)
        self.add_widget(self.sortsGrid) #Add the sort buttons grid to the float layout of MainScreen.

    def getGoodUnit(self, bytes):       #Get a good unit for displaying the sizes of files.
        if bytes == " -":
            return " -"
        else:
            divCount = 0
            divisions = {0: "B", 1: "KB", 2: "MB", 3: "GB", 4: "TB", 5: "PB"}
            while bytes > 1000:
                bytes = bytes/1000
                divCount += 1

            return ("%.2f" % bytes) + divisions[divCount]

    def getSortedFoldersAndFiles(self, fileObjects, inverse=False): # Sorts list of fileObjects by folder/file and name
        folders = []
        files = []
        for i in range(len(fileObjects)):   #Separate into folders and files
            if fileObjects[i].isDir:
                folders.append(fileObjects[i])
            else:
                files.append(fileObjects[i])

        foldersSort = self.sortAlph(folders)   #Quick sort the list of folders and the list of files.
        filesSort = self.sortAlph(files)

        if inverse: #If inverse
            foldersSort = foldersSort[::-1] #Invert the array
            filesSort = filesSort[::-1]

        return foldersSort+filesSort

    def openRecycling(self):  # Open the recycling folder.
        if not os.path.exists(self.recycleFolder):
            print("Recycling folder doesn't exist, making one now.")
            makedirs(self.recycleFolder)

        Popup(title="Changed Mode",
              content=Label(text="You are now in the\nrecycling folder.\nClick files to restore, and \nenter the INFO menu\nto see more information,\nor delete the file permanently."),
              pos_hint={"x_center": .5, "y_center": .5}, size_hint=(.4, .4)).open()
        self.currentDir = self.recycleFolder
        self.removeButtons()
        print(self.currentDir, "current dir")
        self.createButtons(self.List(self.currentDir))


#######Button Creation and button functions#######
    def createButtonsCore(self, array): # Makes each file button with it's information and adds it to the scroll view.
        self.currentList = array
        for item in array:
            if item.name != ".$recycling" and item.name != ".$thumbs": # If the folder is the recycling folder or thumbnail temporary folder, don't draw it.
                back = (1, 1, 1, 1)
                if item.isDir:   # Colour folders darker than files
                    back = (0.3, 0.3, 0.3, 1)   # Works as a tint rather than a colour.

                btn = mainBtns.listButton(self, item, text=("    "+item.name), background_color=back)
                info = mainBtns.infoButton(self, item, background_color=back)
```

```
                btn.bind(size=btn.setter("text_size"))  # Set the text to wrap within the button
                info.bind(size=info.setter("text_size"))
                fileS = Label(text=" "+str(item.size), size_hint=(.1, 1), halign="left", valign="middle")
                fileS.bind(size=fileS.setter("text_size"))  # Wrap text in label
                self.grid.add_widget(btn)
                self.grid.add_widget(info)
                self.grid.add_widget(fileS)

    def createButtons(self, fileObjects, sort=True):
        self.currentList = []
        if sort:
            print("sorting")
            fileObjects = self.getSortedFoldersAndFiles(fileObjects)    #Sort the list of files.

        self.grid = GridLayout(cols=3, size_hint_y=None)
        self.grid.bind(minimum_height=self.grid.setter("height"))
        self.scroll = ScrollView(size_hint=(.99, .79), pos_hint={"x": .005, "y": 0}) #Grid is added to the
scroll view.
        self.scroll.add_widget(self.grid)

        self.add_widget(self.scroll)    #Scroll view is added to the float layout of MainScreen.
        self.createButtonsCore(fileObjects)

    def traverseButton(self, fileObj):  # Function when file is clicked.
        if self.recycleFolder not in self.currentDir:
            if fileObj.isDir:   #If is a folder, then display files within that folder.
                self.previousDir = self.currentDir
                self.currentDir = fileObj.hexPath
                self.ascending = True
                self.resetButtons()
            else:   # If is a file, decrypt the file and open it.
                self.decrypt(fileObj)
        else:
            print("Recovering this file to path:", fileObj.name)
            move(fileObj.hexPath, self.path) # Imported from shutil
            self.refreshFiles()

    def openAddFilePop(self):     # Needs to be asigned to self.smallPop because if the screen is closed with
the popup open (only possible when using Bluetooth), all crucial popups need to be closed.
        self.smallPop = mainSPops.addFilePop(self)
        self.smallPop.open()

    def openAddFolderPop(self):
        self.smallPop = mainSPops.addNewFolderPop(self)
        self.smallPop.open()

    def onFileInfoClose(self, fileObj, _):  # _ is me discarding the popup object.
        if os.path.exists(fileObj.thumbDir):  # Remove temporary thumnail directory once done with thumbnail
            os.remove(fileObj.thumbDir)

    def getFileInfo(self, fileObj):     #Get information about a file/folder.
        size = (.7, .4)  # Size of popup
        if fileObj.extension == "png" or fileObj.extension == "jpg":
            thumb = self.getThumbnail(fileObj)
            size = (.8, .5)  # Increase size of popup to display image preview.

        # Works as: internalLayout -> scrolView + (Image?)
        # scrollView contains infoGrid with all of the file's information.
        internalLayout = BoxLayout(orientation="horizontal", size_hint=(1, 1))
        scrolView = ScrollView()
        self.infoPopup = Popup(title="File Information", content=internalLayout, pos_hint={"center_x": .5,
"center_y": .5}, size_hint=size)
        self.infoPopup.bind(on_dismiss=partial(self.onFileInfoClose, fileObj, ))

        infoGrid = GridLayout(cols=2, size_hint_y=None, row_default_height=40)
        scrolView.add_widget(infoGrid)
        internalLayout.add_widget(scrolView)

```

```
        if fileObj.extension == "png" or fileObj.extension == "jpg":
            internalLayout.add_widget(thumb)

        infoGrid.add_widget(self.infoLabel(text="File Name:", halign="left", valign="middle"))
        infoGrid.add_widget(self.infoLabel(text=fileObj.name, halign="left", valign="middle"))

        infoGrid.add_widget(self.infoLabel(text="Current Location:", halign="left", valign="middle"))
        infoGrid.add_widget(self.infoLabel(text="/Vault/"+fileObj.decryptRelPath(), halign="left",
valign="middle"))

        infoGrid.add_widget(self.infoLabel(text="Size:", halign="left", valign="middle"))
        infoGrid.add_widget(self.infoLabel(text=str(fileObj.size), halign="left", valign="middle"))

        delText = "Delete"
        if self.recycleFolder in self.currentDir:    # If in the recycling folder, then delete the item
permanently.
           delText = "Delete Permanently"

        infoGrid.add_widget(mainBtns.deleteButton(self, fileObj,text=delText))

        decBtnText = "Decrypt File"
        if fileObj.isDir:
            decBtnText = "Decrypt Folder"

        if fileObj.rawSize > 0:
            decBtn = Button(text=decBtnText, halign="left", valign="middle")
            decBtn.bind(on_release=partial(self.decryptFileToLoc, fileObj))
            infoGrid.add_widget(decBtn)

        self.infoPopup.open()

    def makeSendFile(self, fileObj, buttonInstance=None):
        self.sendFile = mainSPops.btTransferPop(self, fileObj)
        self.sendFile.open()

    def moveFileToRecycling(self, fileObj):
        print("Moving", fileObj.hexPath)
        if os.path.exists(fileObj.hexPath):
            move(fileObj.hexPath, self.recycleFolder) # Imported from shutil
        else:
            raise FileNotFoundError(fileObj.hexPath, "Not a file, can't move to recycling.") # Doesn't exist,
so issue with code somewhere.

    def deleteFile(self, fileObj):
        if os.path.exists(fileObj.hexPath): #Checks file actually exists before trying to delete it.
            if self.recycleFolder not in self.currentDir:   # If outside of recycling bin.
                print("Moving", fileObj.hexPath)
                if os.path.exists(self.recycleFolder+fileObj.hexName):
                    if os.path.isdir(self.recycleFolder+fileObj.hexName):
                        rmtree(self.recycleFolder+fileObj.hexName)
                    else:
                        os.remove(self.recycleFolder+fileObj.hexName)
                move(fileObj.hexPath, self.recycleFolder) # Imported from shutil
            else:
                print("Deleting:", fileObj.hexPath, "and checking temp.")
                if os.path.exists(self.osTemp+"FileMate"+self.fileSep+fileObj.name):  # If removing
permanently, check that the file is not decrypted in <system_temp>.
                    os.remove(self.osTemp+"FileMate"+self.fileSep+fileObj.name)
                if fileObj.isDir:    # Delete the file/folder
                    rmtree(fileObj.hexPath) # Imported from shutil
                else:
                    os.remove(fileObj.hexPath)
            self.refreshFiles()
            self.infoPopup.dismiss()

        else:
            raise FileNotFoundError(fileObj.hexPath, "Not a file, can't delete.")

    def goBackFolder(self):     #Go up a folder.
```

```
        if self.currentDir != self.path:    #Can't go further past the vault dir.
            self.previousDir = self.currentDir
            if self.recycleFolder in self.currentDir:
                self.goHome()
            else:
                self.currentDir = self.getPathBack(self.currentDir)
            self.resetButtons()
        else:
            print("Can't go further up.")
            return False

    def getPathForButton(self, item):   # Get the path to the asset for each button.
        return self.assetsPath+item

    def removeButtons(self):    # Remove the list of files.
        self.grid.clear_widgets()
        self.scroll.clear_widgets()
        self.remove_widget(self.scroll)

    def resetButtons(self): # Goes back to self.currentDir, different to refresh.
        self.removeButtons()
        self.nameSort.text = "^"
        self.sizeSort.text = ""
        self.createButtons(self.List(self.currentDir), sort=False)

    def refreshFiles(self):   # Refreshes the files in the current directory
        self.removeButtons()
        self.createButtons(self.List(self.currentDir), sort=False)

    def refreshButtons(self): # Refreshes file list buttons currently displayed.
        self.removeButtons()
        self.createButtons(self.currentList, sort=False)

    def goHome(self):   #Takes the user back to the vault dir.
        self.currentDir = self.path
        self.refreshFiles()

    def List(self, dir):    # Lists a directory, returning File objects.
        fs, fsDec = self.listDir(dir)   # Lists encrypted names and decrypted names.
        listOfFolders = []
        listOfFiles = []
        for i in range(len(fs)):
            if os.path.isdir(dir+fs[i]):
                listOfFolders.append(File(self, dir+fs[i], fs[i], self.fileSep, name=fsDec[i], isDir=True))
            else:
                listOfFiles.append(File(self, dir+fs[i], fs[i], self.fileSep, name=fsDec[i]))

        return listOfFolders+listOfFiles

    def getPathBack(self, origPath):  # Gets the path above the current folder.
        tempDir = origPath.split(self.fileSep)
        del tempDir[-2]
        tempDir = self.fileSep.join(tempDir)
        return tempDir

##########Searches############
    def findAndSortCore(self, dirName, item):
        files = self.List(dirName)
        if len(files) == 0:
            return
        for fileObj in files:
            loc = fileObj.name.find(item) # Find where in the word the item is found, if it is a substring of
the word

            if fileObj.name == item:
                self.searchResults = [fileObj] + self.searchResults
            elif loc != -1: # If the search term is a substring of the current word
                self.unsorted.append((loc, fileObj))   #Adds loc found in word, so that it can be sorted by
where it is found
```

```
512
513             if (fileObj.isDir and self.searchRecursively) and (fileObj.hexPath != self.recycleFolder) and
(fileObj.hexName != self.thumbsName):
514                 self.findAndSortCore(fileObj.hexPath, item)  # Search folder if recursive and not recycle
folder or thumbnail folder.
515
516
517     def findAndSort(self, item):    #Main search function.
518         self.unsorted = []
519         self.findAndSortCore(self.currentDir, item)
520
521         if len(self.unsorted)+len(self.searchResults) > 0:
522             sorted = self.sortSearch(self.unsorted)
523             for i in sorted:
524                 self.searchResults.append(i)
525             mainthread(self.removeButtons())
526             return mainthread(self.createButtons(self.searchResults, False))
527
528         elif len(self.searchResults) == 0:
529             pop = Popup(title="No Results", content=Label(text="No results found for:\n"+item,
halign="center"), pos_hint={"x_center": .5, "y_center": .5}, size_hint=(.4, .4))
530             pop.open()
531
532
533     def searchForItem(self, item):
534         self.searchResults = []
535         Thread(target=self.findAndSort, args=(item,), daemon=True).start()
536
537
538 ####Progress Bar Information####
539     def values(self, st):   #Information for space left on device.
540         values = disk_usage(self.path) # Imported from shutil
541         if st:
542             return self.getGoodUnit(int(values[1]))+" / " + self.getGoodUnit(int(values[0])) + " used."
543         else:
544             return [values[0], values[1]]
545
546
547 ######Encryption Stuff + opening decrypted files + interface with go######
548     def encDec(self, encType, d, targetLoc, newName=None, op=True): # Encrypt and decrypt. A wrapper for the
thread that will do it.
549         if self.encPop != None:
550             self.encPop.dismiss()
551             self.encPop = None
552
553         def encThread(encType, d, targetLoc, op=True):
554             if os.path.isdir(d):
555                 if not os.path.exists(targetLoc):
556                     os.makedirs(targetLoc)
557                 fileList, locList = self.getDirLists(encType, d, targetLoc)
558                 self.encPop = mainSPops.encDecPop(self, encType, fileList, locList, op=op)
559                 mainthread(self.encPop.open())
560                 self.passToPipe(encType+"Dir", "\n".join(fileList), "\n".join(locList))
561             else:
562                 size = os.path.getsize(d)
563                 if size > 10000: # If larger than 10 kb, otherwise don't bother
564                     self.encPop = mainSPops.encDecPop(self, encType, [d], [targetLoc] , op=op)
565                     mainthread(self.encPop.open())
566                 self.passToPipe(encType, d, targetLoc)
567
568             if self.encPop != None:
569                 mainthread(self.encPop.dismiss())
570                 self.encPop = None
571
572             if encType == "y":
573                     self.resetButtons()
574
575             if op and encType == "n":
576                 self.openFileTh(targetLoc, d)
```

```
577
578
579         return Thread(target=encThread, args=(encType, d, targetLoc, op,)).start()
580
581
582     def passToPipe(self, type, d, targetLoc):     #Passes parameters to AES written in go.
583         if self.fileSep == "\\":
584             progname = "AESWin.exe"
585         else:
586             progname = "AES/AES"
587
588         goproc = Popen(self.startDir+progname, stdin=PIPE, stdout=PIPE)
589         out, _ = goproc.communicate((type+", "+d+", "+targetLoc+", "+self.key).encode()) # Send parameters to
    AES
590         return out
591
592     ## Utilising passToPipe function
593     def getDirLists(self, encType, root, targ):  # Communicates with AES to get list of files in a folder, and
    their target.
594         out = self.passToPipe("getLists"+encType, root, targ).decode()
595         out = out.split("--!--") # Separator
596         return out[0].split(",,"), out[1].split(",,")
597
598     def listDir(self, location):
599         out = self.passToPipe("listDir", location, "").decode()
600         out = out.split("--!--") # Separator
601         out = [out[0].split(",,"), out[1].split(",,")]
602         if out[0] == [""]:
603             out[0] = []
604         if out[1] == [""]:
605             out[1] = []
606         return out[0], out[1]
607
608     def encString(self, string):
609         out = self.passToPipe("encString", string, "").decode()
610         return out
611
612     def decString(self, string):
613         out = self.passToPipe("decString", string, "").decode()
614         return out
615
616     def encListString(self, list):
617         out = self.passToPipe("encList", "\n".join(list), "").decode()
618         return out.split(",,")
619
620     def sortSize(self, fileObjects):
621         out = self.passToPipe("sortSize", "\n".join([str(i.rawSize) for i in fileObjects]), "").decode()
622         out = [int(i) for i in out.split(",,")]
623         if len(out) != len(fileObjects):
624             raise ValueError("Length of sizes not the same as original:", len(out), len(fileObjects))
625         outList = []
626         for i in range(len(fileObjects)):
627             outList.append(-1)   # Initialize
628
629         for i in fileObjects:
630             outList[out.index(i.rawSize)] = i  # Insert the file object on the pace in outList that
    corresponds to where it's size is in the 'out' list.
631
632         return [i for i in outList if i != -1] # In case of any left-overs
633
634     def sortAlph(self, fileObjects):
635         out = self.passToPipe("sortAlph", "\n".join([str(i.name) for i in fileObjects]), "").decode()
636         out = [str(i) for i in out.split(",,")]
637
638         return self.matchFileObjToName(fileObjects, out)
639
640     def sortSearch(self, searchResults):
641         out = self.passToPipe("sortSearch", "\n".join([str(i[0]) for i in searchResults]),
    "\n".join([i[1].name for i in searchResults])).decode()
```

```
        out = [str(i) for i in out.split(",,")]

        return self.matchFileObjToName([i[1] for i in searchResults], out)

    def decListString(self, list):
        out = self.passToPipe("decList", "\n".join(list), "").decode()
        return out.split(",,")

    def matchFileObjToName(self, fileObjects, listOfNames):    # Used when sorting file objects by name
        if listOfNames == [""]:
            return []
        if len(listOfNames) != len(fileObjects):
            print(listOfNames)
            print(fileObjects)
            raise ValueError("Length of names not the same as original:", len(listOfNames), len(fileObjects))
        outList = []
        for i in range(len(fileObjects)):
            outList.append(-1)   # Initialize

        for i in fileObjects:
            outList[listOfNames.index(i.name)] = i  # Insert the file object on the pace in outList that corresponds to where it's size is in the 'out' list.

        return [i for i in outList if i != -1] # In case of any left-overs


    def getCheckSum(self, location):  # Communicates to BLAKE to get checksum.
        if self.fileSep == "\\":      # If on windows
            goproc = Popen(self.startDir+"BLAKEWin.exe", stdin=PIPE, stdout=PIPE)
        elif self.fileSep == "/":
            goproc = Popen(self.startDir+"BLAKE/BLAKE", stdin=PIPE, stdout=PIPE)

        out, err = goproc.communicate((location).encode())
        if err != None:
            raise ValueError(err)

        return out.decode()

    def getThumbnail(self, fileObj):
        if self.thumbsName not in self.currentDir:    # Only check this when not in the thumbnail folder
            if self.thumbsName not in os.listdir(self.currentDir): # Checks that there is a thumbnail folder in this directory.
                os.makedirs(self.currentDir+self.thumbsName)
                print("Made thumbnail directory since it wasn't there")

        fileObj.thumbDir = self.currentDir+self.thumbsName+self.fileSep+fileObj.hexName
        self.passToPipe("n", fileObj.hexPath, fileObj.thumbDir) # Decrypts thumnail temporarily. Is deleted once program is finished displaying it.
        thumb = Image(source=fileObj.thumbDir)
        return thumb

    def openFileTh(self, fileLoc, startLoc):   # Creates a thread to open a file (stops program locking up)
        Thread(target=self.openFile, args=(fileLoc, startLoc,), daemon=True).start()

    def openFile(self, location, startLoc):
        locationFolder = location.split(self.fileSep)
        nameOfOriginal = locationFolder[-1]
        locationFolder = self.fileSep.join(locationFolder[:-1])
        if self.fileSep == "\\":
            location = location.split("\\")
            location = "/".join(location) # Windows actually accepts forward slashes in terminal
            command = "START /wait "+'"" '+'"'+location+'"'
        else:
            command = "xdg-open "+'"'+location+'"'      # Quotation marks for if the dir has spaces in it

        startCheckSum = self.getCheckSum(location) # Gets checksum of file before opening.
        os.system(command)# Using the same for both instead of os.startfile because os.startfile doesn't wait for file to close
        # After this line, the file has been closed.
```

```
        if os.path.exists(locationFolder) and nameOfOriginal in os.listdir(locationFolder):
            print("Original still here")
            if self.getCheckSum(location) != startCheckSum:
                print("Original file has changed.")
                self.encDec("y", location, startLoc)

    def onFileDrop(self, window, filePath):  # For draging + dropping files into the window.
        self.checkCanEncrypt(filePath.decode())
        return "Done"

    def decrypt(self, fileObj, op=True):            # Default decrypt for file. Manages opening files etc.
        if not os.path.isdir(self.osTemp+"FileMate"+self.fileSep):
            os.makedirs(self.osTemp+"FileMate"+self.fileSep)
        fileLoc = self.osTemp+"FileMate"+self.fileSep+fileObj.name  #Place in temporary files where it is going to be stored.
        if os.path.exists(fileLoc) and op:         #Checks file exits already in temp files, so it doesn't have to decrypt again.
            self.openFileTh(fileLoc, fileObj.hexPath)
        else:
            self.encDec("n", fileObj.hexPath, fileLoc, newName=fileObj.name, op=op)

    def decryptFileToLoc(self, fileObj, button):   # Decrypt a file/folder to a location (just handles the input)
        mainSPops.decryptFileToLocPop(self, fileObj).open()

    def checkCanEncryptCore(self, inp): # Used for adding new files to the vault by the user.
        if self.checkDirExists(inp):
            inpSplit = inp.split(self.fileSep)

            if os.path.isdir(inp):
                while inpSplit[-1] == "":       # Removes excess "/" from input
                    inpSplit = inpSplit[:-1]
                targ = self.currentDir+self.encString(inpSplit[-1])+self.fileSep
                inp = self.fileSep.join(inpSplit)+self.fileSep
            else:
                targ = self.currentDir+self.encString(inpSplit[-1])
                inp = self.fileSep.join(inpSplit)
            self.encDec("y", inp, targ)

    def checkCanEncrypt(self, inp):  # Used for adding new files to the vault by the user.
        if "--" in inp: # Multiple files/folders input.
            inp = inp.split("--")
            for d in inp:
                self.checkCanEncryptCore(d) # Actally encrypt/decrypt it.
        else:
            self.checkCanEncryptCore(inp)


    def checkDirExists(self, dir):  #Handles UI for checking directory exits when file added.
        if os.path.exists(dir):
            return True
        else:
            self.popup = Popup(title="Invalid", content=Label(text=dir+" - Not a valid directory."), pos_hint={"center_x": .5, "center_y": .5}, size_hint=(.4, .4))
            self.popup.open()
            return False

    def clearUpTempFiles(self):     # Deletes temp files when the program is locked.
        print("Deleting temp files.")
        try:
            rmtree(self.osTemp+"FileMate"+self.fileSep) # Imported from shutil
        except:
            print("No temp files.")
```

`passToPipe` is used to pass commands through `stdin` to AES, and recieve results through `stdout`. There are many functions just below it dedicated to formatting data to be send through the pipe, for sorting files and many other functions. `encDec` is the function used in the program for encryption and decryption, while `decrypt` is a function used as a default operation to perform when a file is decrypted (open it, make a temporary folder etc).

The temporary files are removed when the program is locked using `clearUpTempFiles`, called by `lock` when the BT server is closed, or when the lock button is pressed.

`findAndSort` doesn't return anything, but instead edits `self.searchResults`. This is because it was easier to do it this way than pass it in every time, when it is needed by the rest of the program anyway. I just need to make sure i set it to `self.searchResults = []` before getting new results.

The `File` class (defined in `code/python-go/fileClass.py`) is an integral part of the program, as they are used throughout to handle the file's encrypted path, decrypted name and a host of other important information needed throughout the program. The `File` class has made programming other functions much easier and cleaner, due to the data already being there.

The `values` function returns the values required by the progress bar showing the amount of storage space left on the current device, and can optionally return this in string form for the text above the status bar.

Most custom child widgets that the MainScreen needs are defined in `code/python-go/kivyStuff/mainBtns.py` and `code/python-go/kivyStuff/mainSmallPops.py`, and their styling which is in `code/python-go/kivyStuff/kvFiles/mainScClasses.kv`, but I will talk more about those after I go through the styling for the MainScreen class.

Here is the `.kv` file for MainScreen (`code/python-go/kivyStuff/kvFiles/mainSc.kv`):

```
#:include kivyStuff/kvFiles/mainScButtons.kv
#:include kivyStuff/kvFiles/mainScPops.kv
#:include kivyStuff/kvFiles/mainScLabels.kv

<MainScreen>:
    addFile: addFile
    RelativeLayout:                 #Adds background in case fade transition breaks.
        canvas.before:
            Color:
                rgba: 0,0,0,2
            Rectangle:
                pos: self.pos
                size: self.size

    FloatLayout:
        id: MainLayout

        TextInput:
            id: Search
            size_hint: .52, .08
            font_size: 22
            hint_text: "Search:"
            pos_hint: {"x": 0.16, "top": 1}
            multiline: False
            on_text_validate: root.searchForItem(self.text)

        Button:
            id: home
            size_hint: .06, .08
            pos_hint: {"x": 0.62, "y": 0.84}
            on_release: root.goHome()
            Image:
                source: root.getPathForButton("home.png")
```

```
                center_x: self.parent.center_x
                center_y: self.parent.center_y
                size: 40, 40
                allow_stretch: True

        Button:
            id: settings
            size_hint: .06, .08
            pos_hint: {"x": 0.56, "y": 0.84}
            on_release: root.manager.current = "Settings"
            Image:
                source: root.getPathForButton("settings.png")
                center_x: self.parent.center_x
                center_y: self.parent.center_y
                size: 40, 40
                allow_stretch: True

        Button:
            id: addFolder
            size_hint: .06, .08
            pos_hint: {"x": 0.5, "y": 0.84}
            text_size: self.size
            halign: "center"
            valign: "center"
            on_release: root.openAddFolderPop()
            Image:
                source: root.getPathForButton("newFolder.png")
                center_x: self.parent.center_x+3 # Drop shadow
                center_y: self.parent.center_y
                size: 50, 50

        Button:
            id: recyclingBin
            size_hint: .06, .08
            pos_hint: {"x": 0.44, "y": 0.84}
            on_release: root.openRecycling()
            Image:
                source: root.getPathForButton("recycling.png")
                center_x: self.parent.center_x
                center_y: self.parent.center_y+3
                size: 50, 50

        ProgressBar:
            id: pb1
            min: 0
            max: root.values(False)[0]
            value: root.values(False)[1]
            size_hint: .28, .08
            pos_hint: {"x": 0.16, "y": 0.84}

        Label:
            pos_hint: {"x": 0.2, "y": 0.82}
            size_hint: .16, .16
            text: root.values(True)

        Button:     #Padlock
            id: LogOut
            size_hint: .16, .16
            pos_hint: {"x": 0, "top": 1}
            on_release: root.lock()
            Image:
                source: root.getPathForButton("padlock.png")
                center_x: self.parent.center_x
                center_y: self.parent.center_y
                size: 60, self.size[1]

        Button:
            id: addFile
            size_hint: .16, .16
```

```
            pos_hint: {"right": 1, "top": 1}
            on_release: root.openAddFilePop()
            Image:
                source: root.getPathForButton("addFile.png")
                center_x: self.parent.center_x+2 # Drop shadow
                center_y: self.parent.center_y-5
                size: 100, 133.54
                allow_stretch: False

        Button:
            id: goBackFolder
            size_hint: .16, .16
            pos_hint: {"x": 0.68, "top": 1}
            on_release: root.goBackFolder()
            Image:
                source: root.getPathForButton("backUpFolder.png")
                center_x: self.parent.center_x+2 # Drop shadow
                center_y: self.parent.center_y
                size: 100, 133.54
                allow_stretch: False

```

The first three lines import the styling for the custom child widgets, which I will go through next.

Main Screen Buttons

All of the custom buttons for MainScreen are defined in `code/python-go/kivyStuff/mainBtns.py`. Here is the code:

```
from kivy.uix.button import Button
from kivy.uix.image import Image

from sortsCy import quickSortSize

class listButton(Button):           #File button when using main screen.

    def __init__(self, fileObj, **kwargs):
        super(Button, self).__init__(**kwargs)
        self.fileObj = fileObj          #The file the button corresponds to.

class nameSortButton(Button):           #Sorts the listButtons alphabetically and by folders/files.

    def __init__(self, mainScreen, **kwargs):
        super(Button, self).__init__(**kwargs)   # Run kivy Button.__init__ class with it's key word arguments.
        self.outerScreen = mainScreen

    def changeSortOrder(self):
        self.outerScreen.ascending = not self.outerScreen.ascending
        if self.outerScreen.ascending:
            self.text = "^"
            self.outerScreen.removeButtons()
            self.outerScreen.createButtons(self.outerScreen.currentList, True)
        else:
            self.text = "v"
            self.outerScreen.removeButtons()
            self.outerScreen.createButtons(self.outerScreen.currentList[::-1], False)

class sizeSortButton(Button):           #Sorts the files/folders by size

    def __init__(self, mainScreen, **kwargs):
        super(Button, self).__init__(**kwargs)
        self.outerScreen = mainScreen
        self.ascending = True
        self.sortList = []


    def sortBySize(self):
```

```
        self.sortList = quickSortSize(self.outerScreen.currentList)
        if not self.ascending:
            self.sortList = self.sortList[::-1]    # Reverse sorted list.

        self.outerScreen.removeButtons()
        self.outerScreen.createButtons(self.sortList, False)

    def changeSizeOrder(self):
        self.ascending = not self.ascending
        if self.ascending:
            self.text = "v"
        else:
            self.text = "^"

        if (self.sortList) and (self.outerScreen.previousDir == self.outerScreen.currentDir):   # Checking that the sortList is for the current directory and we haven't moved.
            self.sortList = self.sortList[::-1]
            self.outerScreen.currentList = self.sortList
            self.outerScreen.removeButtons()
            self.outerScreen.createButtons(self.sortList, False)
        else:
            self.outerScreen.previousDir = self.outerScreen.currentDir
            self.sortBySize()

class infoButton(Button):       #The button that displays information about the file.

    def __init__(self, mainScreen, fileObj, **kwargs):
        self.outerScreen = mainScreen
        super(Button, self).__init__(**kwargs)
        self.fileObj = fileObj


class deleteButton(Button):

    def __init__(self, mainScreen, fileObj, **kwargs):
        super(Button, self).__init__(**kwargs)
        self.outerScreen = mainScreen
        self.fileObj = fileObj
```

The `listButton` class is just a regular `Button`, but can take a `File` class (as `fileObj`), and has a reference to the current `MainScreen` object. `listButton` has no custom methods.

The `nameSortButton` class is a regular `Button`, however closely interacs with the `MainScreen` class, to change the order of items in the `ScrollView` that contains the `listButton`s on `MainScreen`. It basically handles `MainScreen`.

The `sizeSortButton` class works similarly to `nameSortButton`, however it has to handle sorting the list by size.

The `infoButton` and `deleteButton` classes are both similar to `listButton` in that they just have a few extra attributes.

Here is the `kv` file for the custom buttons (`code/python-go/kivyStuff/kvFiles/mainScButtons.kv`):

```
#: import Window kivy.core.window.Window

<listButton@Button>:
    font_size: 14
    halign: "left"
    valign: "middle"
    height: 30
    size_hint: 1, None
    on_release: root.outerScreen.traverseButton(self.fileObj)

<nameSortButton@Button>:
    font_size: 14
    size_hint: 10.4, 1
```

```
    on_release: root.changeSortOrder()

<sizeSortButton@Button>:
    font_size: 14
    on_release: root.changeSizeOrder()

<infoButton@Button>:
    font_size: 14
    size_hint: .05, 1
    halign: "left"
    valign: "middle"
    on_release: root.outerScreen.getFileInfo(self.fileObj)
    Image:
        source: self.parent.outerScreen.assetsPath+"info.png"
        center_x: self.parent.center_x
        center_y: self.parent.center_y
        size: 20, 20

<deleteButton@Button>:
    on_release: root.outerScreen.deleteFile(self.fileObj)
```

The first line imports `Window` from `kivy.core.window`. The equivalent in python would be:

```
from kivy.core.window import Window
```

Main Screen Popups

Here is the code for the MainScreen popups (`code/python-go/kivyStuff/mainSmallPops.py`):

```
import os
from threading import Thread
from time import time, sleep
from random import uniform as randUniform

from kivy.uix.scrollview import ScrollView
from kivy.uix.gridlayout import GridLayout
from kivy.uix.label import Label
from kivy.clock import Clock
from kivy.clock import mainthread
from kivy.core.window import Window
from kivy.uix.button import Button
from kivy.uix.progressbar import ProgressBar
from kivy.uix.popup import Popup

from configOperations import dirInputValid

class encDecPop(Popup): #For single files

    def __init__(self, outerScreen, encType, fileList, locList, op=True, **kwargs):
        super(Popup, self).__init__(**kwargs)
        self.outerScreen = outerScreen
        self.fileList = fileList
        self.locList = locList

        # Kivy stuff
        self.title = "Please wait..."
        self.pos_hint = {"center_x": .5, "center_y": .5}
        self.size_hint = (.7, .4)
        self.auto_dismiss = False

        self.grid = GridLayout(cols=1)
        self.subGrid = GridLayout(cols=4)
        self.currFile = Label(text="", halign="center", valign="center")
        self.currFile.bind(size=self.currFile.setter("text_size"))  # Wrap text inside label
        self.per = Label(text="")
```

```
        self.spd = Label(text="")
        self.tim = Label(text="")
        self.outOf = Label(text="")
        self.pb = ProgressBar(value=0, max=os.path.getsize(self.fileList[0]), size_hint=(.9, .2))
        self.wholePb = ProgressBar(value=0, max=self.__getTotalSize(), size_hint=(.9, .2))
        labText = "Encrypting..."
        if encType == "n":
            labText = "Decrypting..."
        self.grid.add_widget(Label(text=labText, size_hint=(1, .4)))
        self.grid.add_widget(self.currFile)
        self.subGrid.add_widget(self.per)
        self.subGrid.add_widget(self.spd)
        self.subGrid.add_widget(self.tim)
        self.grid.add_widget(self.subGrid)
        if len(self.fileList) > 1:   # Don't bother showing 2 progress bars if the user is only doing 1 file.
            self.grid.add_widget(self.pb)
            self.subGrid.add_widget(self.outOf)
        self.grid.add_widget(self.wholePb)
        self.content = self.grid

        self.checkThread = Thread(target=self.encDec, args=(encType, op,), daemon=True)
        self.checkThread.start()

    def __getTotalSize(self):
        total = 0
        for file in self.fileList:
            total += os.path.getsize(file)
        return total

    def getGoodUnit(self, bps):
        divCount = 0
        divisions = {0: "B/s", 1: "KB/s", 2: "MB/s", 3: "GB/s", 4: "TB/s"}
        while bps > 1000:
            bps = bps/1000
            divCount += 1

        return ("%.2f" % bps) + " " + divisions[divCount]

    def __getGoodUnitTime(self, time):
        divCount = 0
        times = [(0.001, "Miliseconds"), (1, "Seconds"), (60, "Minutes"), (3600, "Hours"), (86400, "Days"),
(604800, "Weeks"), (2419200, "Months"), (31557600, "Years")]   # 1 second, 1 minute, 1 hour, 1 day, 1 week, 1
month, 1 year in seconds
        i = 0
        while i < len(times):  # Is broken when return is found
            if time > times[i][0]:
                i += 1
            else:
                return ("%.2f" % float(time/times[i-1][0])) + " " + times[i-1][1] + " left"

        return "A lot of time left."

    def __getRelPathDec(self, path):   # Similar to decryptRelPath in fileClass
        splitPath = (path.replace(self.outerScreen.path, "")).split(self.outerScreen.fileSep)
        return "/Vault/"+self.outerScreen.fileSep.join(self.outerScreen.decListString(splitPath))

    def __getMeanOfList(self, l):
        out = 0
        for i in l:
            out += i
        return out/len(l)

    def encDec(self, encType, op):
        total = 0
        totalPer = 0
        factor = 0.5
        timeLast = 0
        lastSize = 0
        timeDelta = 0
```

```
        perDelta = 0
        per = 0
        prevPer = 0
        lastPerDeltas = [] # Stores 8 of the last percentage deltas so that a mean can be obtained.
        for i in range(len(self.fileList)):
            done = False
            self.pb.value = 0
            self.pb.max = os.path.getsize(self.fileList[i])

            self.outOf.text = str(i)+"/"+str(len(self.fileList))
            if encType == "n":
                self.currFile.text = self.__getRelPathDec(self.fileList[i])
            else:
                self.currFile.text = self.fileList[i]

            while not done: # Padding can cause issues as original size is not known.
                if os.path.exists(self.locList[i]):
                    self.pb.value = os.path.getsize(self.locList[i])
                    self.wholePb.value = total + self.pb.value
                    per = self.wholePb.value_normalized*100

                    a = time()   # Temporary variable to hold the time
                    timeDelta = a - timeLast     # Get time difference
                    if timeDelta >= 0.5:  # Update every 0.5 seconds
                        perDelta = per - prevPer   # Change in percentage in that time.
                        if len(lastPerDeltas) == 8:
                            lastPerDeltas = lastPerDeltas[1:]
                        lastPerDeltas.append(perDelta)
                        perDelta = self.__getMeanOfList(lastPerDeltas)

                        timeLast = a
                        sizeDelta = self.wholePb.value - lastSize  # Get change in size of the file being
encrypted
                        speed = sizeDelta/timeDelta  # Get speed of encryption in bytes/second

                        if speed != 0:
                            self.tim.text = self.__getGoodUnitTime((100 -
(self.wholePb.value_normalized*100))/(perDelta/timeDelta))
                            self.spd.text = self.getGoodUnit(speed)

                        lastSize = self.wholePb.value
                        prevPer = per

                    self.per.text = "{0:.2f}%".format(per)

                if self.pb.value >= self.pb.max-64:  # -64 is due to padding and key.
                    done = True
                else:
                    sleep(0.01) # Reduces the rate the file is checked, so python doesn't use too much CPU.
AES will still run the same regardless, the file just doesn't need to be checked as soon as possible.

            self.pb.value = self.pb.max
            totalPer += 100
            total += self.pb.max


class btTransferPop(encDecPop):

    def __init__(self, mainScreen, fileObjTmp, **kwargs):
        super(Popup, self).__init__(**kwargs)
        self.outerScreen = mainScreen
        self.title = "Please wait..."
        self.size_hint = (.7, .4)
        self.pos_hint = {"center_x": .5, "center_y": .5}
        self.auto_dismiss = False
        self.grid = GridLayout(cols=1)
        self.subGrid = GridLayout(cols=3)
        self.currFile = Label(text=fileObjTmp.path)
        self.per = Label(text="")
```

```
        self.spd = Label(text="")
        self.tim = Label(text="")
        self.pb = ProgressBar(value=0, max=1, size_hint=(.9, .2))
        self.grid.add_widget(Label(text="Sending..."))
        self.grid.add_widget(self.currFile)
        self.subGrid.add_widget(self.per)
        self.subGrid.add_widget(self.spd)
        self.subGrid.add_widget(self.tim)
        self.grid.add_widget(self.subGrid)
        self.grid.add_widget(self.pb)
        self.content = self.grid

        self.sendThread = Thread(target=self.sendFile, args=(fileObjTmp,), daemon=True) # can be cancelled mid way through
        self.sendThread.start()

    def sendFile(self, fileObj):
        # File name is sent with !NAME!#!!<name here>!!~
        # File data is sent right afterwards, ending with ~!!ENDF!
        # Overall, it is sent as: !NAME!#!!<name here>!!~<datahere>~!!ENDF!
        self.outerScreen.clientSock.send("!NAME!{}~~!~~".format(fileObj.name))
        #print("!NAME!{}~~!~~".format(fileObj.name), "Sent")

        newLoc = self.outerScreen.osTemp+"FileMate"+self.outerScreen.fileSep+fileObj.name
        if not os.path.isdir(self.outerScreen.osTemp+"FileMate"+self.outerScreen.fileSep):
            os.makedirs(self.outerScreen.osTemp+"FileMate"+self.outerScreen.fileSep)

        self.outerScreen.passToPipe("n", fileObj.hexPath, newLoc)

        bufferSize = 1024
        buff = []
        fr = open(newLoc, "rb")
        buff = fr.read(bufferSize)    #Read 1Kb of data
        buffCount = 0
        self.per.text = "{0:.2f}%".format(0)

        start = time()
        #Send data
        while buff:
            self.outerScreen.clientSock.send(buff)
            buffCount += bufferSize
            buff = fr.read(bufferSize)

            self.pb.value = buffCount/fileObj.rawSize
            self.per.text = "{0:.2f}%".format(self.pb.value*100)
            self.spd.text = self.getGoodUnit(buffCount/(time() - start))

        self.outerScreen.clientSock.send("~!ENDFILE!")
        self.dismiss()


class decryptFileToLocPop(Popup): # Input box for location of where directory is to be saved.

    def __init__(self, mainScreen, fileObj, **kwargs):
        self.outerScreen = mainScreen
        self.fileObj = fileObj
        super(Popup, self).__init__(**kwargs)

    def makeDirs(self, dir):
        try:
            os.makedirs(dir)
        except OSError as e:
            if "[Errno 13]" in str(e): # OSError doesn't store the error code.
                Popup(title="Invalid", content=Label(text="Can't decrypt here.", halign="center"), size_hint=(.3, .3), pos_hint={"x_center": .5, "y_center": .5}).open()
                return False
            elif "[Errno 36]" in str(e):
                Popup(title="Invalid", content=Label(text="File name too long.", halign="center"), size_hint=(.3, .3), pos_hint={"x_center": .5, "y_center": .5}).open()
```

```
                return False
        else:
            return True

    def checkCanDec(self, inp):
        valid = True
        if dirInputValid(inp, self.outerScreen.fileSep): # Re-use from settings pop, setting self as None because it isn't even used in the function, but is needed to run from within SettingsPop.
            if self.fileObj.isDir:
                if not os.path.exists(inp):
                    valid = self.makeDirs(inp)
                if inp[-1] != self.outerScreen.fileSep: inp += self.outerScreen.fileSep

                if valid:
                    self.outerScreen.encDec("n", self.fileObj.hexPath, inp, op=False)
            else:
                if inp[-1] == self.outerScreen.fileSep:   # If ends with "/", then decrypt with it's file name.
                    if not os.path.exists(inp):
                        valid = self.makeDirs(inp)
                    inp += self.fileObj.name

                if valid:
                    self.outerScreen.encDec("n", self.fileObj.hexPath, inp, op=False)
        else:
            Popup(title="Invalid", content=Label(text="Can't decrypt here, path is invalid.", halign="center"), size_hint=(.3, .3), pos_hint={"x_center": .5, "y_center": .5}).open()

    def getTitle(self):
        if self.fileObj.isDir:
            return "Decrypt Folder"
        else:
            return "Decrypt File"


class addNewFolderPop(Popup):

    def __init__(self, mainScreen, **kwargs):
        super(Popup, self).__init__(**kwargs)
        self.outerScreen = mainScreen

    def makeFolder(self, text):
        if dirInputValid(self.outerScreen.currentDir+text, self.outerScreen.fileSep):
            try:
                os.makedirs(self.outerScreen.currentDir+self.outerScreen.encString(text))
            except OSError as e:
                if "[Errno 36]" in str(e):  #OSError doesn't store the error code for some reason.
                    Popup(title="Invalid Folder Name", content=Label(text="Folder name too long.", halign="center"), size_hint=(.3, .3), pos_hint={"x_center": .5, "y_center": .5}).open()

            self.outerScreen.refreshFiles()
            self.dismiss()
        else:
            Popup(title="Invalid", content=Label(text="Invalid folder name.", halign="center"), size_hint=(.3, .3), pos_hint={"x_center": .5, "y_center": .5}).open()

class addFilePop(Popup):     #The screen (it's actually a Popup) for adding folders/files to the vault.

    def __init__(self, mainScreen, **kwargs):
        super(Popup, self).__init__(**kwargs)
        self.outerScreen = mainScreen

    class ConfirmationPopup(Popup):     #Popup for confirming encryption.

        def __init__(self, fileScreen, input, **kwargs):
            super(Popup, self).__init__(**kwargs)
            self.fileScreen = fileScreen
            self.inputText = input

```

```
300
301     def checkIfSure(self, input):
302         self.ConfirmationPopup(self, input).open()
```

I have not got any styling for `encDecPop` or `btTransferPop` because I have to access the GUI elements a lot. `btTransferPop` inherits from `encDecPop` to get useful methods that need to be used in both classes.

I will break down the way `encDecPop` gets the statistics it needs:

1. The encDecPop is created, and in `__init__` it starts a new thread which executes `self.encDec`.
2. `encDec` goes through the list of files given (`self.fileList` and `self.locList` (which contains the loctations to enc/decrypt to)), while Go encrypts each file separately. As Go is encrypting the files, `encDec` monitors the size of the current file using `os.path.getsize(<file>)`, and monitors it while it's size is less than the size of the original file.
3. The maximum value of the first status bar is set based on the size of the original file, while if enc/decrypting a folder, the second bar is based on the total size of all of the files in `fileList`.
4. Every loop the values of the status bars are updated, while every 0.5 seconds, the statistics are updated using the time difference from the last update.
5. The speed of the operation is obtained by getting the difference in size of the file in the time difference, divided by the time difference (or `sizeDelta/timeDelta`).
6. The time remaining of the operation is obtained by dividing the percentage left of all the files by the time it takes to do 1 percent (`(100 - (self.wholePb.value_normalized*100))/(perDelta/timeDelta)`). The percentage delta (`perDelta`) is calculated by taking a mean of 8 of the last percentage deltas, as this smooths the time prediction so it is not as erratic. This makes for a more accurate time prediction reading.
7. Both of these values have a function to get a nice human-readable output (`__getGoodUnit` for the speed, and `__getGoodUnitTime` for the time remaining).
8. The whole loop sleeps for 0.01 seconds to not max out the CPU, as it doesn't need to be updated that often (reduces usage to about 3 to 7%).

`btTransferPop` does works very similar to this, however since it is sending the data itself, it can get 100% accurate measurements of the statistics. Every time another batch of data is sent, the popup is updated.

`decryptFileToLocPop` is just a text input popup that is opened when the user wants to decrypt a file or folder to a certain location. It validates the input is a correct file path, and then creates a new `encDecPop` to handle the rest of the operation.

`addFilePop` is very similar to `decryptFileToLocPop`, however it has a bit more information, and is for encrypting a new file into the Vault (at `MainScreen.currentDir`). It has it's own child popup that asks for confirmation.

I named the file `mainSmallPops` incase I added large popups that filled the entire screen, in which case they would have their own file called `mainLargePops`, just to help me distinguish between the two.

Here is the styling for `mainSmallPops` (`code/python-go/kivyStuff/kvFiles/mainScPops.kv`):

```
1  #: import Clock kivy.clock.Clock
2
3  <addNewFolderPop@Popup>:
4      title: "Add New Folder"
5      size_hint: .7, .4
6      pos_hint: {"center_x": .5, "center_y": .5}
7      auto_dismiss: True
8      GridLayout:
9          cols: 1
10         Label:
11             text: "New Folder Name:"
12         TextInput:
```

```
            id: folderNameInput
            size_hint: .7, .4
            multiline: False
            hint_text: "Name"
            on_text_validate: root.makeFolder(self.text)

<decryptFileToLocPop@Popup>:
    title: root.getTitle()
    size_hint: .7, .4
    pos_hint: {"center_x": .5, "center_y": .5}
    auto_dismiss: True
    GridLayout:
        cols: 1
        Label:
            text: "Input the destination:"
        TextInput:
            id: decDirInput
            size_hint: .7, .4
            multiline: False
            hint_text: "Directory:"
            on_text_validate: root.checkCanDec(self.text)


<addFilePop@Popup>:
    id: addFile
    submitDirs: submitDirs
    size_hint: .7, .7
    title: "Add File"
    FloatLayout:
        Label:
            size_hint: .46, .08
            font_size: 18
            text: "Enter the directories what files you would like to encrypt (can be a folder).\nYou can
seperate each directory with '--' if you want to do multiple locations."
            pos_hint: {"center_x": 0.5, "y": 0.8}

        Button:
            size_hint: .16, .16
            pos_hint: {"center_x": .5, "center_y": .2}
            text: "Close"
            on_release: root.dismiss()

        TextInput:
            size_hint: .9, .12
            font_size: 22
            hint_text: "Directories"
            id: dirInp
            pos_hint: {"center_x": 0.5, "center_y": 0.7}
            multiline: False

        Button:
            id: submitDirs
            size_hint: .16, .16
            pos_hint: {"center_x": .5, "center_y": .4}
            text: "Submit"
            on_release: root.checkIfSure(root.ids.dirInp.text)


<ConfirmationPopup@Popup>:
    title: "Confirmation"
    size_hint: .4, .4
    pos_hint: {"center_x": .5, "center_y": .5}
    auto_dismiss: False
    FloatLayout:
        Label:
            text: "Are you sure?"
            pos_hint: {"center_x": .5, "center_y": .7}
        Button:
            text: "No!!!"
```

```
            pos_hint: {"center_x": .25, "center_y": .25}
            size_hint: .4, .3
            on_release: Clock.schedule_once(root.dismiss, -1)

        Button:
            text: "Yes"
            pos_hint: {"center_x": .75, "center_y": .25}
            size_hint: .4, .3
            on_release: Clock.schedule_once(root.dismiss,
-1);root.fileScreen.outerScreen.checkCanEncrypt(root.inputText)
```

Main Screen Labels

There is only one custom Label in my program, so this should be short.

It is defined in the `MainScreen` class:

```
class MainScreen(Screen):

    class infoLabel(Label):
      pass
```

Here is the styling for the class (`code/python-go/kivyStuff/kvFiles/mainScLabels.kv`):

```
<infoLabel@Label>:
    text_size: self.width, None
    height: self.texture_size[1]
```

What this does is wrap the text and constrain it within it's area. `infoLabel` is used for the information in the information popup, so it has to be constrained into it's area. The `text_size` is set to `self.width, None` because it is in a grid layout, so the grid should change it's size.

And that is everything in MainScreen.

Settings Screen

Here is the code for `SettingsScreen` (`code/python-go/kivyStuff/settingsScreen.py`):

```
from os import path, makedirs
from kivy.uix.popup import Popup
from kivy.uix.screenmanager import Screen

from configOperations import changeVaultLoc, editConfTerm

class SettingsScreen(Screen):

    def __init__(self, mainScreen, configLoc, **kwargs):
        self.outerScreen = mainScreen
        self.config = configLoc
        super(Screen, self).__init__(**kwargs)   # Done after so that when Screen.__init__ runs, it already has
those attributes.

        self.ids.searchSwitch.bind(active=self.searchSwitchCallback)
        self.ids.btSwitch.bind(active=self.btSwitchCallback)

    def searchSwitchCallback(self, switch, value):
        self.outerScreen.searchRecursively = not self.outerScreen.searchRecursively
        return editConfTerm("searchRecursively", str(value), self.config)

    def btSwitchCallback(self, switch, value):
```

```
        self.outerScreen.useBTTemp = not self.outerScreen.useBTTemp
        return editConfTerm("bluetooth", str(value), self.config)

    def changeVault(self, inp):
        if inp[0] != self.outerScreen.fileSep: # Relative path
            temp = self.outerScreen.startDir.split(self.outerScreen.fileSep)
            inp = self.outerScreen.fileSep.join(temp[:-4])+self.outerScreen.fileSep+inp
            if inp[-1] != self.outerScreen.fileSep:
                inp += self.outerScreen.fileSep # End with file separator


        if inp[len(inp)-1] != self.outerScreen.fileSep:
            inp += self.outerScreen.fileSep
        try:
            worked = changeVaultLoc(inp, self.outerScreen.fileSep, self.config)
        except FileNotFoundError:
            Popup(title="Invalid", content=self.outerScreen.infoLabel(text="Directory not valid:\n"+inp),
size_hint=(.4, .4), pos_hint={"x_center": .5, "y_center": .5}).open()
        except PermissionError as e:
            Popup(title="Invalid", content=self.outerScreen.infoLabel(text="Can't make a folder here:\n"+inp),
size_hint=(.4, .4), pos_hint={"x_center": .5, "y_center": .5}).open()
        except Exception as e:
            print(e)
            Popup(title="Invalid", content=self.outerScreen.infoLabel(text="Can't make a folder here:\n"+inp),
size_hint=(.4, .4), pos_hint={"x_center": .5, "y_center": .5}).open()
        else:
            if worked:
                done = Popup(title="Done", content=self.outerScreen.infoLabel(text="Changed Vault Location
to:\n"+inp), size_hint=(.4, .4), pos_hint={"x_center": .5, "y_center": .5})
                self.outerScreen.path = inp
                self.outerScreen.currentDir = inp
                self.outerScreen.recycleFolder =
self.outerScreen.path+self.outerScreen.recycleName+self.outerScreen.fileSep
                done.open()
            else:
                Popup(title="Invalid", content=self.outerScreen.infoLabel(text="Directory not valid:\n"+inp),
size_hint=(.4, .4), pos_hint={"x_center": .5, "y_center": .5}).open()
```

Here is the styling for this screen:

```
<SettingsScreen>:
    auto_dismiss: False
    newLoc: newLoc
    title: "Settings"
    GridLayout:
        cols: 2
        Label:
            canvas.before:
                Color:
                    rgba: 0.33, 0.33, 0.33, 1     # Aproximately the same as kivy's default button colour.
                Rectangle:
                    pos: self.pos
                    size: self.size

            text: "Settings Menu"
            font_size: 40
        Label:
            canvas.before:
                Color:
                    rgba: 0.33, 0.33, 0.33, 1
                Rectangle:
                    pos: self.pos
                    size: self.size


        Label:
            text: "Vault Location:"
```

```
            font_size: 20
        Label:
            text: root.outerScreen.path
            font_size: 14

        Label:
            text: "Change Vault Location:"
            font_size: 16
        GridLayout:
            cols: 2
            TextInput:
                id: newLoc
                size_hint_x: .85
                font_size: 22
                multiline: False
                hint_text: "Location"
            Button:
                size_hint_x: .15
                text: "Submit"
                on_release: root.changeVault(newLoc.text)


        Label:
            text: "Search folders recursively\n(takes longer but searches through folders)"
        Switch:
            id: searchSwitch
            active: root.outerScreen.searchRecursively

        Label:
            text: "Bluetooth login (as default)"
        Switch:
            id: btSwitch
            active: root.outerScreen.useBTTemp

        Label:
        Label:

        Label:
        Label:

        Label:
            text: "Note: Changes that you make that affect the login method only take effect once the program
is restarted."
            text_size: self.size
        Label:

        Button:
            text: "Exit"
            font_size: 20

            on_release: root.manager.current = "Main"


```

There are a few blank labels to fill the space in-between the exit button, and the rest of the settings.

This screen is quite simple, and most of the code is managing the GUI (boring).

Mobile App GUI Code

All of the mobile code is in Python 2, other than SHA, which is Python 3.

The root of the GUI

The main file of the program is `main.py` in `code/mobile/main.py`. Here is the code of `main.py`:

```
from kivy.app import App
from kivy.uix.screenmanager import ScreenManager, Screen, FadeTransition
from kivy.lang import Builder

from padScreen import PadScreen
from mainScreen import MainScreen
from fileSelectionScreen import FileSelectionScreen


class ScreenManagement(ScreenManager):
    pass

presentation = Builder.load_file(u"pad.kv")

class uiApp(App):

    def build(self):
        return presentation

def runUI():
    ui = uiApp()
    ui.run()


if __name__ == u"__main__":
    runUI()

```

All this does it load the `pad.kv` file, which contains the styling for the entire program, and also import all of the screens.

Here is `pad.kv` (`code/mobile/pad.kv`):

```
#: import FadeTransition kivy.uix.screenmanager.FadeTransition
#: import Window kivy.core.window.Window
#: import Clock kivy.clock.Clock

ScreenManagement:
    id: screenmanager
    transition: FadeTransition()
    PadScreen:
        name: "Pad"
        id: Pad
        manager: screenmanager
    MainScreen:
        name: "Main"
        id: Main
        manager: screenmanager
    FileSelectionScreen:
        name: "Select"
        id: Select
        manager: screenmanager

<PadNum@Button>:
    font_size: 30
    on_release: root.root.addNum(self.text)   # = PadScreen.addnNum(self.text)

<DeviceButton@Button>:
    font_size: 80
    on_release: self.devicePop.setupBT(self.text)

<PadScreen>:
    display: display
```

```
    FloatLayout:
        GridLayout:
            size_hint_y: .7
            cols: 3
            Button:
                text: "7"
                on_release: root.addNum(self.text)
            Button:
                text: "8"
                on_release: root.addNum(self.text)
            Button:
                text: "9"
                on_release: root.addNum(self.text)

            Button:
                text: "4"
                on_release: root.addNum(self.text)
            Button:
                text: "5"
                on_release: root.addNum(self.text)
            Button:
                text: "6"
                on_release: root.addNum(self.text)

            Button:
                text: "1"
                on_release: root.addNum(self.text)
            Button:
                text: "2"
                on_release: root.addNum(self.text)
            Button:
                text: "3"
                on_release: root.addNum(self.text)


            Button:
                text: "Delete"
                on_release: root.backSpace()
            Button:
                text: "0"
                on_release: root.addNum(self.text)
            Button:
                text: "Submit"
                on_release: root.confirm()

        Label:
            id: display
            text: root.numsString
            font_size: Window.height/20
            pos_hint: {"center_x": .5, "y": .35}

<MainScreen>:
    FloatLayout:
        Label:
            text: "To lock the Vault, close the program.\nAll downloaded files are stored in\nyour 'Download'
folder."

        Button:
            pos_hint: {"x": .25, "y": .2}
            size_hint: .5, .2
            text: "Select files from PC"
            on_release: root.manager.current = "Select"

<listButton@Button>:
    size_hint: 1, None
    on_release: root.outerScreen.selectFile(self.fileName)

<FileSelectionScreen>:
    FloatLayout:
```

```
        Button:
            text: "Exit"
            size_hint: .4, .14
            background_color: (0.8, 0.8, 0.8, 1)
            pos_hint: {"top": 1, "left": 1}
            on_release: root.exit()

        Button:
            text: "Go back"
            size_hint: .4, .14
            background_color: (0.8, 0.8, 0.8, 1)
            pos_hint: {"top": 1, "right": 1}
            on_release: root.getBackDir()
```

The way the app is built is slightly different than my PC app, as the mobile app is more built around the main `kv` file. The ScreenManager (`ScreenManagement`) is set as the root widget of the `kv` file, and then the app is built from the `kv` file.

Pad Screen

Here is the code for the `PadScreen`, which also contains the 'screen' (actually a popup) that lets you select a device:

```
from kivy.uix.gridlayout import GridLayout
from kivy.uix.label import Label
from kivy.uix.floatlayout import FloatLayout
from kivy.uix.button import Button
from kivy.uix.popup import Popup
from kivy.core.window import Window
from kivy.uix.scrollview import ScrollView
from kivy.clock import Clock
from kivy.uix.screenmanager import Screen
from jnius import autoclass

from btShared import recieveFileList
import SHA

# Import java Bluetooth classes.
BluetoothAdapter = autoclass(u"android.bluetooth.BluetoothAdapter")
BluetoothDevice = autoclass(u"android.bluetooth.BluetoothDevice")
BluetoothSocket = autoclass(u"android.bluetooth.BluetoothSocket")
UUID = autoclass(u"java.util.UUID")

def createSocketStream(self, devName):
    pairedDevs = BluetoothAdapter.getDefaultAdapter().getBondedDevices().toArray()
    socket = None
    found = False
    for dev in pairedDevs:
        if dev.getName() == devName:
            socket = dev.createRfcommSocketToServiceRecord(UUID.fromString("80677070-a2f5-11e8-b568-
0800200c9a66")) #Random UUID from https://www.famkruithof.net/uuid/uuidgen
            rStream = socket.getInputStream()   # Stream for recieving data
            sStream = socket.getOutputStream()  #Stream for sending data
            self.devName = devName
            found = True
            break   #Stop when device found
    if found:
        socket.connect()
        return rStream, sStream
    else:
        raise ConnectionAbortedError(u"Couldn't find + connect to device.")

class PadScreen(Screen, FloatLayout):

    class DeviceSelectionPopup(Popup):
```

```
42
43          class DeviceButton(Button):
44
45              def __init__(self, devPopup, **kwargs):
46                  self.devicePop = devPopup
47                  super(Button, self).__init__(**kwargs)
48                  self.outerScreen = self.devicePop.outerScreen
49
50          def __init__(self, padScreen, **kwargs):
51              self.outerScreen = padScreen
52              super(Popup, self).__init__(**kwargs)
53              self.devName = ""
54              self.connected = False
55              self.setupAll()
56
57          def setupAll(self, instance=None):
58              paired = self.getDeviceList()
59              if paired:   # If there are paired devices.
60                  self.setupDevButtons(paired)
61              else:
62                  grid = GridLayout(cols=1)
63                  info = Label(text="No paired devices found.\nPlease make sure your Bluetooth\nis on, you are
    in range of\nyour device, and you are paired\nto your device.")
64                  btn = Button(text="Retry", size_hint_y=.2)
65                  btn.bind(on_release=self.setupAll)
66                  self.content = grid   # Change content of popup to the grid
67
68          def setupDevButtons(self, listOfDevs):    # Similar to `createButtons` in `MainScreen` on PC app
69              self.layout = GridLayout(cols=1, spacing=20, size_hint_y=None)
70              self.layout.bind(minimum_height=self.layout.setter("height"))   # Set due to ScrollView
71
72              for devName in listOfDevs:
73                  btn = self.DeviceButton(self, text=devName, size_hint_y=None, height=Window.height/10,
    halign="left", valign="middle")
74                  self.layout.add_widget(btn)
75
76              self.view = ScrollView(size_hint=(1, 1))
77              self.view.add_widget(self.layout)
78              self.content = self.view
79
80          def getDeviceList(self):
81              result = []
82              pairedDevs = BluetoothAdapter.getDefaultAdapter().getBondedDevices().toArray()
83              for dev in pairedDevs:
84                  result.append(dev.getName())  # Get the names of each device.
85
86              return result
87
88
89          def changeToDeviceList(self, instance=None): # has to be a function as it is bound to a button
90              self.content = self.view
91
92          def setupBT(self, devName):
93              try:
94                  self.outerScreen.rStream, self.outerScreen.sStream = createSocketStream(self, devName)   #
    Create the two streams for communicating with the PC app
95              except Exception, e:
96                  print u"Can't connect to device."
97                  self.connected = False
98                  grid = GridLayout(cols=1)
99                  info = Label(text="Can't connect to device\nplease make sure the\ndevice has Bluetooth on,\nis
    in range, and is\nrunning the FileMate app.")
100                 btn = Button(text="Retry", size_hint_y=.2)
101                 btn.bind(on_press=self.changeToDeviceList)
102                 grid.add_widget(info)
103                 grid.add_widget(btn)
104                 self.content = grid
105             else:
106                 print u"Connected to:", devName
```

```
                self.connected = True
                self.dismiss()


    def __init__(self, **kwargs):
        super(PadScreen, self).__init__(**kwargs)
        self.nums = []
        self.numsString = u""
        self.rStream = None
        self.sStream = None
        self.deviceSelection = self.DeviceSelectionPopup(self, title="Select your device:",
title_align="center", size_hint=(1, 1), pos_hint={"x_center": .5, "y_center": .5}, auto_dismiss=False)
        Clock.schedule_once(self.deviceSelection.open, 0.5)

    def addNum(self, num):
        if len(self.nums) < 16:    # Maximum length of key is 16
            self.nums.append(int(num))
            self.numsString += "*"
            self.updateDisplay()

    def updateDisplay(self):       # Updates the Label at the top of PadScreen
        self.ids.display.text = self.numsString   # self.numsString just contains asterisks "*"

    def backSpace(self):      # For deleting the input
        if len(self.nums) != 0:
            del self.nums[-1]
            self.numsString = self.numsString[:len(self.nums)]
            self.updateDisplay()


    def confirm(self):
        pop = Popup(title="Please Wait...", content=Label(text="Waiting for confirmation."), size_hint=(1, 1),
pos_hint={"x_center": .5, "y_center": .5}, auto_dismiss=False)
        if self.rStream != None and self.sStream != None:  # if the connection is still up
            self.sStream.write("{}".format("#"))   # Key sent as #<key>~
            self.nums = SHA.getSHA128of16(self.nums)
            for num in self.nums:
                self.sStream.write("{},".format(num))
            self.sStream.write("{}".format("~"))
            self.sStream.flush()
            print u"Numbers sent."
            pop.open()

            data = self.rStream.read()
            while len(str(data)) == 0:
                try:
                    data = self.rStream.read()
                except Exception as e:
                    print e, u"Couldn't recieve data."

            print u"Out of while loop"
            print data, u"Response"
            if data == 49:   # Response sent by the PC if the key is valid.
                pop.dismiss()
                print u"Valid"

                corPop = Popup(title="Valid.", content=Label(text="Valid passcode!\nPlease leave the app open
in the background\notherwise the vault will lock."), size_hint=(.9, .5), pos_hint={"x_center": .5, "y_center":
.5})
                Clock.schedule_once(corPop.open, -1)

                # Time to recieve file names of current directory
                listOfFiles = recieveFileList(self.rStream)

                self.manager.get_screen("Main").sStream, self.manager.get_screen("Main").rStream =
self.sStream, self.rStream # Hand over the streams to the other screens

                self.manager.get_screen("Select").sStream, self.manager.get_screen("Select").rStream =
self.sStream, self.rStream
```

```
                self.manager.get_screen("Select").fileList = listOfFiles

                self.manager.current = "Main"

            elif data == 48: # Response sent by the PC if code is invalid.
                print u"Invalid."
                pop.dismiss()
                invPop = Popup(title="Invalid.", content=Label(text="Invalid passcode, please try again."),
size_hint=(.9, .5), pos_hint={"x_center": .5, "y_center": .5})
                self.nums = []
                self.numsString = u""
                self.updateDisplay()
                invPop.open()
            else:
                print type(data), "data was not either 49 or 48..."
        else:
            print u"Can't connect to device."
            Popup(self, title="Can't connect.",
                  content=Label(text="Can't connect to device\nplease make sure the\ndevice has Bluetooth
on,\nis in range, and is\nrunning the FileMate program."),
                  title_align="center",
                  size_hint=(.6, .6),
                  pos_hint={"x_center": .5, "y_center": .5},
                  auto_dismiss=True).open()

            self.deviceSelection.open()
```

The class `DeviceSelectionPopup` is inside of `PadScreen`, because it is only ever needed by `PadScreen`, and shoudln't exist unless `PadScreen` exists. The same thing applies with `DeviceButton`.

As soon as the screen opens, the `DeviceSelectionPopup` is opened, as it is needed at start up.

Most of this is just GUI.

Main Screen

This is the home screen of the app, although it is extremely basic (literally a Label and a Button).

Here is the code (`code/mobile/mainScreen.py`):

```
from kivy.uix.label import Label
from kivy.uix.floatlayout import FloatLayout
from kivy.uix.popup import Popup
from kivy.uix.screenmanager import Screen
from time import sleep

from btShared import recieveFile

class MainScreen(Screen, FloatLayout):

    def __init__(self, **kwargs):
        super(MainScreen, self).__init__(**kwargs)
        self.sStream = None
        self.rStream = None
```

Modules used in the `.kv` file, that are not from Kivy, have to be imported here.

File Seletion Screen & Shared Bluetooth functions

This screen is where the can browse the folders in the Vault, or download files from it instead.

I have used the protocol in the **Design** section to recieve both the list of files and to download files.

Here is the code for recieving a list of files, and for recieving a file (`code/mobile/btShared.py`):

```
from plyer import storagepath
from os import remove
from kivy.uix.label import Label
from kivy.uix.popup import Popup

#Shared methods
def recieveFileList(rStream, buffAlreadyKnown=[]):
    buff = buffAlreadyKnown    # If called from other places, some of they data may already
    data = ""

    endList = [126, 33, 33, 69, 78, 68, 76, 73, 83, 84, 33]          #~!!ENDLIST!

    while buff[-11:] != endList:        # If last 11 elements of the buffer is ~!!ENDLIST!
        try:
            data = rStream.read()
        except Exception as e:
            print e, "Failed while getting file list."
            break
        else:
            buff.append(data)

    buff = buff[10:-11] # Get the actuall list of files from the buffer

    listOfFiles = "".join([chr(i) for i in buff]) # Join input into a string
    listOfFiles = listOfFiles.split("--")[1:]  # First element will be "" due to first part of string being "--
""

    print "List of files given:", listOfFiles
    return listOfFiles

def recieveFile(rStream, buffAlreadyKnown=[]):
    print("Recieve file has been called.")
    # File is sent with    !NAME!<name here>~~!~<data>~!!ENDF!   like a data sandwich.
    # To do: make dictionary with each nameInstruction, startHeader etc, so they can be
    # easily identified.
    downloadsDir = storagepath.get_downloads_dir()

    buff = buffAlreadyKnown
    data = ""
    nameInstruction = [33, 78, 65, 77, 69, 33]                  # !NAME!
    endFile         = [126, 33, 69, 78, 68, 70, 73, 76, 69, 33] # ~!ENDFILE!
    separator       = [126, 126, 33, 126, 126]                  # ~~!~~
    nameFound = False
    name = []
    fo, fw = None, None
    fileName = ""
    bufferSize = 1024
    buffCount = 0

    while len(str(data)) > -1:   # While connection is open
        try:
            data = rStream.read()   # Read from the recieving stream
        except Exception as e:
            print e, u"Failed recieving file."
            if buffCount > 0:  # Clean up the file if it has been edited
                fo.close()
                remove(downloadsDir+"/"+fileName)  # Remove incomplete file. (from os module)
            return False
        else:
            buff.append(data)

        if not nameFound:
            name = []
            for i in range(len(buff)-6):  # -6 because that is the length of nameInstruction (scan is 6 wide)
                if buff[i:i+6] == nameInstruction:     # Are these 6 items the same as nameInstruction
                    z = i+6  # Move past nameInstruction
```

```
                    while (buff[z:z+5] != separator) and (z+5 < len(buff)):   # Scans current buffer for the name every time a new element is added to buffer, while the name has not been found.
                        name.append(buff[z])
                        z += 1

                    if buff[z:z+5] == separator:  # Once you get to the separator, then you know the name has been recieved.
                        nameFound = True          # Name has been found
                        buff[i:z+5] = [] # Clear name + separator

                        for letter in name:
                            fileName += chr(letter)

                        fo = open(downloadsDir+"/"+fileName, "wb") # Open for writing


        elif ((len(buff) > bufferSize+10) or (buff[-10:] == endFile)):   # If end of file header found
            if buff[-10:] == endFile:
                buff[-10:] = []
                print u"End found"
                fo.write(bytearray(buff))
                fo.close()

                pop = Popup(title="Success!", content=Label(text="File recieved successfuly.\nYou can find your file in\nyour 'Download' folder."), pos_hint={"x_center": .5, "y_center": .5}, size_hint=(.7, .4))
                pop.open()
                return True

            else:
                fo.write(bytearray(buff[:bufferSize]))
                buff[:bufferSize] = []
                buffCount += bufferSize
```

`recieveFileList` is called when `!FILELIST!` is recieved while changing directory, or when first entering the screen. It waits for `~!ENDLIST!`, and then joins the contents of the data recieved (that is not the start header) into a string, then splits the string by "--" to get the list of files. The first element of this list will be [""], because the file list looks like this: `--item1--item2`.

`recieveFile` is called when `!NAME!` is recieved while waiting for a response from `!FILESELECT!` command (sent when a file/folder is selected while browsing the files), and the response will be `!FILELIST!` if the item was a folder (containing list of items in that folder), or `!NAME!` followed by the file's data (if the item was a file).

Moving on to the file selection screen (`FileSelectionScreen` at `code/mobile/fileSelectionScreen.py`).

Here is the code:

```
from kivy.uix.gridlayout import GridLayout
from kivy.uix.floatlayout import FloatLayout
from kivy.uix.button import Button
from kivy.core.window import Window
from kivy.uix.scrollview import ScrollView
from kivy.uix.screenmanager import Screen

from btShared import recieveFileList, recieveFile

class FileSelectionScreen(Screen, FloatLayout):

    class listButton(Button):

        def __init__(self, mainScreen, fileName, **kwargs):
            super(Button, self).__init__(**kwargs)
            self.outerScreen = mainScreen
            self.fileName = fileName

```

```
19
20      def __init__(self, **kwargs):
21          super(FileSelectionScreen, self).__init__(**kwargs)
22          self.sStream = None
23          self.rStream = None
24          self.fileList = []
25
26          # List of possible responses
27          self.endOfTreeResponse = [33, 69, 78, 68, 79, 70, 84, 82, 69, 69, 33]  # !ENDOFTREE!
28          self.startList         = [33, 70, 73, 76, 69, 76, 73, 83, 84, 33]      # !FILELIST!
29          self.nameInstruction   = [33, 78, 65, 77, 69, 33]                      # !NAME!  --Start of a file
30          self.fileNotFound      = [33, 78, 79, 84, 70, 79, 85, 78, 68, 33]      # !NOTFOUND!  --Response to
    file selection
31
32
33      def on_enter(self):
34          self.createButtons(self.fileList)
35
36      def on_leave(self):
37          self.removeButtons()
38
39      def removeButtons(self):     # Clears all the widgets off the screen
40          self.grid.clear_widgets()
41          self.scroll.clear_widgets()
42          self.grid = 0
43          try:
44              self.remove_widget(self.scroll)
45          except Exception as e:
46              print e, u"Already removed?"
47          self.scroll = 0
48
49      def createButtons(self, array):   # Similar to createButtons on the PC app
50          self.grid = GridLayout(cols=1, size_hint_y=None) # Added in case I need to add more columns in the
    future (file size etc)
51          self.grid.bind(minimum_height=self.grid.setter("height"))
52          for item in array:
53              btn = self.listButton(self, item, text=("    "+str(item)), height=Window.height/10, halign="left",
    valign="middle")
54              btn.bind(size=btn.setter("text_size"))
55              self.grid.add_widget(btn)
56
57          self.scroll = ScrollView(size_hint=(1, .86))
58          self.scroll.add_widget(self.grid)
59          self.add_widget(self.scroll)
60
61      def recreateButtons(self, array):
62          self.removeButtons()
63          self.createButtons(array)
64
65      def selectFile(self, fileName):
66          # File request looks like: !FILESELECT!<name here>~!ENDSELECT!
67          msg = [33, 70, 73, 76, 69, 83, 69, 76, 69, 67, 84, 33] # !FILESELECT!
68
69          for letter in fileName:
70              msg.append(ord(letter))
71
72          msg += [126, 33, 69, 78, 68, 83, 69, 76, 69, 67, 84, 33] # End header: ~!ENDSELECT!
73
74          self.sStream.flush() # Clear write buffer on data stream.
75
76          for i in msg:
77              self.sStream.write(i)
78
79          # Get response
80          buff = []
81          data = ""
82          responseFound = False
83          print u"Waiting for response"
84
```

```
        while not responseFound:
            try:
                data = self.rStream.read()
            except Exception as e:
                print e, "Failed recieving response to select file."
                return False
            else:
                buff.append(data)

            if (buff[:6] == self.nameInstruction) and (len(buff) >= 6):  # If the response is !NAME!, then it was a file and will be sent to this program
                print u"Is name instruction"
                recieveFile(self.rStream, buff)
                responseFound = True
                buff = []

            elif (buff[:10] == self.fileNotFound) and (len(buff) >= 10): # If the response was !NOTFOUND! then the host couldn't find the item we wanted
                print u"Response is fileNotFound."
                raise ValueError("File was not found by host.")
                responseFound = True
                buff = []

            elif (buff[:10] == self.startList) and (len(buff) >= 10):    # If the response was !FILELIST! then it was a folder, so prepare to recieve the list of files in that folder.
                print u"Response is a file list."
                self.fileList = recieveFileList(self.rStream, buff)
                responseFound = True
                self.recreateButtons(self.fileList)

            elif len(buff) >= 13:                           # Reset the buffer and wait for next command
                print u"Didn't get response :(", buff
                buff = []


    def getBackDir(self):
        # Back dir request looks like: !BACK!
        backCommand = [33, 66, 65, 67, 75, 33]
        self.sStream.flush() # Clear the buffer for sending
        for i in backCommand:
            self.sStream.write(i)

        data = ""
        buff = []
        responseFound = False
        while not responseFound:
            try:
                data = self.rStream.read()
            except Exception as e:
                print e, "Failed recieving server response to BACK request."
                return False
            else:
                buff.append(data)

            if (buff[:11] == self.endOfTreeResponse) and (len(buff) >= 11):   # If you cannot go further back in the directory, !ENDOFTREE! is sent from the PC
                print "END OF TREE"
                buff = []
                responseFound = True

            elif (buff[:10] == self.startList) and (len(buff) >= 10):   # Otherwise, it should be a list of new file names
                responseFound = True
                self.fileList = recieveFileList(self.rStream, buff)
                self.recreateButtons(self.fileList)

            elif len(buff) >= 11:
                print "start header not found yet :(", buff
                buff = []
```

Again like `PadScreen`, this screen has and embedded class. `listButton`'s are displayed showing the contents of the current directory.

`selectFile` is called when a `listButton` is pressed, and requests to navigate that button.

`getBackDir` is called when the back button is pressed, and requests the list of items that are in the directory above the one we are currently in.

SHA

SHA is the exact same on the mobile app, as it is on the PC program.

What is buildozer.spec?

`buildozer.spec` is used for building the app and putting it onto the mobile device, and is unrelated to the rest of the code.

For transparency, here is the contents:

```
[app]

# (str) Title of your application
title = FM Pad
# (str) Package name
package.name = PadApp

# (str) Package domain (needed for android/ios packaging)
package.domain = org.test

# (str) Source code where the main.py live
source.dir = .

# (list) Source files to include (let empty to include all the files)
source.include_exts = py,png,jpg,kv,atlas

# (str) Application versioning (method 1)
version = 0.1

# (str) Application versioning (method 2)
# version.regex = __version__ = ['"](.*)['"]
# version.filename = %(source.dir)s/main.py

# (list) Application requirements
# comma seperated e.g. requirements = sqlite3,kivy
requirements = python2,android,plyer,pyjnius,kivy

# (str) Custom source folders for requirements
# Sets custom source for any requirements with recipes
# requirements.source.kivy = ../../kivy

# (list) Garden requirements
#garden_requirements =

# (str) Presplash of the application
#presplash.filename = %(source.dir)s/data/presplash.png

# (str) Icon of the application
#icon.filename = %(source.dir)s/data/icon.png

# (str) Supported orientation (one of landscape, portrait or all)
orientation = portrait

```

```
# (list) List of service to declare
#services = NAME:ENTRYPOINT_TO_PY,NAME2:ENTRYPOINT2_TO_PY

#
# OSX Specific
#

#
# author = © Copyright Info

# change the major version of python used by the app
osx.python_version = 3

# Kivy version to use
osx.kivy_version = 1.10.1

#
# Android specific
#

# (bool) Indicate if the application should be fullscreen or not
fullscreen = 0

# (string) Presplash background color (for new android toolchain)
# Supported formats are: #RRGGBB #AARRGGBB or one of the following names:
# red, blue, green, black, white, gray, cyan, magenta, yellow, lightgray,
# darkgray, grey, lightgrey, darkgrey, aqua, fuchsia, lime, maroon, navy,
# olive, purple, silver, teal.
#android.presplash_color = #FFFFFF

# (list) Permissions
android.permissions = BLUETOOTH,BLUETOOTH_ADMIN,BLUETOOTH_PRIVILEGED

[buildozer]

# (int) Log level (0 = error only, 1 = info, 2 = debug (with command output))
log_level = 2

# (int) Display warning if buildozer is run as root (0 = False, 1 = True)
warn_on_root = 1

# (str) Path to build artifact storage, absolute or relative to spec file
build_dir = /home/kivy/VMOUT/
```

And that is all of the code.

Testing

For testing my program, I will mostly be doing black-box testing, with some unit testing of important functions.

Unit Tests

The unit tests are only for the Go programs, as the `"testing"` package for Go makes testing very easy. Testing files in Go are made with the file name `<name-here>_test.go`. You may have noticed this in the **File Structure** section.

AES

To test AES, there are multiple `*_test.go` files, which I will go through individually. I will go through the results of the tests once I have gone through how I am doing them.

Testing the core algorithm

To test the core algorithm, I made tests for each of the functions in `code/python-go/AES/src/AES/aes.go` using test vectors that I worked out by hand (easy ones like shift rows), and some from official documentation or Wikipedia (The American government is shut down at the moment so the NIST, the National Institute of Standards and Technology (they do all the SHA contests and AES contests), website is down, so official test vectors for AES were not available, apart from the MixColumns step which has some on Wikipedia (https://en.wikipedia.org/wiki/Rijndael_MixColumns#TestVectors)).

Anyway, here is `aes_test.go` in `code/python-go/AES/src/AES/aes_test.go`:

```
1  package AES
2
3  import (
4    "fmt"
5    "testing"
6  )
7
8  func TestSubBytes(t *testing.T) {
9    testVector := []byte{ 76, 201,  25, 213,
10                         255,  41,  13,  94,
11                          44,  14, 215, 104,
12                         168, 101,  19,  89} // Randomly generated by Python
13
14   expectedOutcome := fmt.Sprintf("%x", []byte{41, 221, 212, 3,
15                                               22, 165, 215, 88,
16                                               113, 171, 14, 69,
17                                               194, 77, 125, 203})
18   subBytes(testVector)
19   actualOutcome := fmt.Sprintf("%x", testVector)
20   if actualOutcome != expectedOutcome {
21     t.Fatalf("Expected %s but got %s", expectedOutcome, actualOutcome)
22   }
23 }
24
25 func TestInvSubBytes(t *testing.T) {
26   testVector := []byte{41, 221, 212, 3,
27                        22, 165, 215, 88,
28                        113, 171, 14, 69,
29                        194, 77, 125, 203}
30
31   expectedOutcome := fmt.Sprintf("%x", []byte{ 76, 201,  25, 213,
32                                               255,  41,  13,  94,
33                                                44,  14, 215, 104,
34                                               168, 101,  19,  89})
35   invSubBytes(testVector)
36   actualOutcome := fmt.Sprintf("%x", testVector)
37   if actualOutcome != expectedOutcome {
38     t.Fatalf("Expected %s but got %s", expectedOutcome, actualOutcome)
39   }
40 }
41
42 func TestShiftRows(t *testing.T) {
43   testVector := []byte{ 76, 201,  25, 213,  // Taken from TestSubBytes
44                         255,  41,  13,  94,
45                          44,  14, 215, 104,
46                         168, 101,  19,  89}
47
48   expectedOutcome := fmt.Sprintf("%x", []byte{ 76,  41, 215,  89,
49                                               255,  14,  19, 213,
50                                                44, 101,  25,  94,
```

```
                                          168, 201,  13, 104})

  shiftRows(testVector) // Done by reference
  actualOutcome := fmt.Sprintf("%x", testVector)
  if actualOutcome != expectedOutcome {
    t.Fatalf("Expected %s but got %s", expectedOutcome, actualOutcome)
  }
}

func TestInvShiftRows(t *testing.T) {
  testVector := []byte{ 76,  41, 215,  89, // Taken from TestSubBytes
                       255,  14,  19, 213,
                        44, 101,  25,  94,
                       168, 201,  13, 104}

  expectedOutcome := fmt.Sprintf("%x", []byte{ 76, 201,  25, 213,
                                              255,  41,  13,  94,
                                               44,  14, 215, 104,
                                              168, 101,  19,  89})
  invShiftRows(testVector)
  actualOutcome := fmt.Sprintf("%x", testVector)
  if actualOutcome != expectedOutcome {
    t.Fatalf("Expected %s but got %s", expectedOutcome, actualOutcome)
  }
}

func TestMixColumns(t *testing.T) {
  testVector := []byte{0xdb, 0x13, 0x53, 0x45, // Different test vectors from
https://en.wikipedia.org/wiki/Rijndael_MixColumns
                       0xf2, 0x0a, 0x22, 0x5c,
                       0x01, 0x01, 0x01, 0x01,
                       0x2d, 0x26, 0x31, 0x4c}

  expectedOutcome := fmt.Sprintf("%x", []byte{0x8e, 0x4d, 0xa1, 0xbc,
                                              0x9f, 0xdc, 0x58, 0x9d,
                                              0x01, 0x01, 0x01, 0x01,
                                              0x4d, 0x7e, 0xbd, 0xf8})

  mixColumns(testVector)
  actualOutcome := fmt.Sprintf("%x", testVector)
  if actualOutcome != expectedOutcome {
    t.Fatalf("Expected %s but got %s", expectedOutcome, actualOutcome)
  }
}

func testInvMixColumns(t *testing.T) {
  testVector := []byte{0x8e, 0x4d, 0xa1, 0xbc,
                       0x9f, 0xdc, 0x58, 0x9d,
                       0x01, 0x01, 0x01, 0x01,
                       0x4d, 0x7e, 0xbd, 0xf8}

  expectedOutcome := fmt.Sprintf("%x", []byte{0xdb, 0x13, 0x53, 0x45,
                                              0xf2, 0x0a, 0x22, 0x5c,
                                              0x01, 0x01, 0x01, 0x01,
                                              0x2d, 0x26, 0x31, 0x4c})
  invMixColumns(testVector)
  actualOutcome := fmt.Sprintf("%x", testVector)
  if actualOutcome != expectedOutcome {
    t.Fatalf("Expected %s but got %s", expectedOutcome, actualOutcome)
  }
}

func TestKeyExpansionCore(t *testing.T) {
  testVector := [4]byte{1, 2, 3, 4}
  // 2, 3, 4, 1
  // sBox[2], sBox[3], sBox[4], sBox[1]
  // = 119, 123, 242, 124
  // 119 ^ rcon[0] = 119 ^ 0x8d = 250
  // 250, 123, 242, 124
```

```
  expectedOutcome := fmt.Sprintf("%x", [4]byte{250, 123, 242, 124})
  actualOutcome := fmt.Sprintf("%x", keyExpansionCore(testVector, 0))
  if actualOutcome != expectedOutcome {
    t.Fatalf("Expected %s but got %s", expectedOutcome, actualOutcome)
  }
}

func TestKeyExpansion(t *testing.T) {
  testVector00 :=   []byte{0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0}
  testVector1234 := []byte{1, 2, 3, 4, 5, 6, 7, 8, 9, 0, 1, 2, 3, 4, 5, 6}
  testVectorff :=   []byte{0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
0xff, 0xff}

  // Expected key expansion for each of the keys:
  expectedOutcome00 := fmt.Sprintf("%x", [176]byte{0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
                                                   0x62, 0x63, 0x63, 0x63, 0x62, 0x63, 0x63, 0x63, 0x62, 0x63,
0x63, 0x63, 0x62, 0x63, 0x63, 0x63,
                                                   0x9b, 0x98, 0x98, 0xc9, 0xf9, 0xfb, 0xfb, 0xaa, 0x9b, 0x98,
0x98, 0xc9, 0xf9, 0xfb, 0xfb, 0xaa,
                                                   0x90, 0x97, 0x34, 0x50, 0x69, 0x6c, 0xcf, 0xfa, 0xf2, 0xf4,
0x57, 0x33, 0x0b, 0x0f, 0xac, 0x99,
                                                   0xee, 0x06, 0xda, 0x7b, 0x87, 0x6a, 0x15, 0x81, 0x75, 0x9e,
0x42, 0xb2, 0x7e, 0x91, 0xee, 0x2b,
                                                   0x7f, 0x2e, 0x2b, 0x88, 0xf8, 0x44, 0x3e, 0x09, 0x8d, 0xda,
0x7c, 0xbb, 0xf3, 0x4b, 0x92, 0x90,
                                                   0xec, 0x61, 0x4b, 0x85, 0x14, 0x25, 0x75, 0x8c, 0x99, 0xff,
0x09, 0x37, 0x6a, 0xb4, 0x9b, 0xa7,
                                                   0x21, 0x75, 0x17, 0x87, 0x35, 0x50, 0x62, 0x0b, 0xac, 0xaf,
0x6b, 0x3c, 0xc6, 0x1b, 0xf0, 0x9b,
                                                   0x0e, 0xf9, 0x03, 0x33, 0x3b, 0xa9, 0x61, 0x38, 0x97, 0x06,
0x0a, 0x04, 0x51, 0x1d, 0xfa, 0x9f,
                                                   0xb1, 0xd4, 0xd8, 0xe2, 0x8a, 0x7d, 0xb9, 0xda, 0x1d, 0x7b,
0xb3, 0xde, 0x4c, 0x66, 0x49, 0x41,
                                                   0xb4, 0xef, 0x5b, 0xcb, 0x3e, 0x92, 0xe2, 0x11, 0x23, 0xe9,
0x51, 0xcf, 0x6f, 0x8f, 0x18, 0x8e})

  expectedOutcomeff := fmt.Sprintf("%x", [176]byte{0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
0xff, 0xff, 0xff, 0xff, 0xff, 0xff,
                                                   0xe8, 0xe9, 0xe9, 0xe9, 0x17, 0x16, 0x16, 0x16, 0xe8, 0xe9,
0xe9, 0xe9, 0x17, 0x16, 0x16, 0x16,
                                                   0xad, 0xae, 0xae, 0x19, 0xba, 0xb8, 0xb8, 0x0f, 0x52, 0x51,
0x51, 0xe6, 0x45, 0x47, 0x47, 0xf0,
                                                   0x09, 0x0e, 0x22, 0x77, 0xb3, 0xb6, 0x9a, 0x78, 0xe1, 0xe7,
0xcb, 0x9e, 0xa4, 0xa0, 0x8c, 0x6e,
                                                   0xe1, 0x6a, 0xbd, 0x3e, 0x52, 0xdc, 0x27, 0x46, 0xb3, 0x3b,
0xec, 0xd8, 0x17, 0x9b, 0x60, 0xb6,
                                                   0xe5, 0xba, 0xf3, 0xce, 0xb7, 0x66, 0xd4, 0x88, 0x04, 0x5d,
0x38, 0x50, 0x13, 0xc6, 0x58, 0xe6,
                                                   0x71, 0xd0, 0x7d, 0xb3, 0xc6, 0xb6, 0xa9, 0x3b, 0xc2, 0xeb,
0x91, 0x6b, 0xd1, 0x2d, 0xc9, 0x8d,
                                                   0xe9, 0x0d, 0x20, 0x8d, 0x2f, 0xbb, 0x89, 0xb6, 0xed, 0x50,
0x18, 0xdd, 0x3c, 0x7d, 0xd1, 0x50,
                                                   0x96, 0x33, 0x73, 0x66, 0xb9, 0x88, 0xfa, 0xd0, 0x54, 0xd8,
0xe2, 0x0d, 0x68, 0xa5, 0x33, 0x5d,
                                                   0x8b, 0xf0, 0x3f, 0x23, 0x32, 0x78, 0xc5, 0xf3, 0x66, 0xa0,
0x27, 0xfe, 0x0e, 0x05, 0x14, 0xa3,
                                                   0xd6, 0x0a, 0x35, 0x88, 0xe4, 0x72, 0xf0, 0x7b, 0x82, 0xd2,
0xd7, 0x85, 0x8c, 0xd7, 0xc3, 0x26})

  expectedOutcome1234 := fmt.Sprintf("%x", [176]byte{0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08, 0x09,
0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06,
                                                     0xf2, 0x69, 0x6c, 0x7f, 0xf7, 0x6f, 0x6b, 0x77, 0xfe,
0x6f, 0x6a, 0x75, 0xfd, 0x6b, 0x6f, 0x73,
                                                     0x8f, 0xc1, 0xe3, 0x2b, 0x78, 0xae, 0x88, 0x5c, 0x86,
0xc1, 0xe2, 0x29, 0x7b, 0xaa, 0x8d, 0x5a,
                                                     0x27, 0x9c, 0x5d, 0x0a, 0x5f, 0x32, 0xd5, 0x56, 0xd9,
0xf3, 0x37, 0x7f, 0xa2, 0x59, 0xba, 0x25,
```

```
                                                0xe4, 0x68, 0x62, 0x30, 0xbb, 0x5a, 0xb7, 0x66, 0x62,
0xa9, 0x80, 0x19, 0xc0, 0xf0, 0x3a, 0x3c,
                                                0x78, 0xe8, 0x89, 0x8a, 0xc3, 0xb2, 0x3e, 0xec, 0xa1,
0x1b, 0xbe, 0xf5, 0x61, 0xeb, 0x84, 0xc9,
                                                0xb1, 0xb7, 0x54, 0x65, 0x72, 0x05, 0x6a, 0x89, 0xd3,
0x1e, 0xd4, 0x7c, 0xb2, 0xf5, 0x50, 0xb5,
                                                0x17, 0xe4, 0x81, 0x52, 0x65, 0xe1, 0xeb, 0xdb, 0xb6,
0xff, 0x3f, 0xa7, 0x04, 0x0a, 0x6f, 0x12,
                                                0xf0, 0x4c, 0x48, 0xa0, 0x95, 0xad, 0xa3, 0x7b, 0x23,
0x52, 0x9c, 0xdc, 0x27, 0x58, 0xf3, 0xce,
                                                0x81, 0x41, 0xc3, 0x6c, 0x14, 0xec, 0x60, 0x17, 0x37,
0xbe, 0xfc, 0xcb, 0x10, 0xe6, 0x0f, 0x05,
                                                0x39, 0x37, 0xa8, 0xa6, 0x2d, 0xdb, 0xc8, 0xb1, 0x1a,
0x65, 0x34, 0x7a, 0x0a, 0x83, 0x3b, 0x7f})

  outcome00 := fmt.Sprintf("%x", ExpandKey(testVector00))
  if outcome00 != expectedOutcome00 {
    t.Fatalf("00 Expected %s but got %s", expectedOutcome00, outcome00)
  }

  outcome1234 := fmt.Sprintf("%x", ExpandKey(testVector1234))
  if outcome1234 != expectedOutcome1234 {
    t.Fatalf("1234 Expected %s but got %s", expectedOutcome1234, outcome1234)
  }

  outcomeff := fmt.Sprintf("%x", ExpandKey(testVectorff))
  if outcomeff != expectedOutcomeff {
    t.Fatalf("ff Expected %s but got %s", expectedOutcomeff, outcomeff)
  }
}
```

Benchmarks are run multiple times, and get the time taken for each run, and the amount of bytes processed and the number of variable allocations made.

The test vectors for `ExpandKey` were calculated using an old version of AES I made in Python while I was making my project, and I have verified it using this website http://aes.online-domain-tools.com/, just to check it encrypts data correctly (it was fine).

Testing AESfiles

Here is the test file for the `AESfiles` package (`code/python-go/AES/src/AES/AESfiles/aesFiles_test.go`):

```
package AESfiles

import (
  "fmt"
  "log"
  "testing"
  "os/exec"
  "strings"
  "AES"
)

const (
  largeFile = "/home/josh/GentooMin.iso"
  largeFileTemp = "/home/josh/temp"
  largeFileDec = "/home/josh/decTemp.iso"

  mediumFile = "/home/josh/8k.png"
  mediumFileTemp = "/home/josh/8kTemp"
  mediumFileDec = "/home/josh/8kDec.png"

  smallFile = "/home/josh/a.txt"
  smallFileTemp = "/home/josh/temp2"
```

```
  smallFileDec = "/home/josh/smallDec.txt"
)

var (
  expandedKey = AES.ExpandKey([]byte{0x00, 0x0b, 0x16, 0x1d, 0x2c, 0x27, 0x3a, 0x31, 0x58, 0x53, 0x4e, 0x45, 0x74, 0x7f, 0x62, 0x69})
)

func BenchmarkEncryptFileLarge(b *testing.B) {
  for n := 0; n < b.N; n++ {
    EncryptFile(&expandedKey, largeFile, largeFileTemp)
  }
}

func BenchmarkDecryptFileLarge(b *testing.B) {
  for n := 0; n < b.N; n++ {
    DecryptFile(&expandedKey, largeFileTemp, largeFileDec)
  }
}

func BenchmarkEncryptFileMedium(b *testing.B) {
  for n := 0; n < b.N; n++ {
    EncryptFile(&expandedKey, mediumFile, mediumFileTemp)
  }
}

func BenchmarkDecryptFileMedium(b *testing.B) {
  for n := 0; n < b.N; n++ {
    DecryptFile(&expandedKey, mediumFileTemp, mediumFileDec)
  }
}

func TestEncDecMediumFile(t *testing.T) {
  out, err := exec.Command("/bin/bash", "-c", "b2sum '"+mediumFile+"'").Output() // Gets hash of original file using the b2sum utility in the GNU core utils
  if err != nil { panic(err) }

  initialHash := strings.Replace(fmt.Sprintf("%s", out), mediumFile, "", -1) // b2sum outputs the dir after the checksum is output, so remove the dir.
  log.Output(0, fmt.Sprintf("initialHash: %s", initialHash))

  EncryptFile(&expandedKey, mediumFile, mediumFileTemp)
  DecryptFile(&expandedKey, mediumFileTemp, mediumFileDec)

  out, err = exec.Command("/bin/bash", "-c", "b2sum '"+mediumFileDec+"'").Output()
  finalHash := strings.Replace(fmt.Sprintf("%s", out), mediumFileDec, "", -1)
  log.Output(0, fmt.Sprintf("finalHash: %s", finalHash))

  if finalHash != initialHash {
    t.Fatalf("Expected %s but got %s", initialHash, finalHash)
  }
}

func TestEncDecSmallFile(t *testing.T) {
  out, err := exec.Command("/bin/bash", "-c", "b2sum '"+smallFile+"'").Output() // Gets hash of original file using the b2sum utility in the GNU core utils
  if err != nil { panic(err) }

  initialHash := strings.Replace(fmt.Sprintf("%s", out), smallFile, "", -1) // b2sum outputs the dir after the checksum is output, so remove the dir.
  log.Output(0, fmt.Sprintf("initialHash: %s", initialHash))

  EncryptFile(&expandedKey, smallFile, smallFileTemp)
  DecryptFile(&expandedKey, smallFileTemp, smallFileDec)

  out, err = exec.Command("/bin/bash", "-c", "b2sum '"+smallFileDec+"'").Output()

  finalHash := strings.Replace(fmt.Sprintf("%s", out), smallFileDec, "", -1)
  log.Output(0, fmt.Sprintf("finalHash: %s", finalHash))
```

```
87
88    if finalHash != initialHash {
89      t.Fatalf("Expected %s but got %s", initialHash, finalHash)
90    }
91  }
```

When testing enc/decryption of files, I will get the blake checksum of the file before and after encryption and decryption (one after the other, not separate) using the `b2sum` utility included in the GNU core utilities on Linux. That is what line 55, 64, 74 and 83 are for. The output of `b2sum` looks like `<checksum here> <file name done>`, so the last part has to be removed (as the file will be decrypted to a different file), which is what `strings` and `fmt` are needed for.

The checksums are also printed to the terminal using `log.Output`, so I can compare them myself too, in case of a bug with the test.

After decryption of the encrypted file, the checksums are compared, and if they are different then the test has failed.

That's it for the code of the AES unit tests.

Running the tests

To run the tests I have made a few bash scripts that just run a set of commands so that I don't have to remember them. These are `testAES.sh` and `testBenchAES.sh`, both in `code/python-go/AES/`.

Here is `testAES.sh`:

```
1  #!/bin/bash
2  export GOPATH="/home/josh/nea-12ColcloughJ/code/python-go/AES/"
3  cd src/AES && go test -v
4  cd AESfiles && go test -v
```

`-v` means verbose output, so Go shows each of the tests individually and what it is doing. The last two lines just change directories to where the tests are relative to `code/python-go/AES/`, as otherwise Go can't find the test files.

`testBenchAES.sh` is the same, but it runs benchmarks after doing the tests. Here it is:

```
1  #!/bin/bash
2  export GOPATH="/home/josh/nea-12ColcloughJ/code/python-go/AES/"
3  cd src/AES && go test -v -bench=. -benchmem
4  cd AESfiles && go test -v -bench=. -benchmem
```

`-bench=.` tells Go to run all benchmarks that match a regular expression. A `.` just says that it can be anything. `-benchmem` outputs how many bytes were processed during the operation, and how many variable allocations were made.

Here are the results of the tests (running `testBenchAES.sh`):

```
1  === RUN   TestSubBytes
2  --- PASS: TestSubBytes (0.00s)
3  === RUN   TestInvSubBytes
4  --- PASS: TestInvSubBytes (0.00s)
5  === RUN   TestShiftRows
6  --- PASS: TestShiftRows (0.00s)
7  === RUN   TestInvShiftRows
8  --- PASS: TestInvShiftRows (0.00s)
```

```
=== RUN   TestMixColumns
--- PASS: TestMixColumns (0.00s)
=== RUN   TestKeyExpansionCore
--- PASS: TestKeyExpansionCore (0.00s)
=== RUN   TestKeyExpansion
--- PASS: TestKeyExpansion (0.00s)
PASS
ok    AES 0.001s
=== RUN   TestEncDecMediumFile
2019/01/04 12:06:00 initialHash:
9336f1fc79ff254c8644f1df83fccfd576388c5075754ae9142c2640dd9530c5e08403937296afc7ca8138cedaf0794117e78d247ce6949
ee40304284c39b7ed
2019/01/04 12:06:01 finalHash:
9336f1fc79ff254c8644f1df83fccfd576388c5075754ae9142c2640dd9530c5e08403937296afc7ca8138cedaf0794117e78d247ce6949
ee40304284c39b7ed
--- PASS: TestEncDecMediumFile (0.91s)
=== RUN   TestEncDecSmallFile
2019/01/04 12:06:01 initialHash:
0c8b815719e57e1e3529a20df69c31d8cabab90212bce1b7a3296c8f70f307d1a7e8e64ed5bb17fc7b7f3b9cc3150e4f59c4a70922a0d3b
46bfda1652e735588
2019/01/04 12:06:01 finalHash:
0c8b815719e57e1e3529a20df69c31d8cabab90212bce1b7a3296c8f70f307d1a7e8e64ed5bb17fc7b7f3b9cc3150e4f59c4a70922a0d3b
46bfda1652e735588
--- PASS: TestEncDecSmallFile (0.01s)
goos: linux
goarch: amd64
pkg: AES/AESfiles
BenchmarkEncryptFileLarge-4            1  1871293107 ns/op  244325952 B/op      3790 allocs/op
BenchmarkDecryptFileLarge-4            1  2042360853 ns/op  244320832 B/op      3757 allocs/op
BenchmarkEncryptFileMedium-4           3   378539062 ns/op  48565877 B/op      769 allocs/op
BenchmarkDecryptFileMedium-4           3   417413577 ns/op  48491632 B/op      768 allocs/op
PASS
ok    AES/AESfiles  9.640s
```

Every test passed, and I can now calculate the speed of encryption and decryption using the time taken on average for each operation (ns/op). I made a small Python script to do this (it isn't part of my project):

```python
def getGoodUnit(bytes):       #Get a good unit for displaying the sizes of files.
    if bytes == " -":
        return " -"
    else:
        divCount = 0
        divisions = {0: "B", 1: "KB", 2: "MB", 3: "GB", 4: "TB", 5: "PB"}
        while bytes > 1000:
            bytes = bytes/1000
            divCount += 1

        return ("%.2f" % bytes) + " " + divisions[divCount]

def calc(time, data):
    time = time * (10**-9)  # 10^-9 because the time is in nano seconds.
    datTime = data/time
    return getGoodUnit(datTime)

print(calc(float(input("Time taken: ")), int(input("Num of bytes: ")))+"/s")
```

It steals the `getGoodUnit` function from my project. There is no error checking because I am the only person who will be using it, and also I am lazy.

The result (on an i5-6600k - 4 cores) is that when encrypting, the speed was `129.97 MB/s`, and when decrypting the speed was `119.63 MB/s` which is slightly slower (`10.34 MB/s`), probably because it has to check for padding. Before I changed my code to pass by reference, and also before I made AES parallel using goroutines, it had a performance of `18.92 MB/s` when encrypting. If I compare the single core performance (by dividing `129.97` by 4

(4 cores)), the single core performance of the new AES is `32.49 MB/s`, which is 1.72 times as fast, just by passing by reference.

BLAKE

All of the bash files for BLAKE are the same as AES with minor changes.

Like AES, BLAKE also has some unit tests. There is only one test file (`code/python-go/BLAKE/src/BLAKE/blake_test.go`):

```
package BLAKE

import (
  "fmt"
  "testing"
)

const largeFile = "/home/josh/GentooMin.iso"
const smallFile = "/home/josh/a.txt"

func BenchmarkBLAKELarge(b *testing.B) {
  for n := 0; n < b.N; n++ {
    GetChecksum(largeFile, 64)
  }
}

func BenchmarkBLAKESmall(b *testing.B) {
  for n := 0; n < b.N; n++ {
    GetChecksum(smallFile, 64)
  }
}

func TestBLAKELarge(t *testing.T) {
  actualResult := fmt.Sprintf("%x", GetChecksum(largeFile, 64))
  expectedResult :=
"640ac216c91f85d69b450b070828b0f2f54db51af3ecf1daffeafdd657ae1a8d4e5732b4594f936c9d2d853ee12a1df58e6fa63535c1ed
3e170e9578da740e5d"  // Obtained using b2sum tool in GNU core utilities

  if actualResult != expectedResult {
    t.Fatalf("Expected %s but got %s", expectedResult, actualResult)
  }
}

func TestBLAKESmall(t *testing.T) {
  actualResult := fmt.Sprintf("%x", GetChecksum(smallFile, 64))
  expectedResult :=
"f545377b0ab74d283ff65ec5518bc00633d46125ec28bbd11f417da16949e8937759d8f1aa97556845e24edc676d8f288d49aae1bb195a
12e5595525713427c4"

  if actualResult != expectedResult {
    t.Fatalf("Expected %s but got %s", expectedResult, actualResult)
  }
}

func TestBlakeMix(t *testing.T) {
  arr := []uint64{0x70f3abeaaf82f2d2, 0x48221449c090c5cb, 0x1631bc17f31ed4ef, 0xdf4a6c4edfb6012e,
                  0x4011c31f6e4fbe98, 0xeca6fe4ecfbd235d,  0xc732f6aacdfed23, 0x6c59d3af929a71a7,
                  0x726e4d94d076d220, 0xd55261f05e988e99, 0x47c5fed6073fff6f, 0xafdc6ec84b5122fd,
                  0x828789a16ddf8fcc, 0x9219a1cce5eaceb3, 0x81c389d523f73c81, 0xc518f0411804f255} // Randomly
generated in python.

  // Tested using working version
  expectedResult := []uint64{0x24f71c9177a10424, 0x48221449c090c5cb, 0x1631bc17f31ed4ef, 0xdf4a6c4edfb6012e,
                             0x216426a085db4092, 0xeca6fe4ecfbd235d,  0xc732f6aacdfed23, 0x6c59d3af929a71a7,
                             0xaa69fe02ab573a54, 0xd55261f05e988e99, 0x47c5fed6073fff6f, 0xafdc6ec84b5122fd,
                             0x9771847d3761d4df, 0x9219a1cce5eaceb3, 0x81c389d523f73c81, 0xc518f0411804f255}

```

```
  blakeMix(arr, 0, 4, 8, 12, &arr[0], &arr[1]) // Simulates first mix of the compression function.

  if fmt.Sprintf("%x", arr) != fmt.Sprintf("%x", expectedResult) {
    t.Fatalf("Expected %x but got %x", expectedResult, arr)
  }
}
```

For most of the tests, the result of the command `b2sum` is hard coded rather than retrieved from the terminal, as I was having issues comparing the output of BLAKE and the `b2sum` command.

Here are the test results:

```
=== RUN   TestBLAKELarge
--- PASS: TestBLAKELarge (1.68s)
=== RUN   TestBLAKESmall
--- PASS: TestBLAKESmall (0.00s)
=== RUN   TestBlakeMix
--- PASS: TestBlakeMix (0.00s)
goos: linux
goarch: amd64
pkg: BLAKE
BenchmarkBLAKELarge-4            1  1676409286 ns/op  2198866712 B/op     7476 allocs/op
BenchmarkBLAKESmall-4       300000        5282 ns/op      3264 B/op       10 allocs/op
PASS
ok    BLAKE 5.004s
```

All tests passed, and using the same Python script as in AES, the speed was `145.74 MB/s`. The speed is ok, however if you open and edit a very large file (> 145 MB), it will take more than 1 second to open and close, after decryption and before encryption. This is not much of an issue however, since not many people will be editing files that are that large it shouldn't be an issue for most people, since the checksum is not calculated when merely adding and removing files from the Vault.

Black-box tests

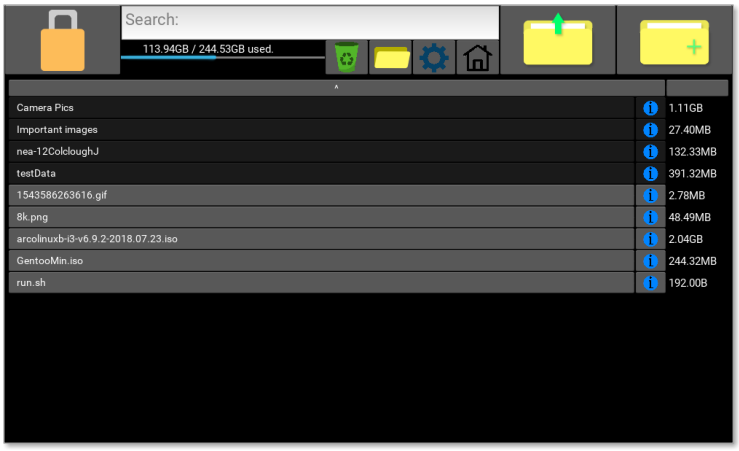
The key for the different types of data (where applicable) will be:

- T = Typical Data
- E = Erroneous Data
- B = Boundary Data

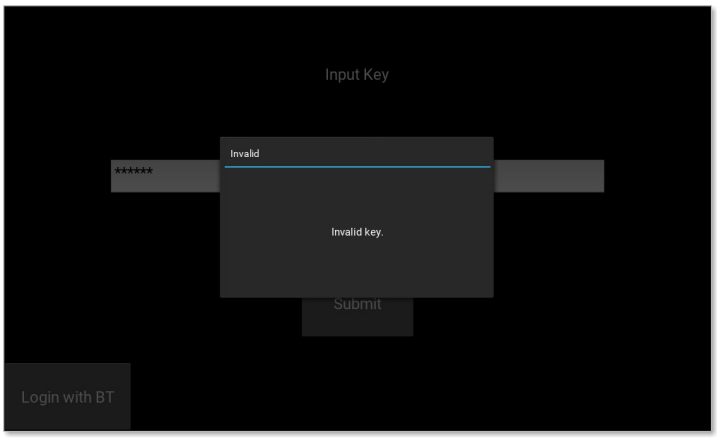
Test Number	1
Relevant Objective	1.g
Description	Input various data into the key input of the regular login screen. The valid key I will use will be 1234.
Purpose	To ensure that the login screen is both secure and works as intended.
Test Data	T: [1]: 1234 [2]: 222333 [3]: 2001 E: [4]: My name is jeff [5]: 12345678901234567 [6]: 1a2b3c4ddeed [7]: abcdefghijklmnopq B: [8]: 9999999999999999 [9]: 0000000000000000 [10]: 00000000000000000 [11]: (nothing)
Expected Outcome	[1]: Should be accepted as the correct key and main screen should open. [2]: Program should tell the user that the key is invalid, as it is not the key I set (1234). [3]: Program should tell the user that the key is invalid, as it is not the key I set (1234). [4]: Program should tell the user that the key is invalid, as it contains characters. [5]: Program should tell the user that the key is invalid, as it is longer than 16 in length. [6]: Program should tell the user that the key is invalid, as it contains characters. [7]: Program should tell the user that the key is invalid, as it is longer then 16 in length. [8]: Program should tell the user that the key is invalid, as it is not the key I set (1234) ([8] is 16 in length). [9]: Program should tell the user that the key is invalid, as it is not the key I set (1234) ([9] is 16 in length). [10]: Program should tell the user that the key is invalid, as it is longer than 16 in length. [11]: Program should tell the user that the key is invalid, as the key has to at least be 1 in length.
Actual Outcome	[All]: Pass

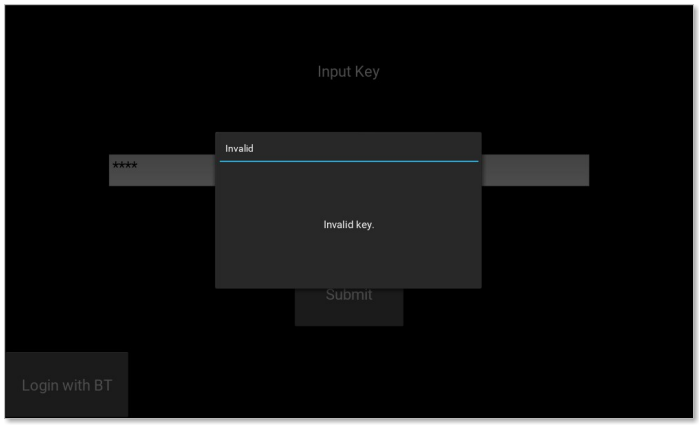
Evidence:

[1]: Opened

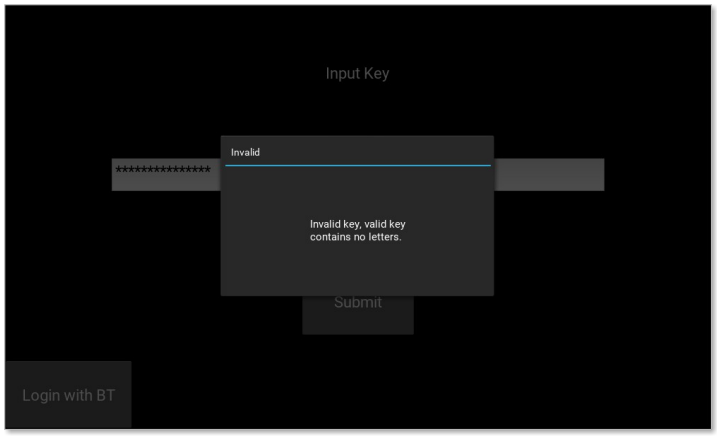


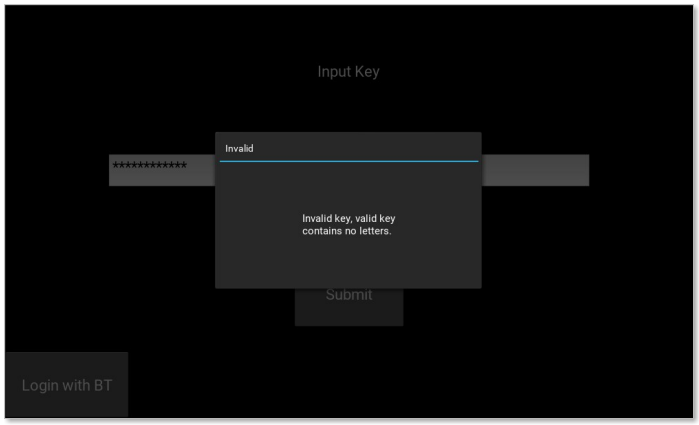
[2, 3]: Invalid



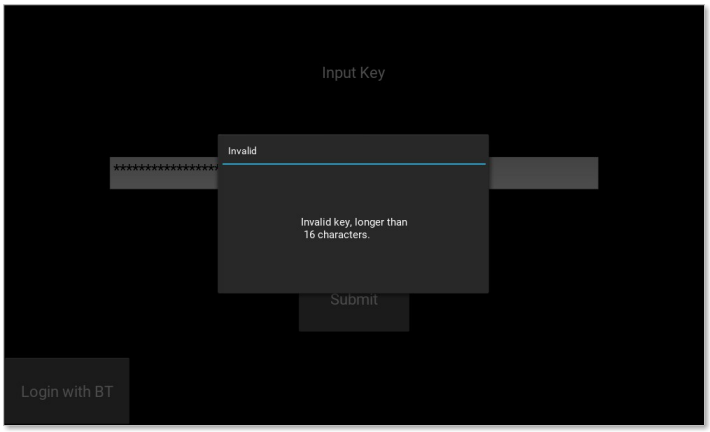


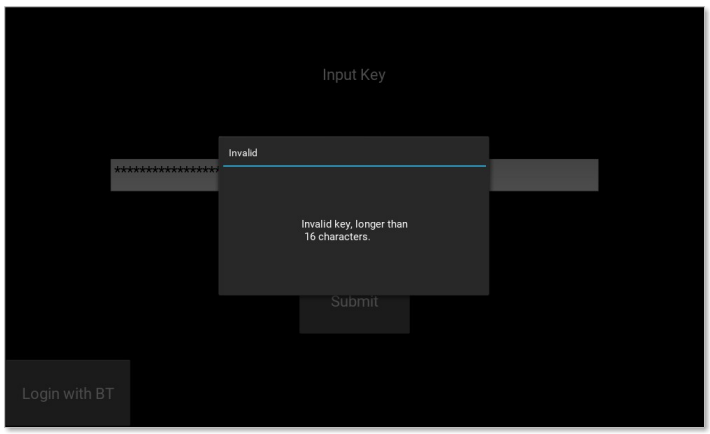
[4, 6]: No characters:

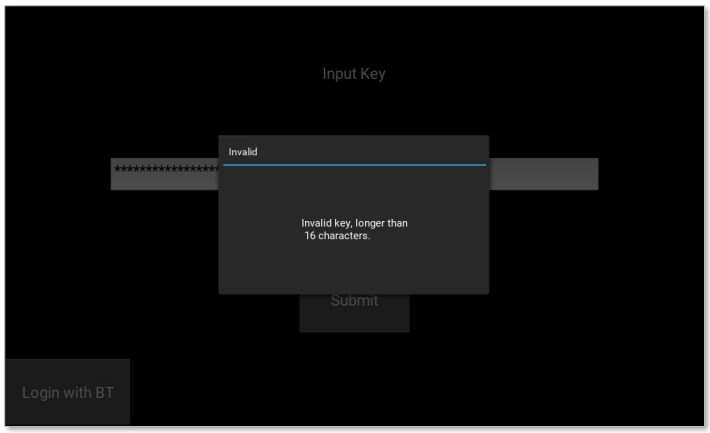




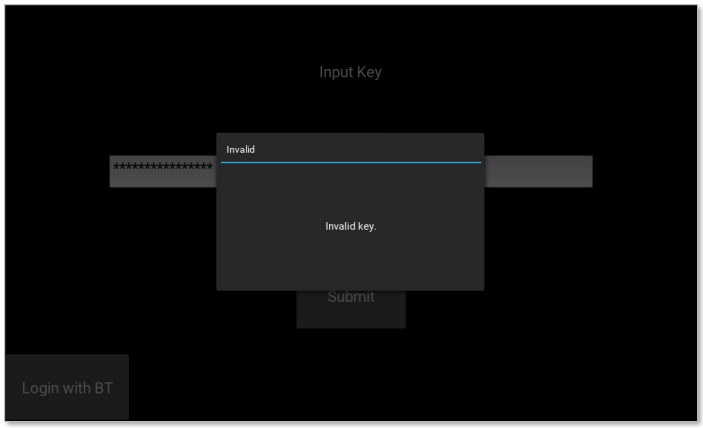
[5, 7, 10]: Input too long:

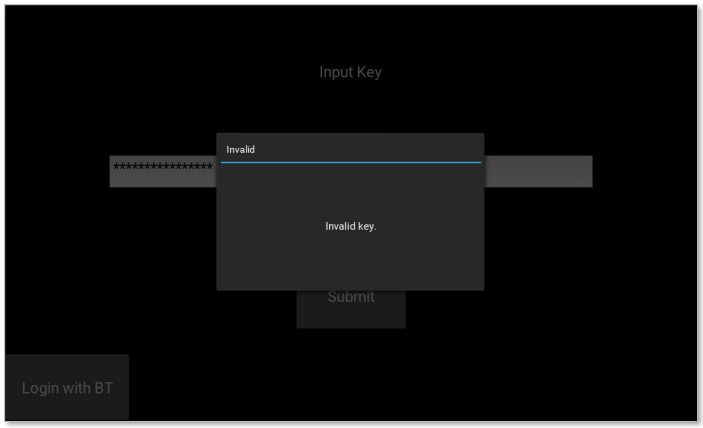




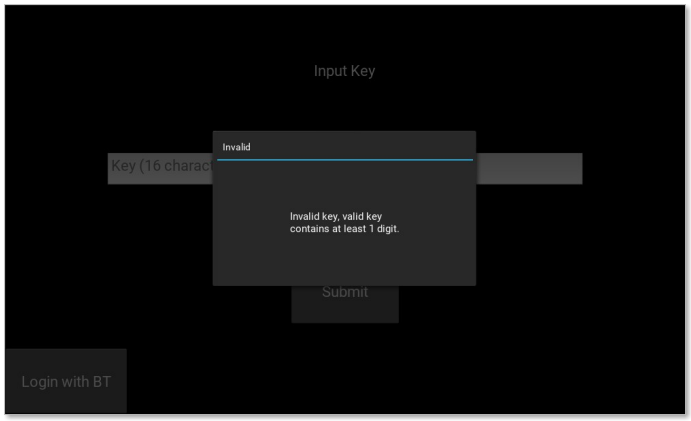


[8, 9]: Invalid key





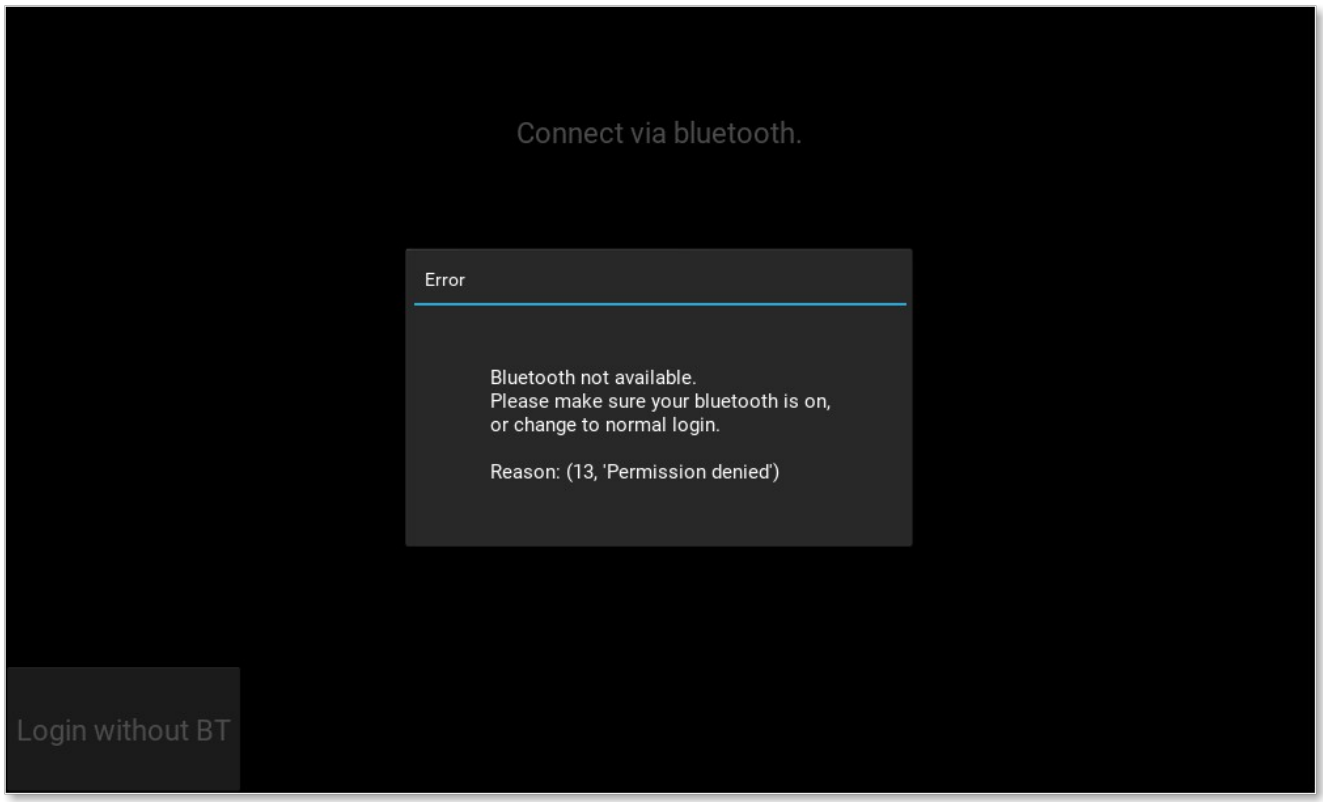
[11]: Invalid key, has to be at least 1 in length.



Test Number	2
Relevant Objective	1.L
Description	Switch login screen to Bluetooth login screen from regular login screen with Bluetooth disabled.
Purpose	To check that it will warn the user that Bluetooth is not available.

Test Data	Only one available input: (T) Click “Login with BT” button.
Expected Outcome	A popup should appear telling the user that Bluetooth is not available, and why (for the user to debug their Bluetooth problem).
Actual Outcome	Pass

Evidence:



Test Number	3
Relevant Objective	2.b
Description	Connect to PC from mobile device.
Purpose	To check that the mobile device can actually connect, and if not displays the appropriate message.
Test Data	T: [1]: Click “josh-pc” to connect to my PC. E: [2]: Click “josh-pc” when the program is not running on the PC. [3]: Click “josh-laptop” when the program is running on the PC. B: [4]: Click “josh-pc” when the program is running on both my laptop and the PC. [5]: Click “josh-laptop” in the same situation as [4].
Expected Outcome	[1]: Connects successfully and changes screen to the pad screen. [2]: Should not connect and asks user to retry. [3]: Should not connect and asks user to retry. [4]: Should connect to “josh-pc” successfully and change screen on the PC. [5]: Should connect to “josh-laptop” successfully and change screen on the PC.

Actual Outcome	[All]: Pass

Evidence:

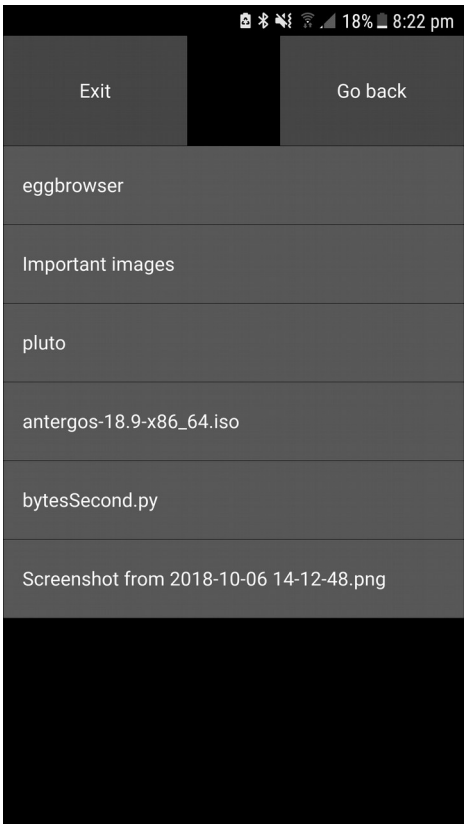
Test Number	4
Relevant Objective	1.g.ii, 2.b, 2.d
Description	Enter the key from the mobile app.
Purpose	Test that the key is either accepted, or declined by the server.
Test Data	(The app doesn't let you enter more than 16 numbers.) T: [1]: 1234 (The set key) [2]: 12340 [3]: 2001 B: [4]: 9876543210123456 [5]: 7389123612645815 [6]: 0000000000000000 [7]: (nothing)
Expected Outcome	[1]: PC program should log in and change screen to main screen. [2-7]: App should say that the key is invalid.
Actual Outcome	[All]: Pass

Evidence:

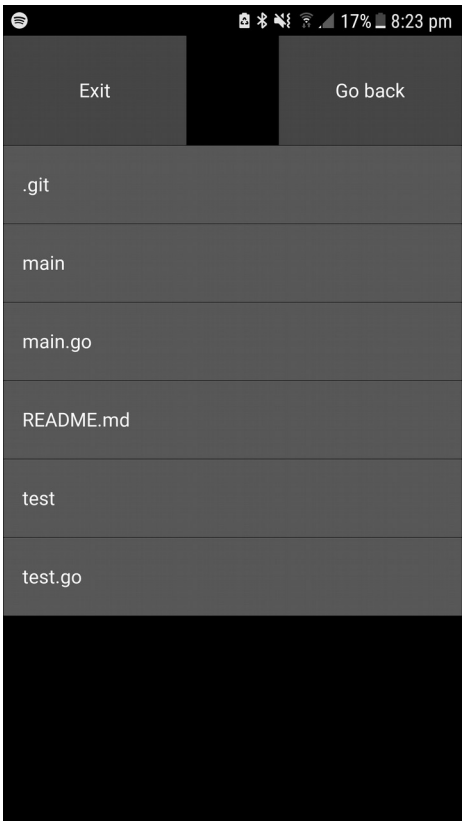
Test Number	5
Relevant Objective	2.f
Description	Browse files + download files within the mobile app.
Purpose	To test that the user can browse the files in the Vault and also download.
Test Data	T: [1]: Click to open the file browser. [2]: Click a folder. [3]: Click a file. [4]: Click to go back up one directory. [5]: Exit the file browser.
Expected Outcome	[1]: File browser should open. [2]: The file browser should navigate to that folder. [3]: The file should download to the users downloads folder. A popup should open on the PC showing the current status of the transfer, and once complete, the file should be found in the users "Download" folder. [4]: The file browser should display the contents of the folder above the current folder. [5]: Should return to main screen.
Actual Outcome	[All]: Pass

Evidence:

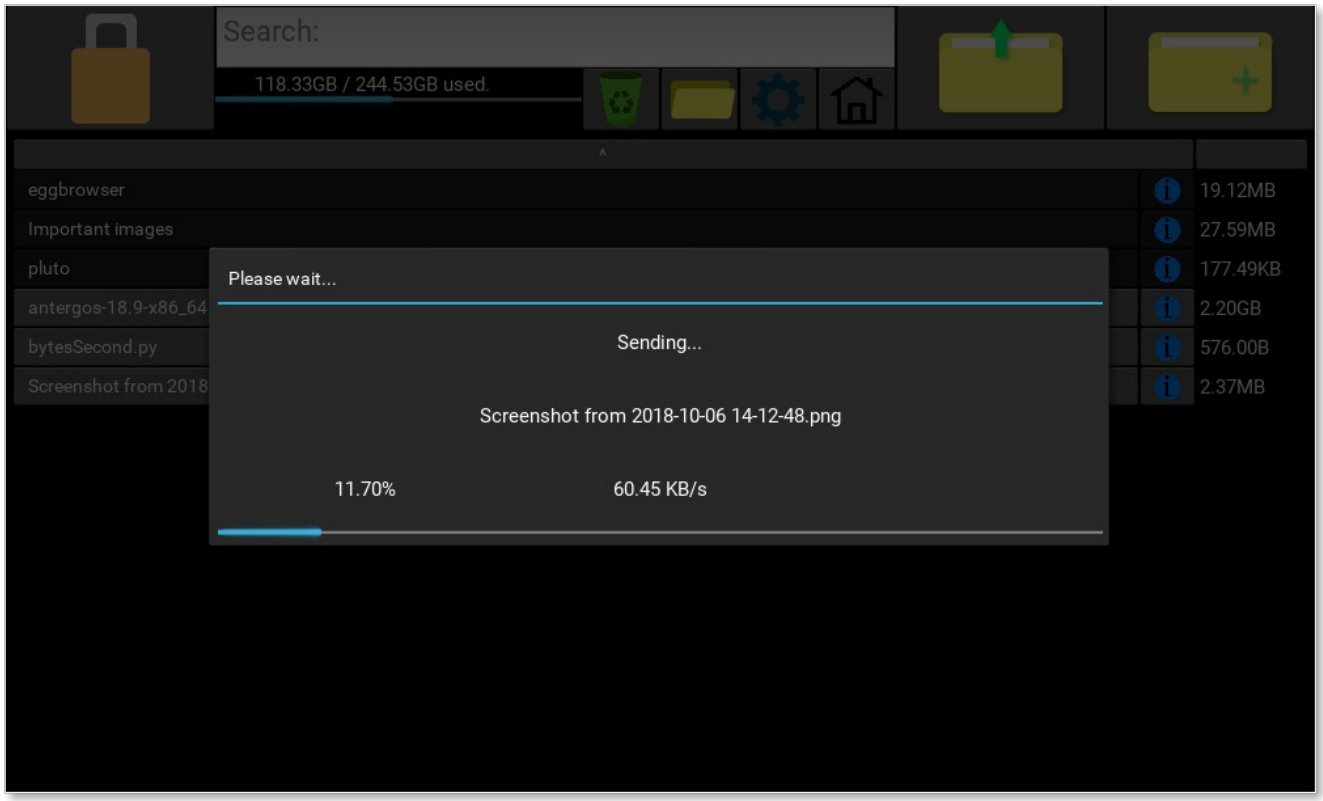
[1] Opening the file browser:



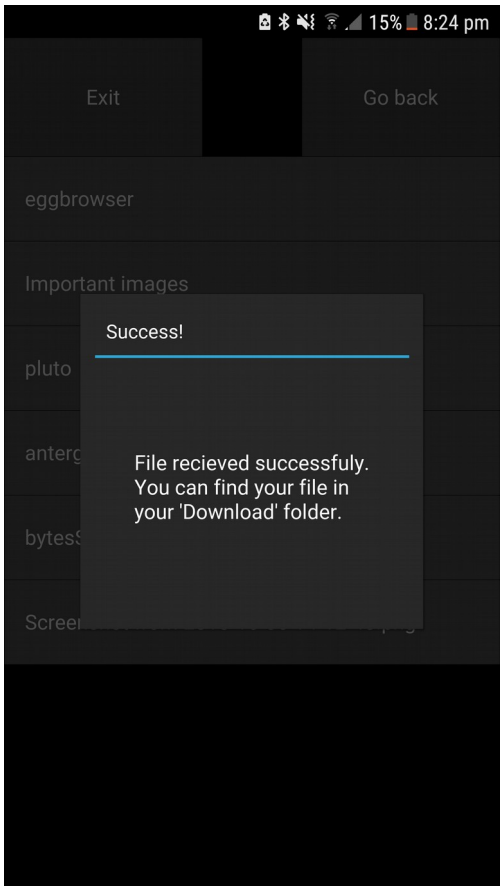
[2] Opening a folder:



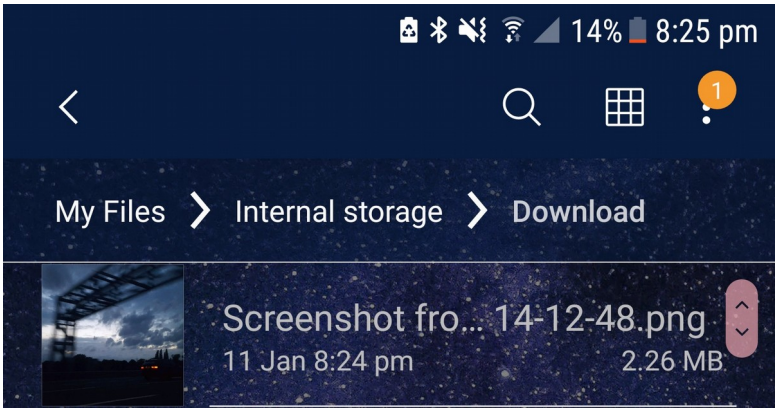
[3] Clicking a file (“Screenshot from 2018-10-06 14-12-48”):
View on PC program:



When done on phone:



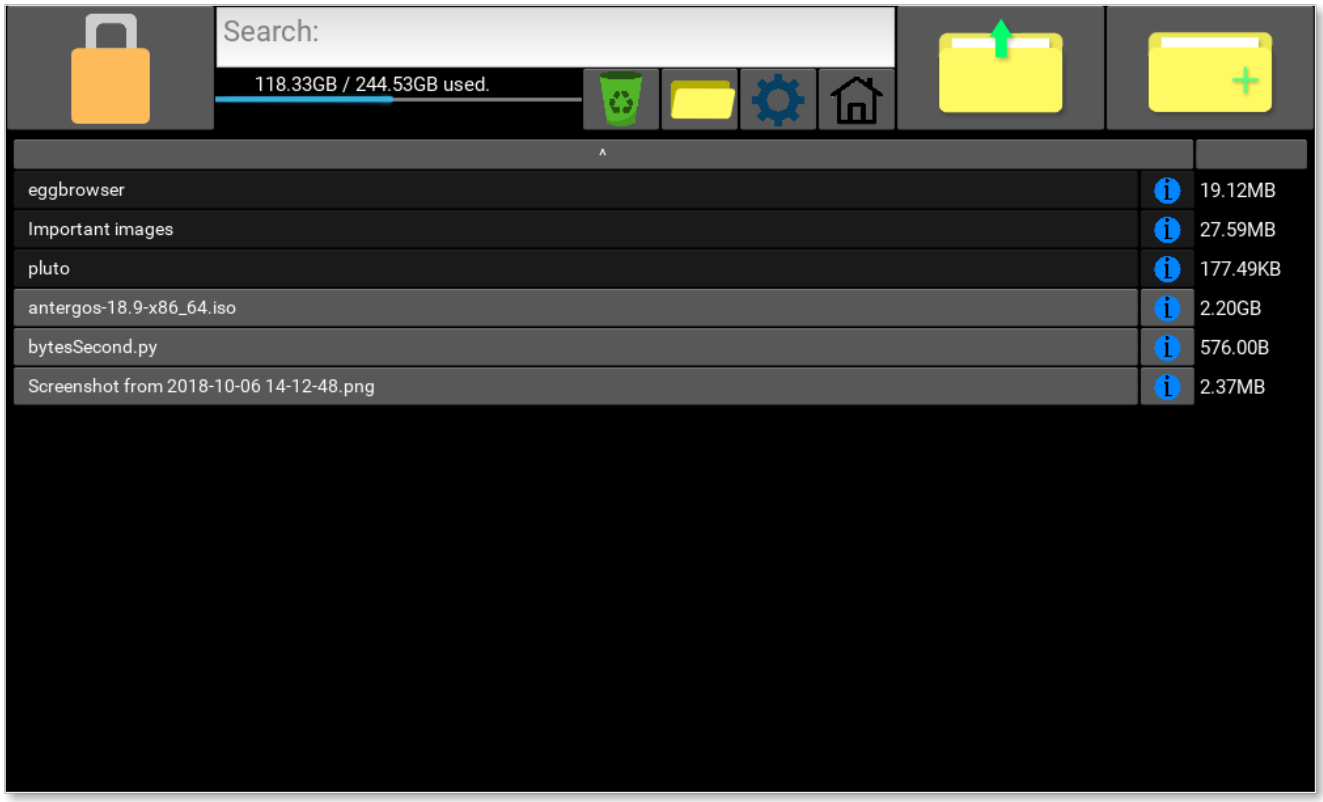
Download folder:



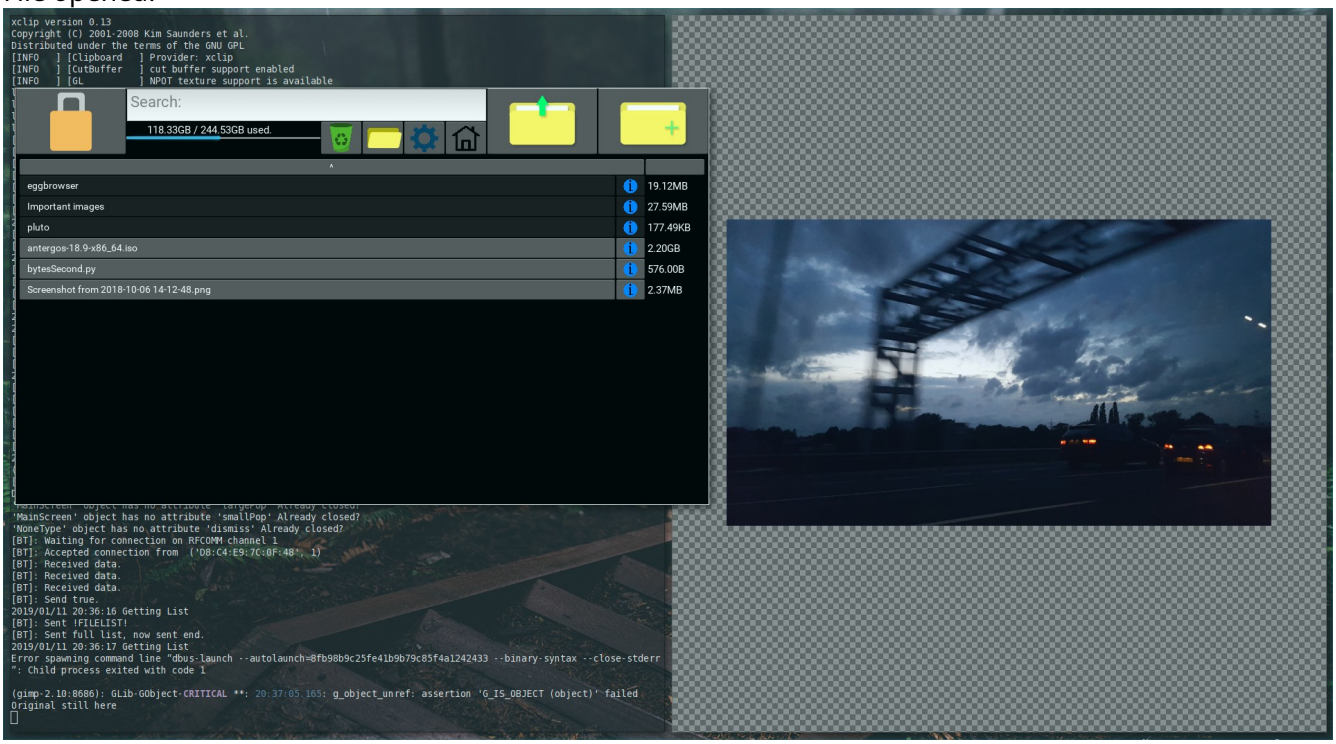
Test Number	6
Relevant Objective	3.c
Description	Disconnect from the Bluetooth server. (Close the mobile app)
Purpose	To check that temporary files are deleted and that the program is locked once connection is lost to the mobile device.
Test Data	`T: [1]: Log into the program using the mobile device, open a file, close the file and disconnect from the program.`
Expected Outcome	`[1]: The temporary files should be deleted and the program should be locked.`
Actual Outcome	`[All]: Pass`

Evidence:

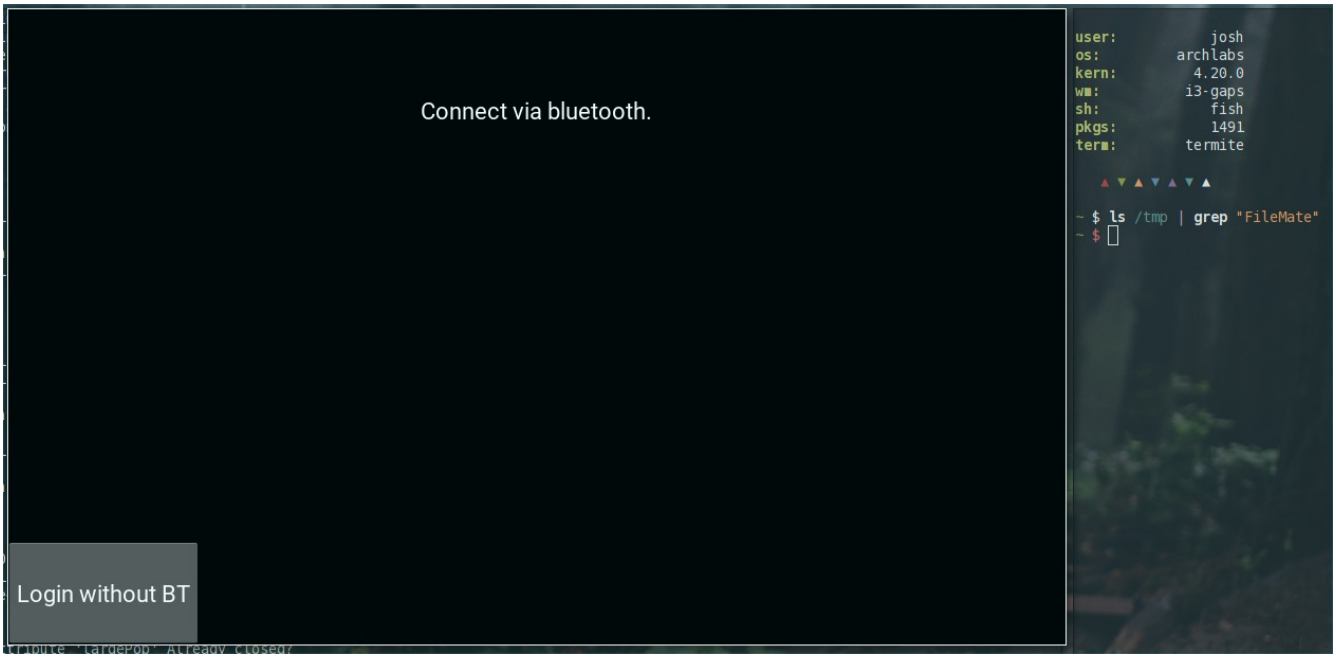
Vault unlocked using app:



File opened:



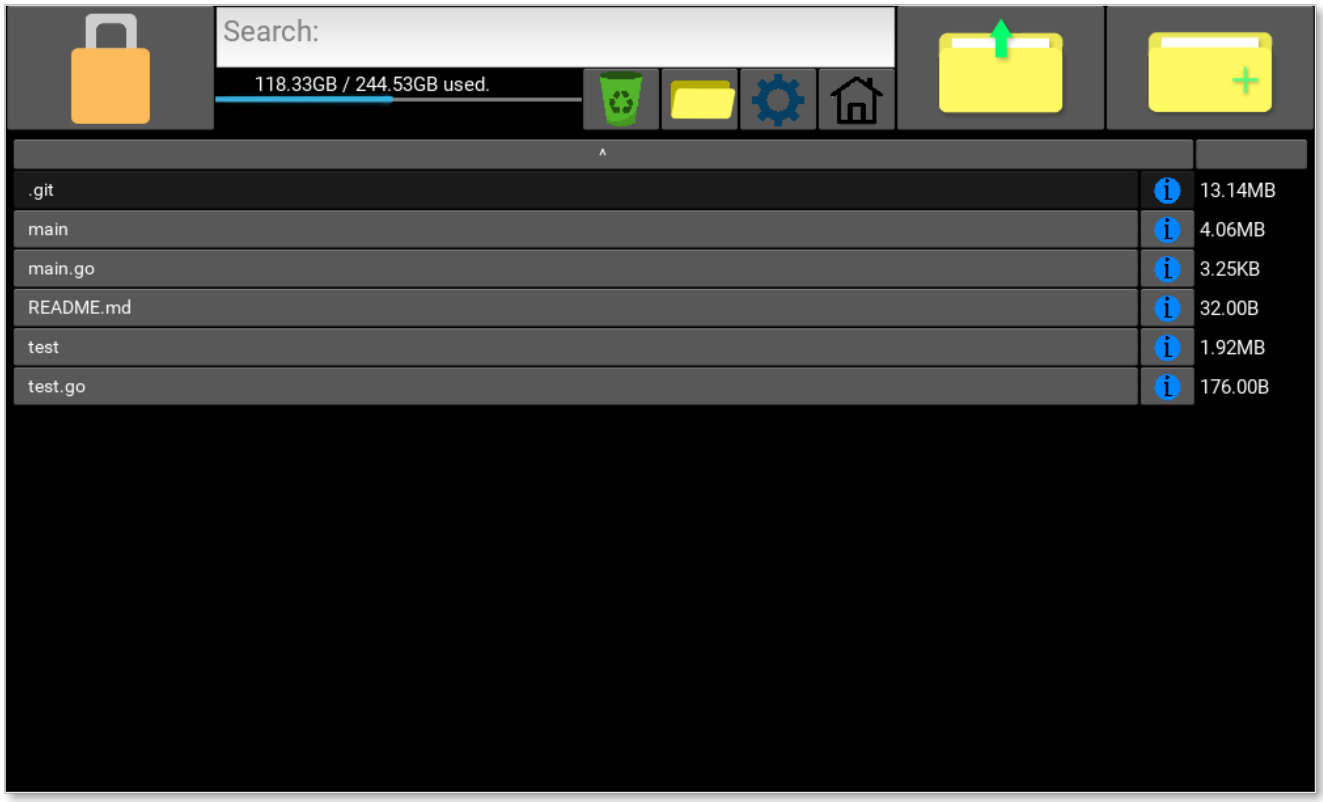
Disconnected from vault, and list /tmp directory to make sure temporary files have been deleted:



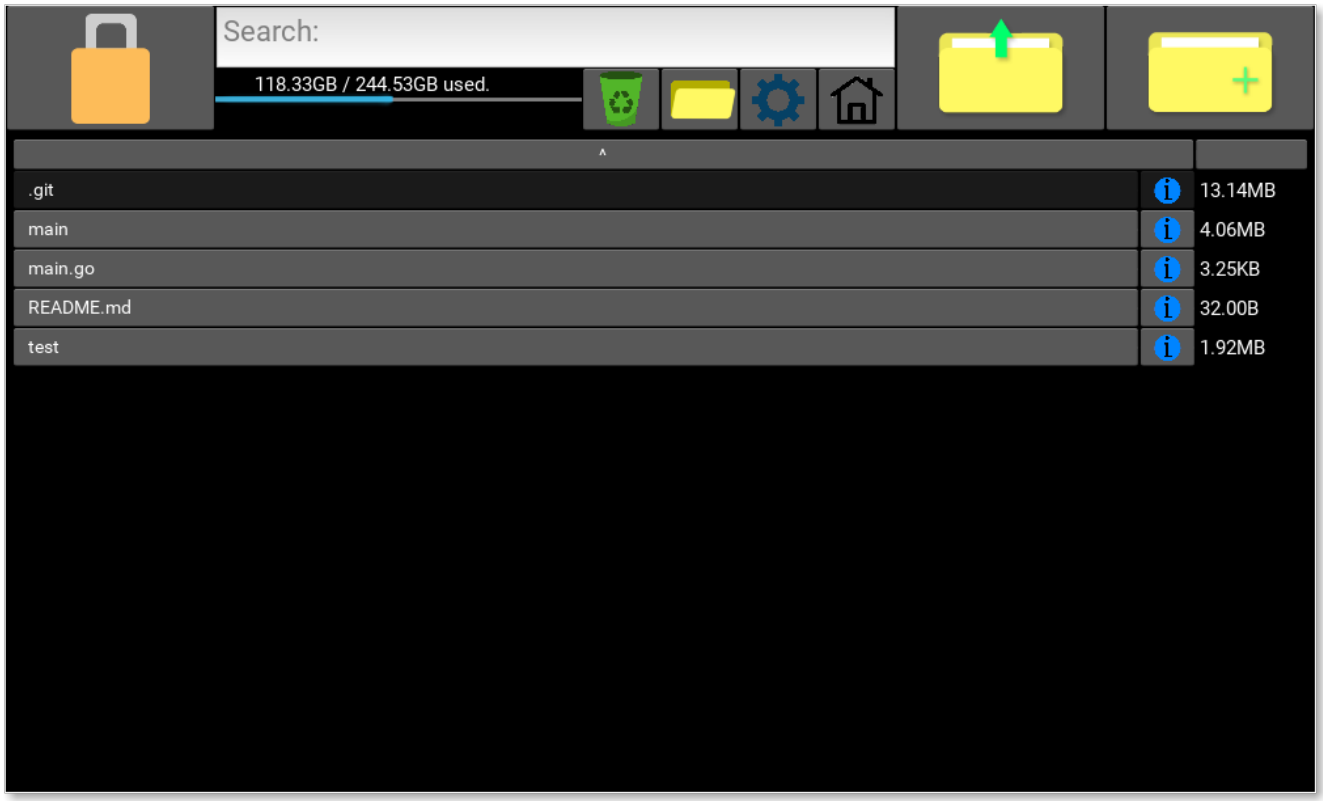
Test Number	7
Relevant Objective	3.e
Description	Delete a file, open the recycling folder and recover it.
Purpose	To check that when a file is deleted and recovered to the correct location.
Test Data	Delete a file in the Vault, go into the recycling folder, click the file, exit the recycling folder and see if it has been recovered.
Expected Outcome	The file should be in the recycling folder when the file has been deleted, and should return to the Vault where it was deleted from once you recover it.
Actual Outcome	The file is recovered to the root folder of the Vault, instead of the place it was deleted from.

Evidence:

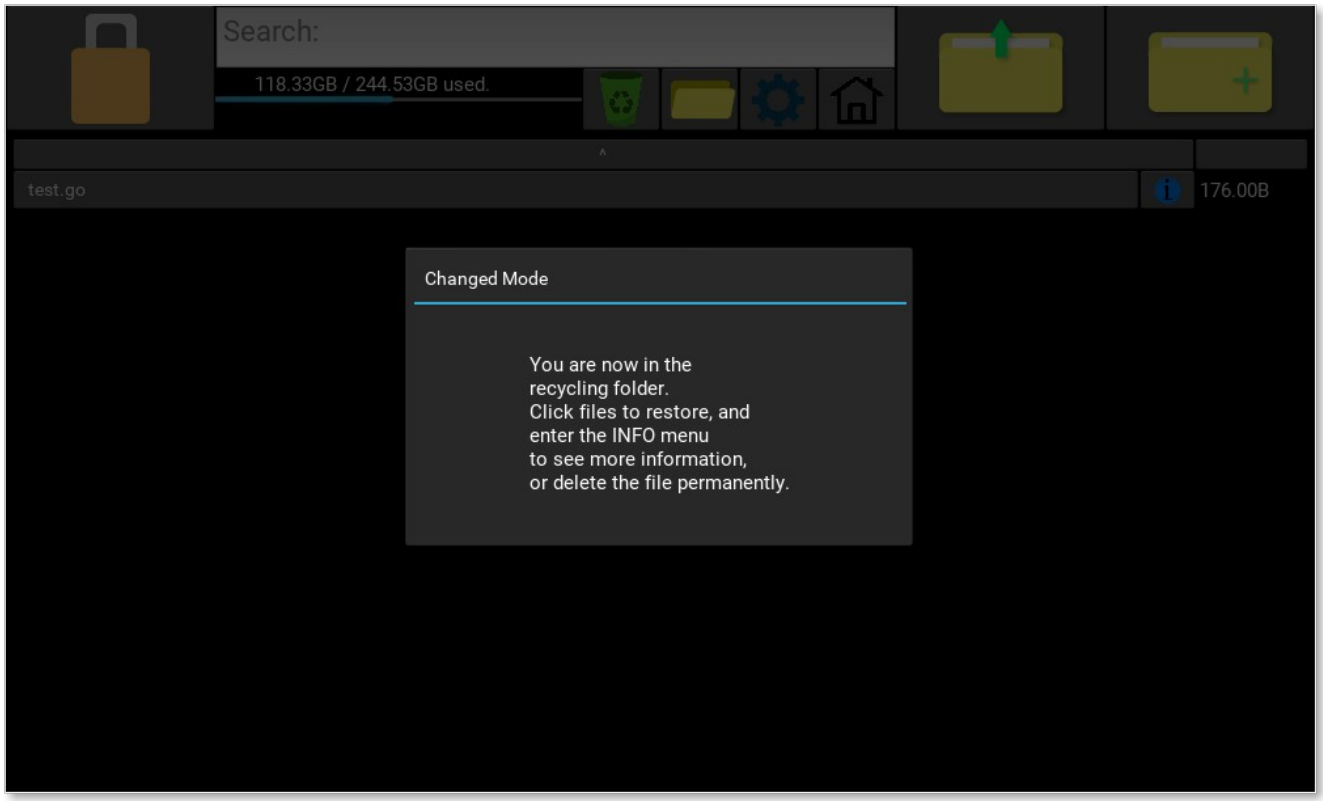
Files in Vault/eggbrowser/:



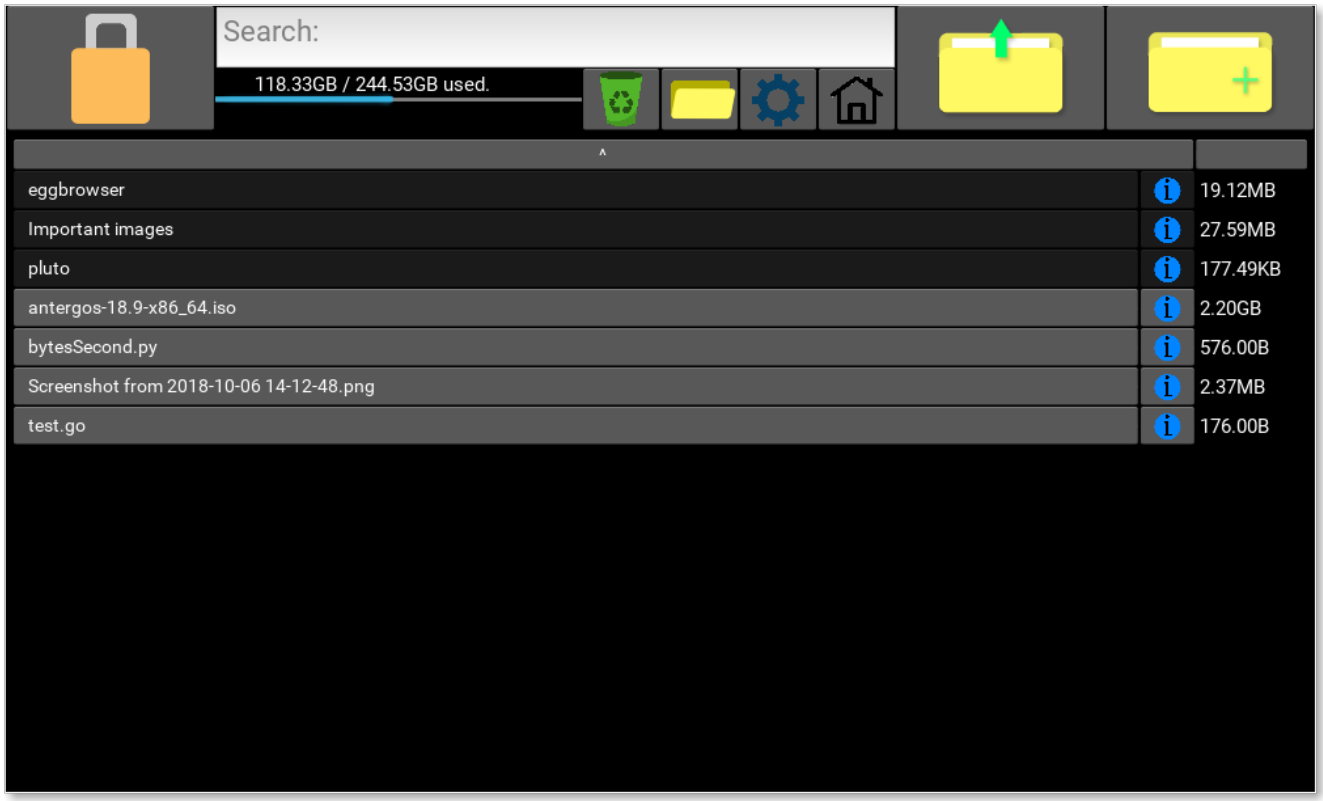
Delete test.go:



Go to recycling folder:



Recover test.go, and return to the root directory of the vault:

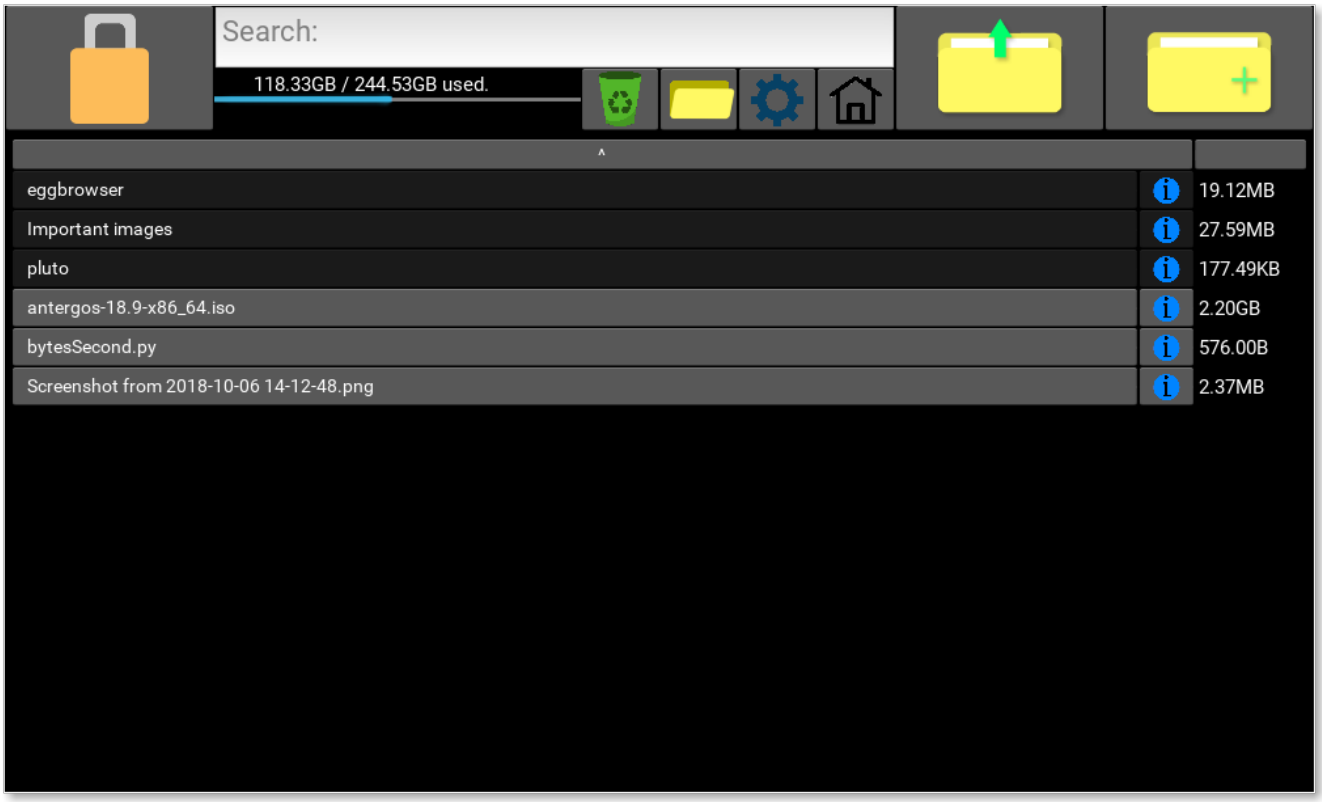


Test Number	8
Relevant Objective	1.m
Description	Click the home button to return to the root directory of the Vault..
Purpose	Check that the home button functions as required.
Test Data	`T: [1]: Click the home button while in the root directory.` `[2]: Click the home button while in another folder.`
Expected Outcome	`[1]: Buttons in the file browser should remain the same.` `[2]: The contents of the home folder should be loaded into the file browser.`
Actual Outcome	`[All]: Pass`

Evidence:

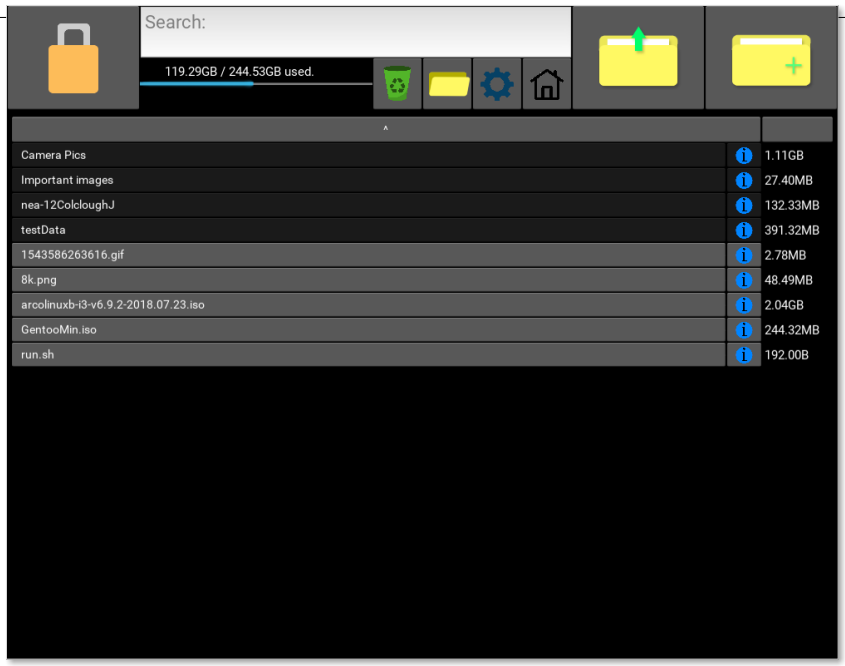
In a folder:

Pressed home button:



Test Number	9
Relevant Objective	1.k
Description	Re-size the window.
Purpose	Check that the GUI remains intact when you resize the window.
Test Data	`T: Resize the window.`
Expected Outcome	`Widgets on the screen should resize to fit the new window size.`
Actual Outcome	`Pass`

Evidence:



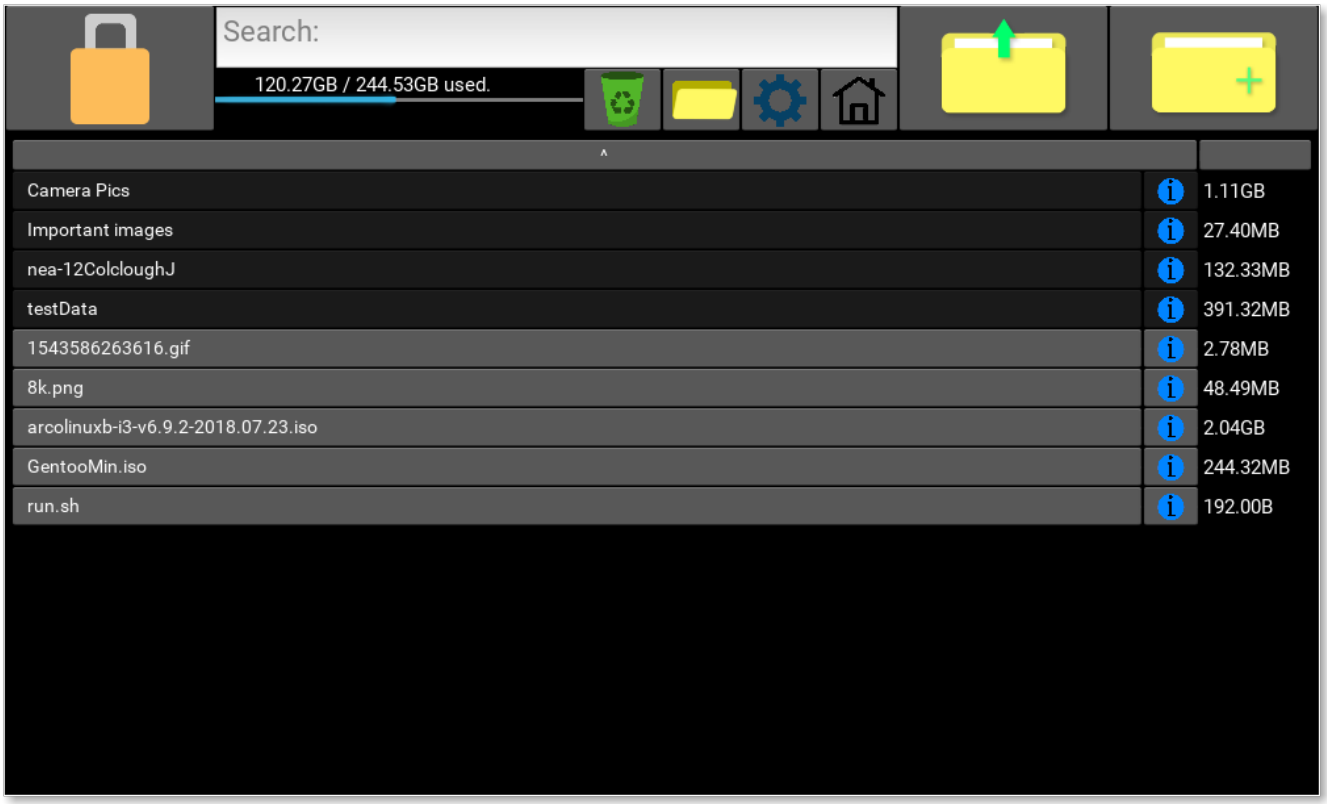
Test Number	10
Relevant Objective	1.o
Description	Change the direction of the sorts.
Purpose	To check that the sorts work.

Test Data	`[1]: Sort by name ascending (folders separated by files).`
	`[2]: Sort by name descending (folders separated by files).`
	`[3]: Sort by size ascending.`
	`[4]: Sort by size descending.`

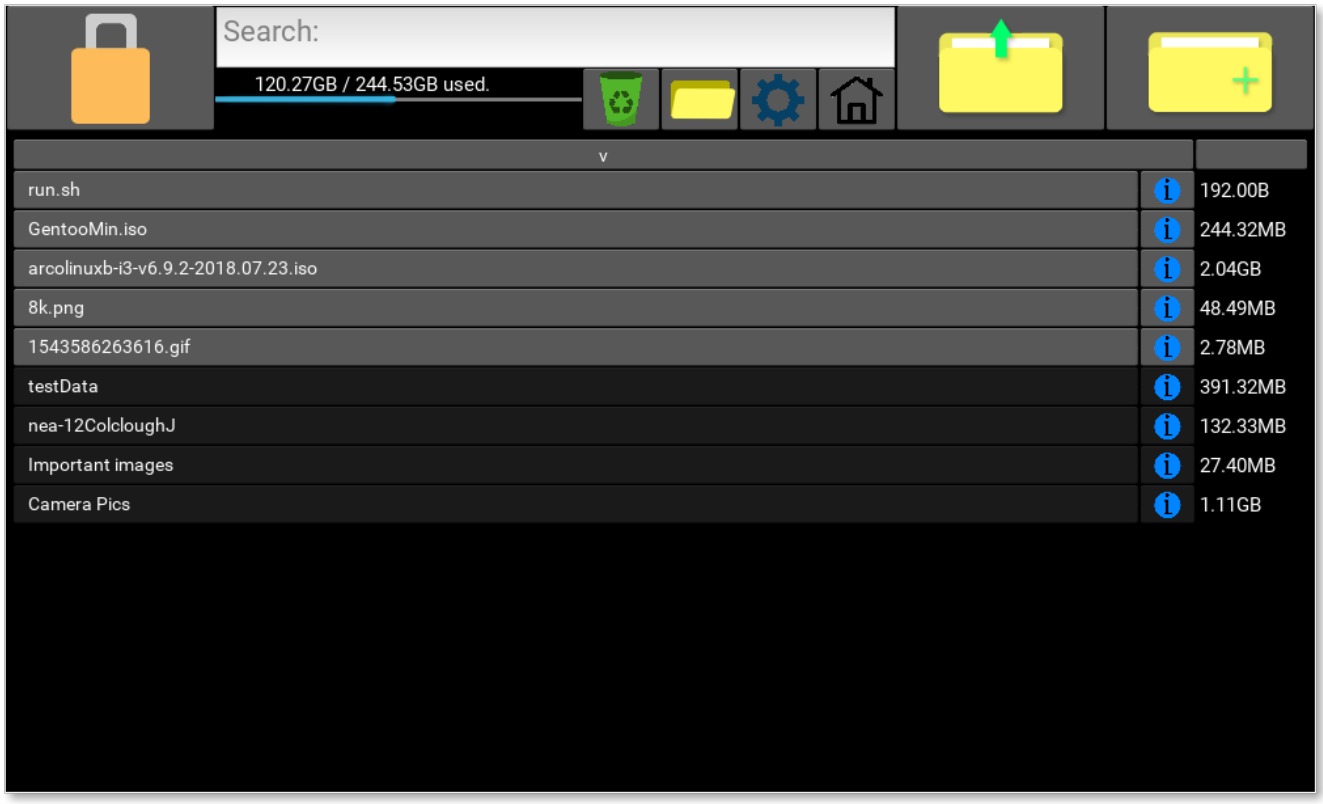
Expected Outcome	`[All]: Should sort correctly.`
Actual Outcome	`[All]: Pass`

Evidence:

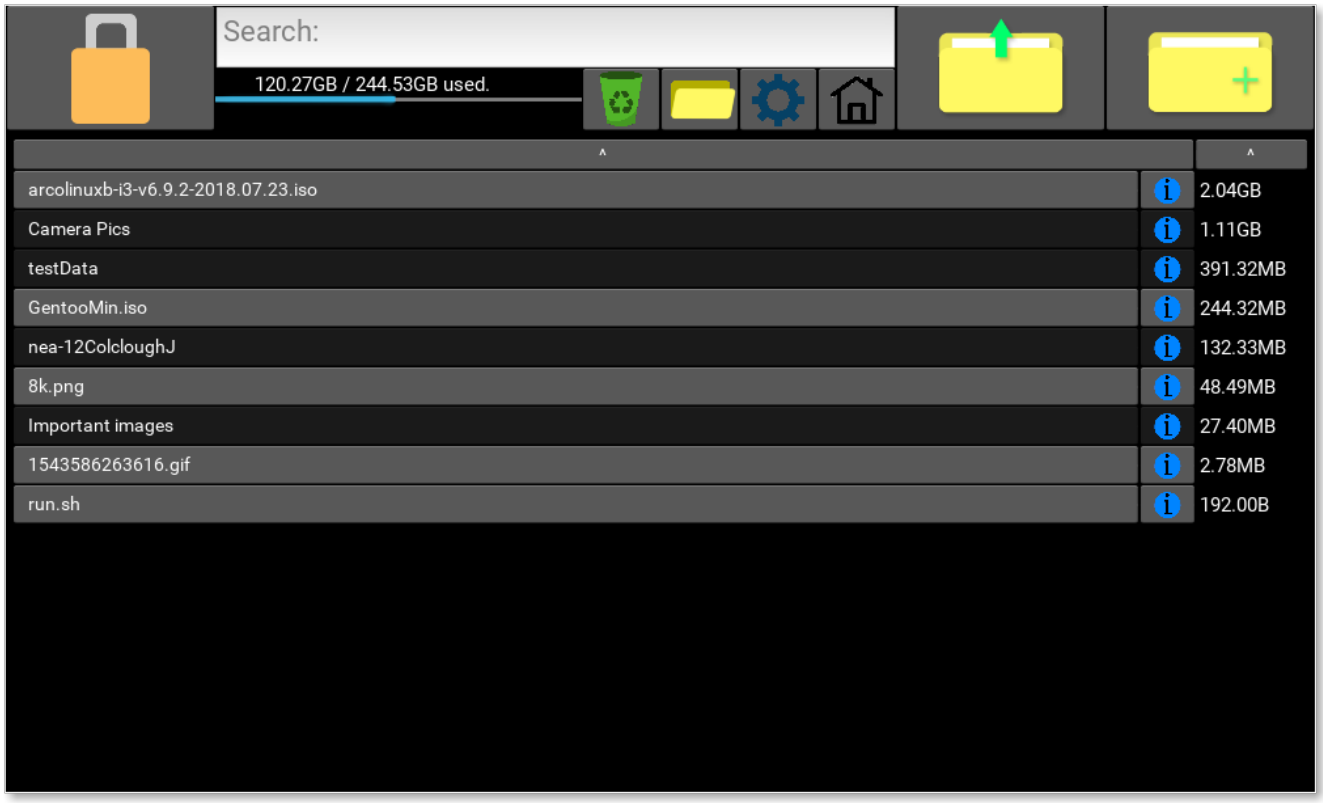
[1]:



[2]:


Search:
120.27GB / 244.53GB used.
v
run.sh
192.00B
GentooMin.iso
244.32MB
arcolinuxb-i3-v6.9.2-2018.07.23.iso
2.04GB
8k.png
48.49MB
1543586263616.gif
2.78MB
testData
391.32MB
nea-12ColcloughJ
132.33MB
Important images
27.40MB
Camera Pics
1.11GB

[3]:

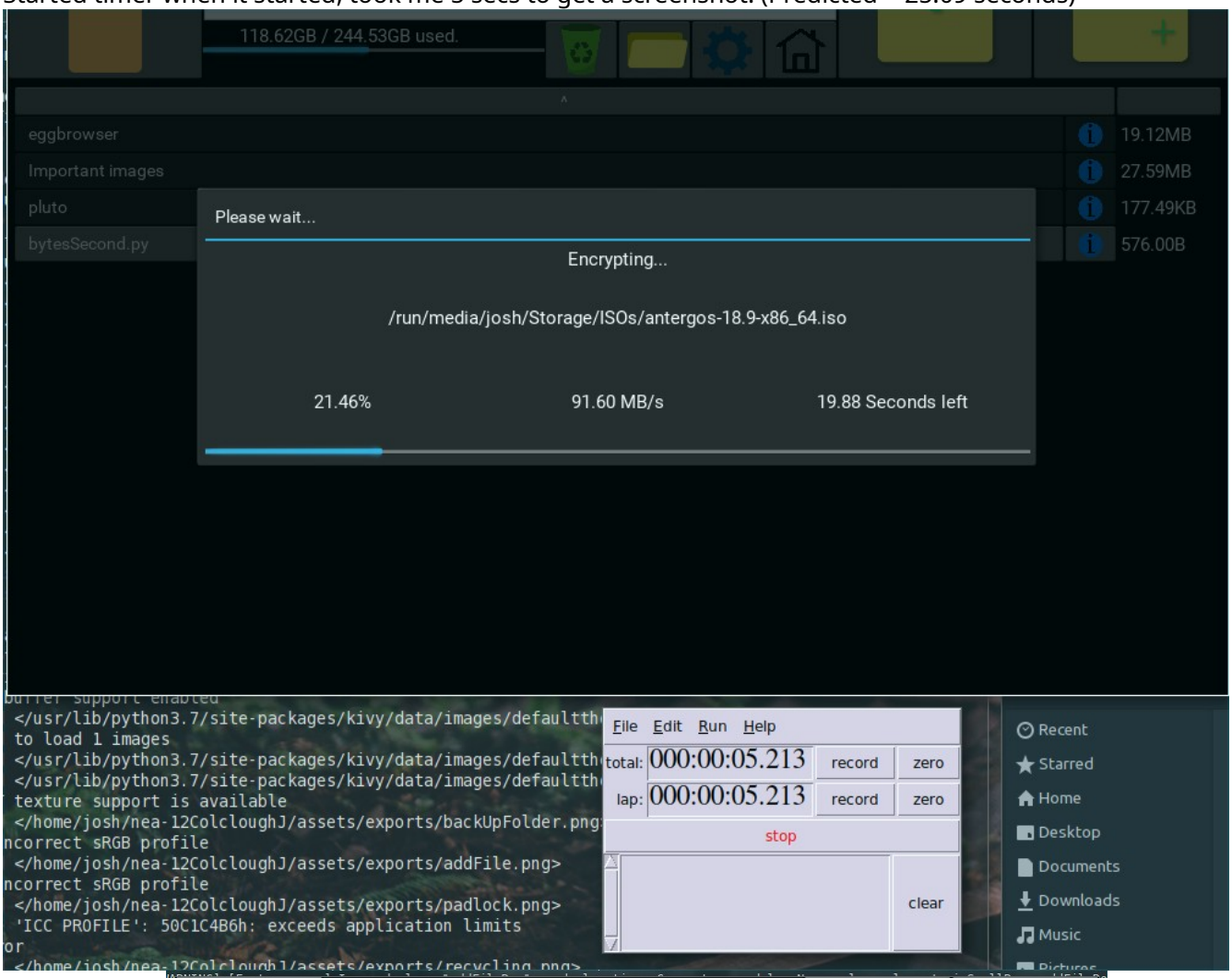

Search:
120.27GB / 244.53GB used.
^
^
arcolinuxb-i3-v6.9.2-2018.07.23.iso
2.04GB
Camera Pics
1.11GB
testData
391.32MB
GentooMin.iso
244.32MB
nea-12ColcloughJ
132.33MB
8k.png
48.49MB
Important images
27.40MB
1543586263616.gif
2.78MB
run.sh
192.00B

[4]:

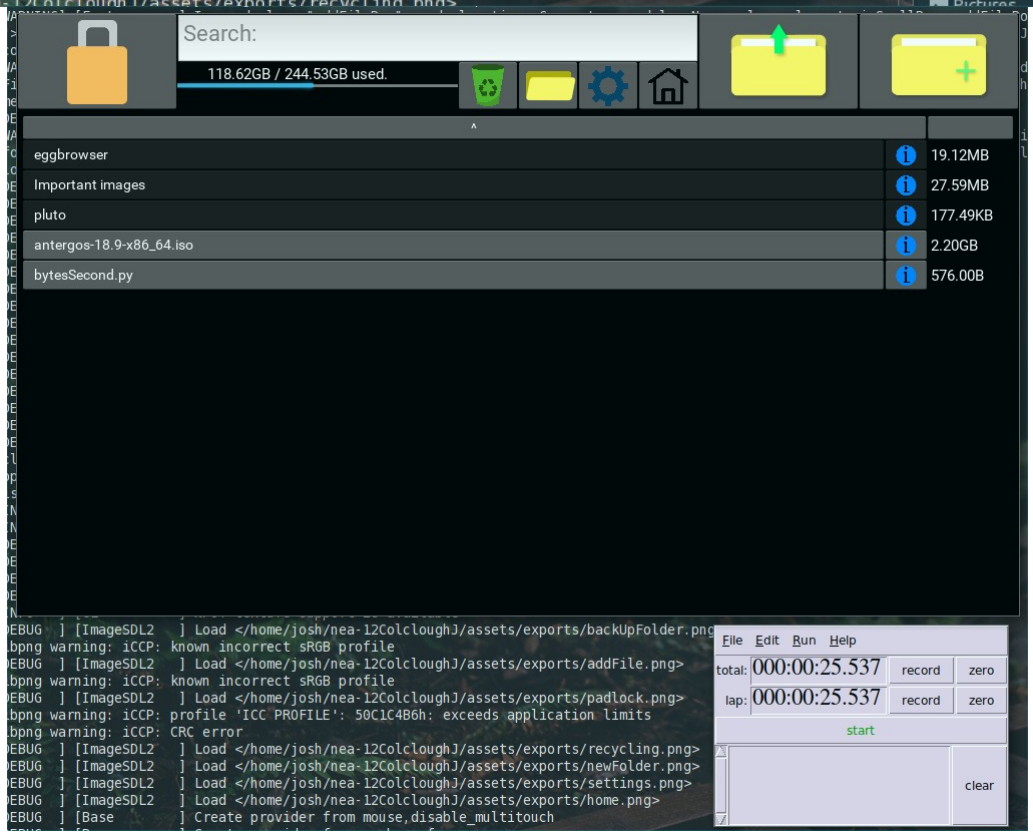
Test Number	11
Relevant Objective	1.n.iii
Description	Time how long it takes to decrypt a large file (2.04GB) compared to the prediction made by the popup that opens (encDecPop) displaying the predictions.
Purpose	Make sure the time prediction is accurate (otherwise it is pretty infuriating for the user).
Test Data	`Decrypt a 2.2 GB file (2,203,779,072) and time it. Get the first available time prediction.`
Expected Outcome	`The difference between the time actually taken and the prediction should be +-2 seconds.`
Actual Outcome	`Pass: Predicted 25.09 seconds (19.88+5.21), took 25.537 seconds.`

Evidence:

Started timer when it started, took me 5 secs to get a screenshot. (Predicted = 25.09 seconds)



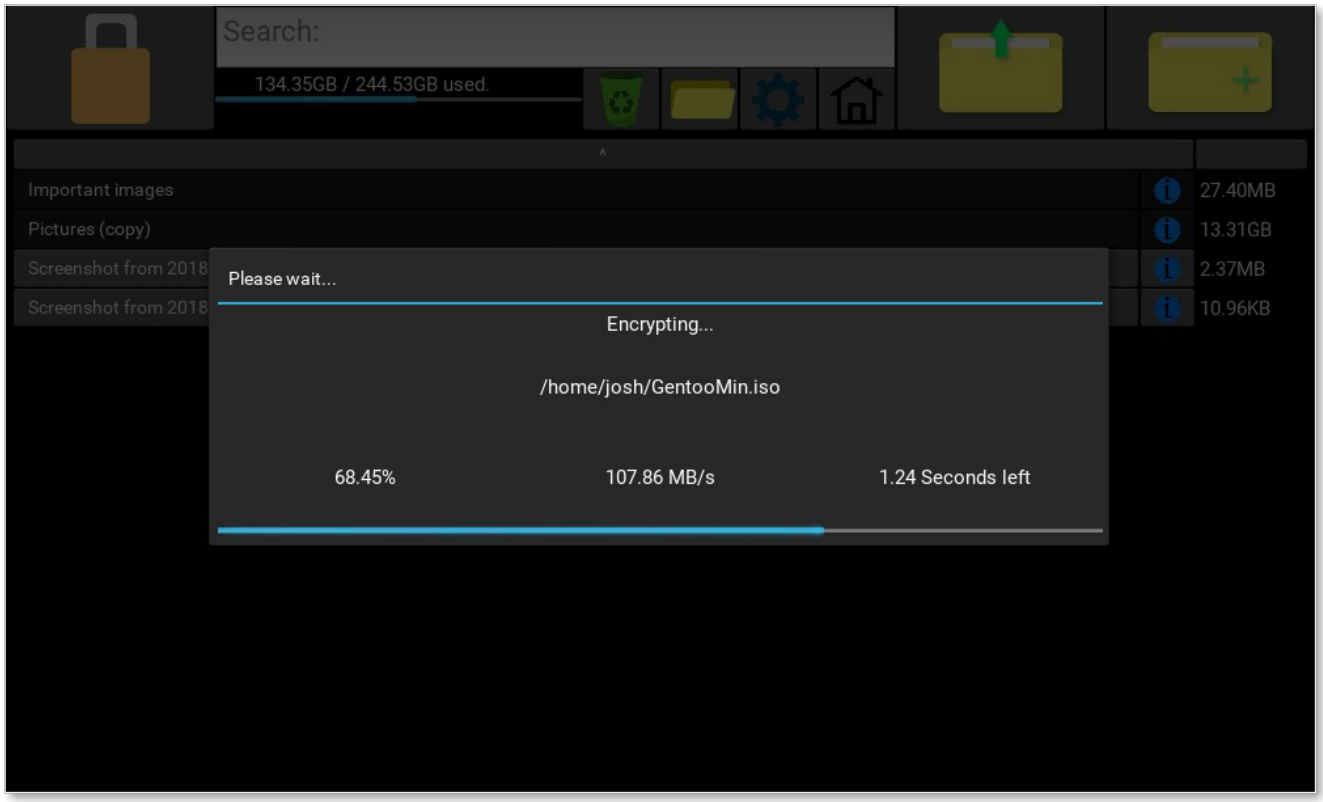
Finished:



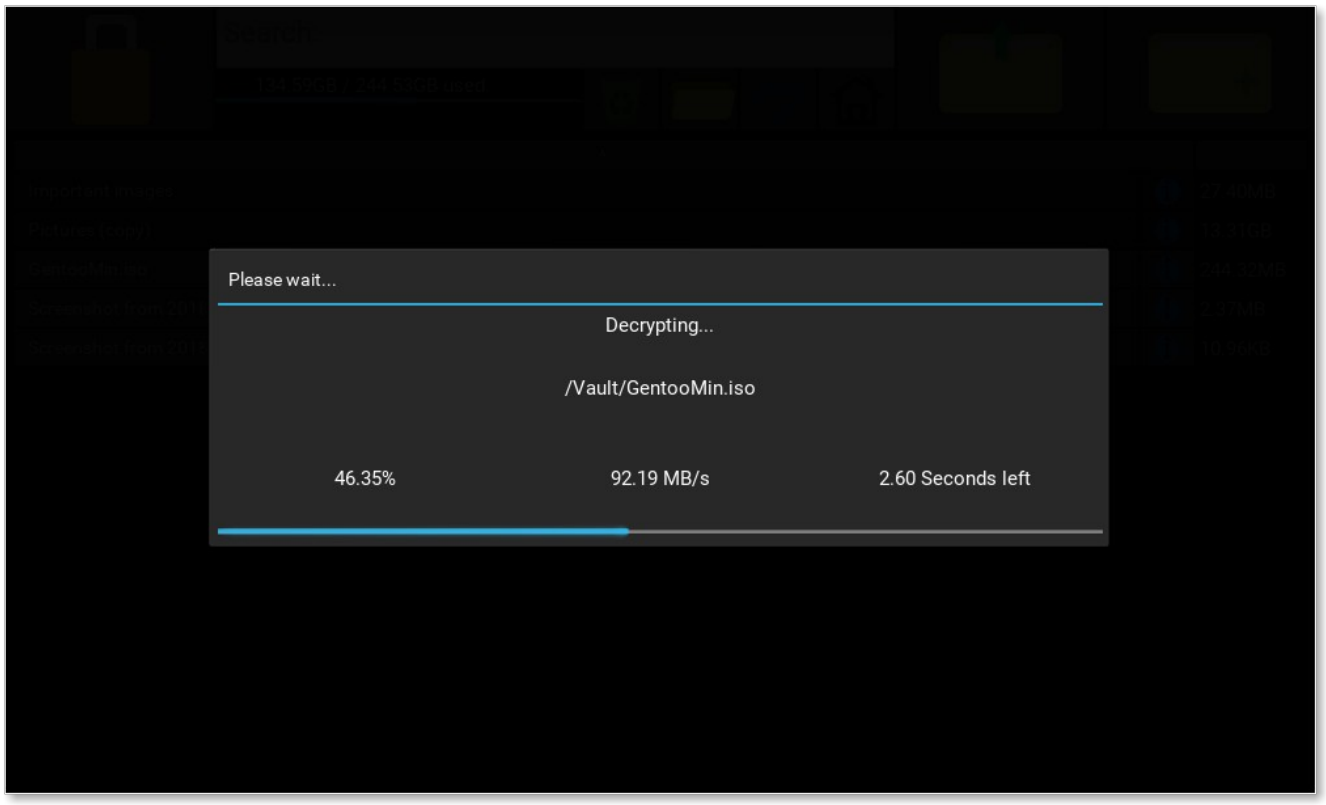
Test Number	12
Relevant Objective	1.n.ii
Description	Compare the speed of encryption/decryption with the Go benchmark function.
Purpose	To check that the speed is found to be accurate.
Test Data	[1]: Encrypt a 244.3 MB file using the PC program. [2]: Encrypt a 244.3 MB file using Go benchmark. [3]: Decrypt a 244.3 MB file using the PC program. [4]: Decrypt a 244.3 MB file using Go benchmark.
Expected Outcome	[All]: Speeds should be similar (within +-5 MB/s).
Actual Outcome	(Done on different computer to in unit tests) [1]: 107.86 MB/s 2269321613 ns/op [2]: 107.66 MB/s [3]: 95.56 MB/s 2556627030 ns/op [4]: 92.19 MB/s

Evidence:

[1, 2]:

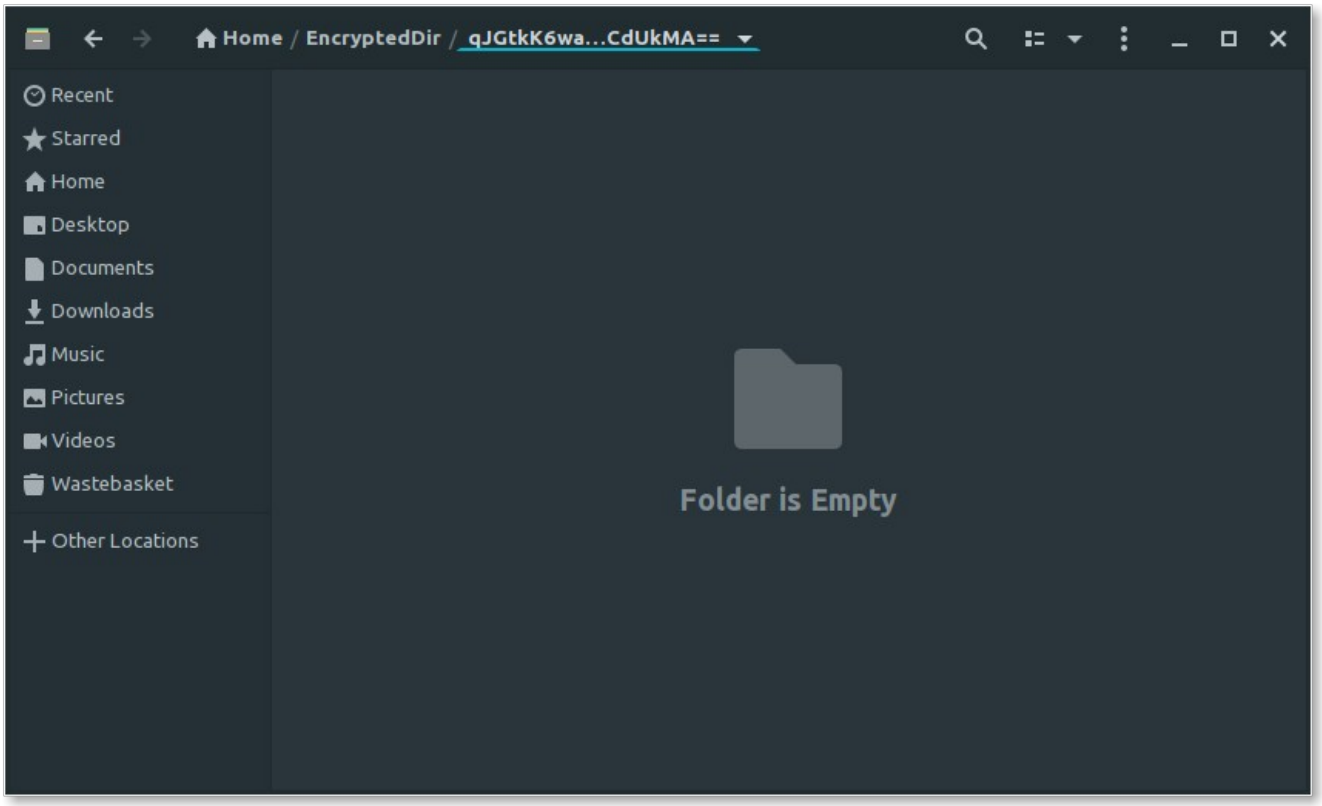


[3, 4] (darker background due to multiple popups):



Test Number	13
Relevant Objective	3.e
Description	Delete a file into the recycling bin, and then delete it permanently and check it has been deleted.
Purpose	Check that it works.
Test Data	`Permanently delete the file called “TqAoUIWq1yvmQBgyAIS8PQ==” in encrypted form, “test12_3.png” in decrypted form.`
Expected Outcome	`The file should not be available anywhere.`
Actual Outcome	`Pass`

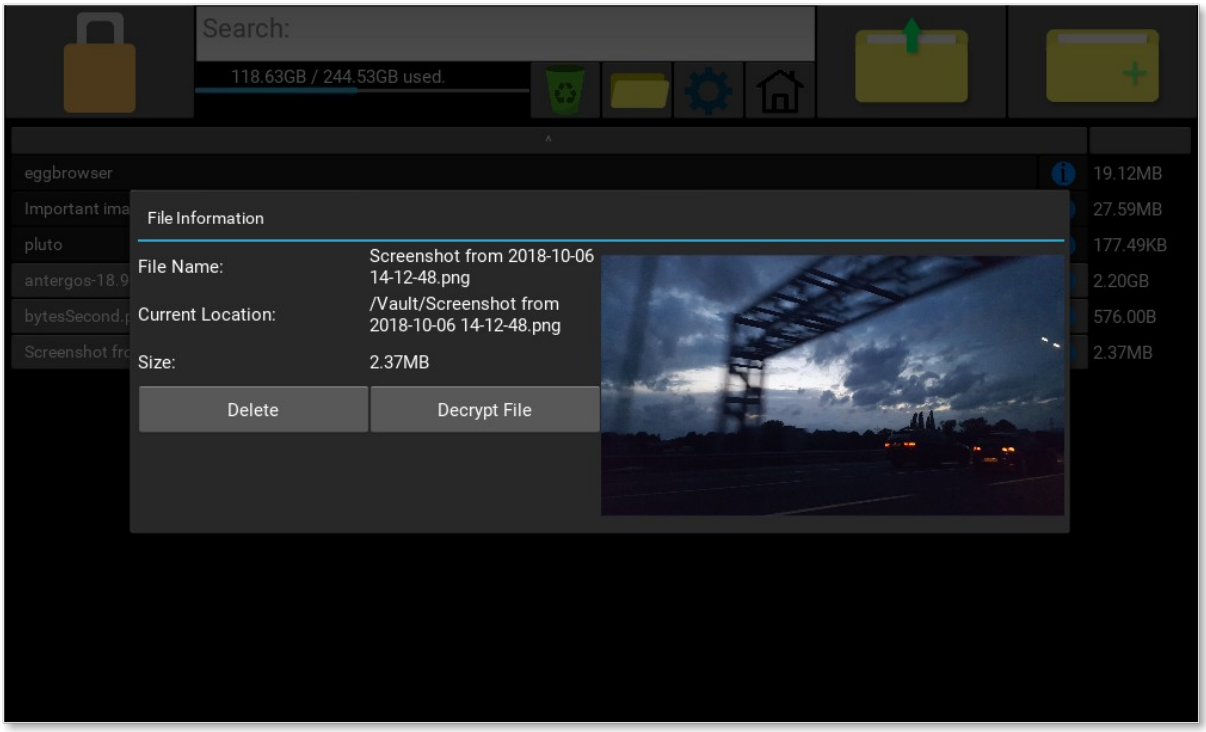
Evidence (checking recycling bin in vault):



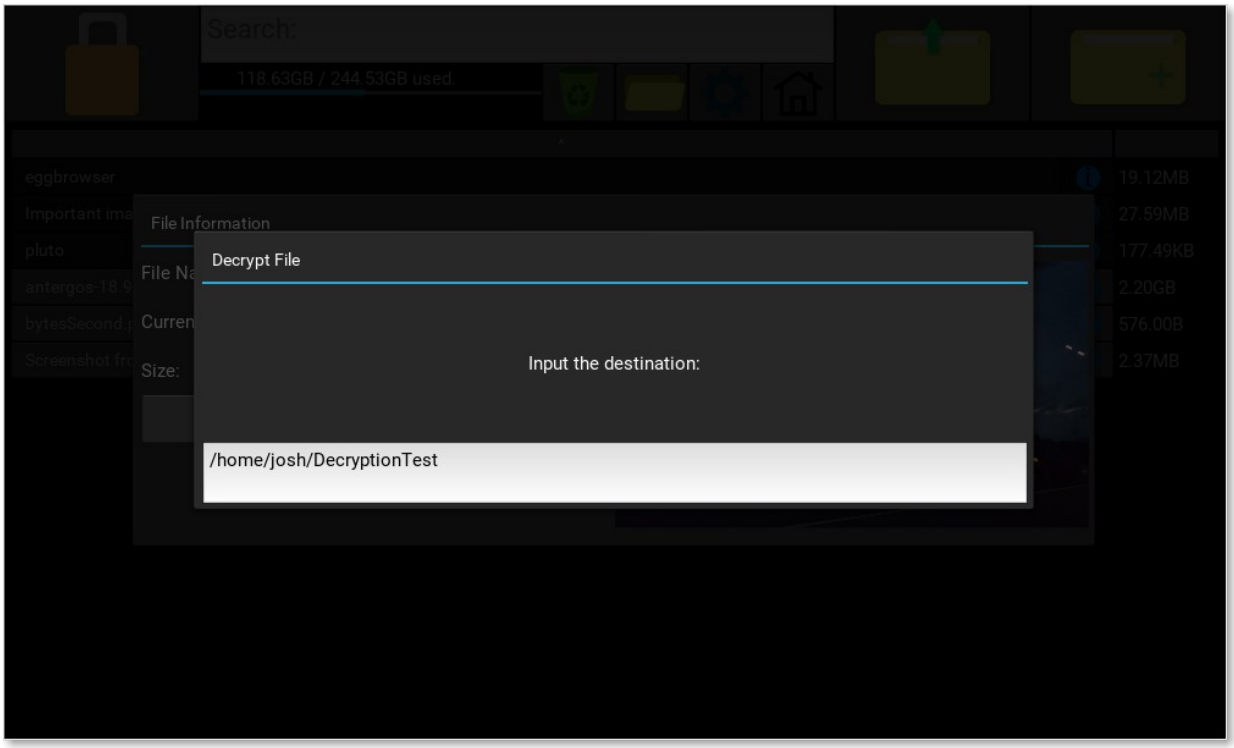
Test Number	14
Relevant Objective	3.i
Description	Decrypt a file to a location outside of the vault.
Purpose	To check it works normally.
Expected Outcome	`File should be decrypted successfully.`
Actual Outcome	Pass

Evidence:

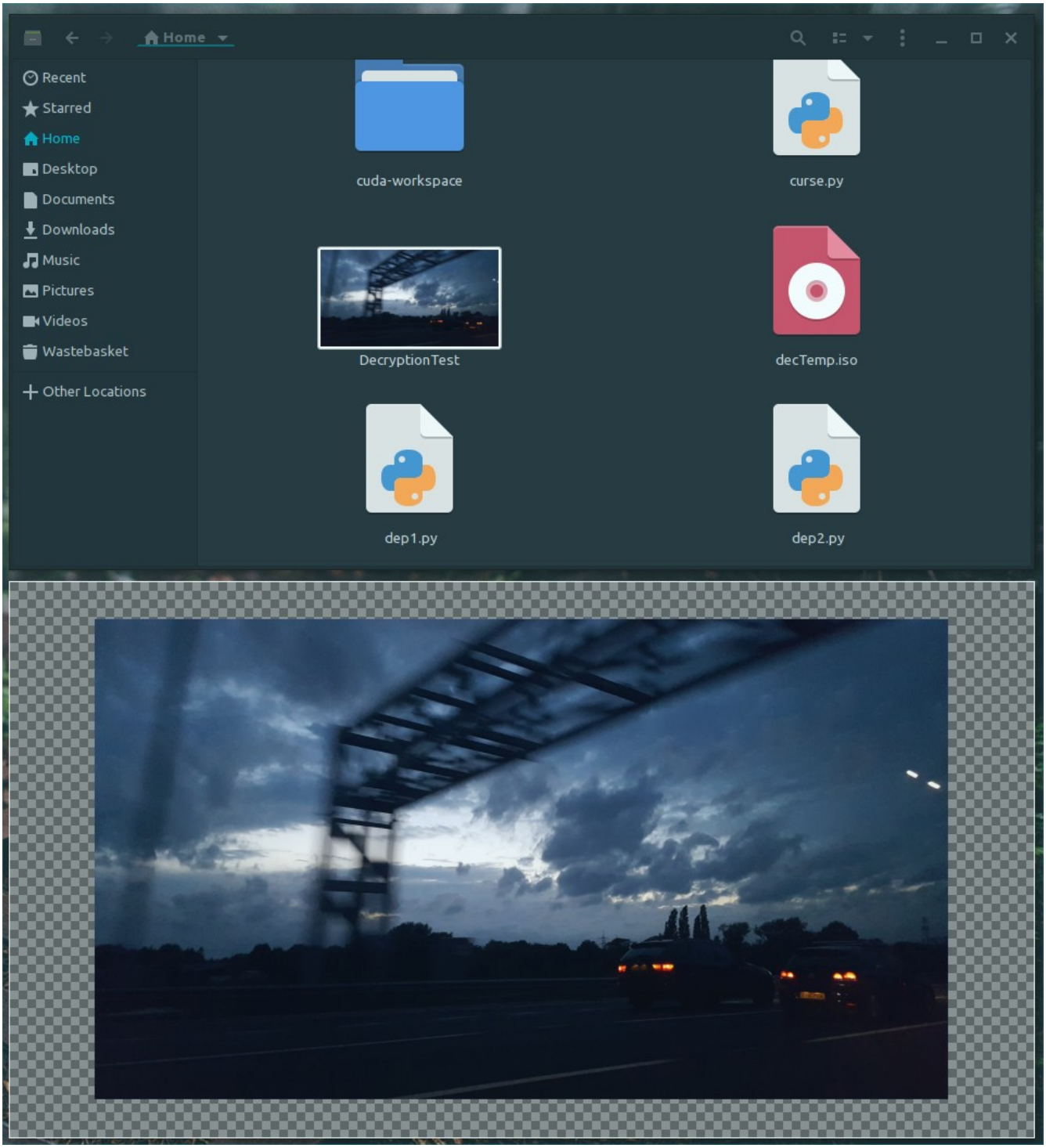
Before:


Search:
118.63GB / 244.53GB used.
eggbrowser
Important ima
pluto
antergos-18.9
bytesSecond.
Screenshot fro
19.12MB
27.59MB
177.49KB
2.20GB
576.00B
2.37MB
File Information
File Name:
Screenshot from 2018-10-06 14-12-48.png
Current Location:
/Vault/Screenshot from 2018-10-06 14-12-48.png
Size:
2.37MB
Delete
Decrypt File

Input:


Search:
118.63GB / 244.53GB used.
File Information
Decrypt File
Input the destination:
/home/josh/DecryptionTest

After:



Top tile is file manager in /home/josh/, bottom is the open decrypted image.

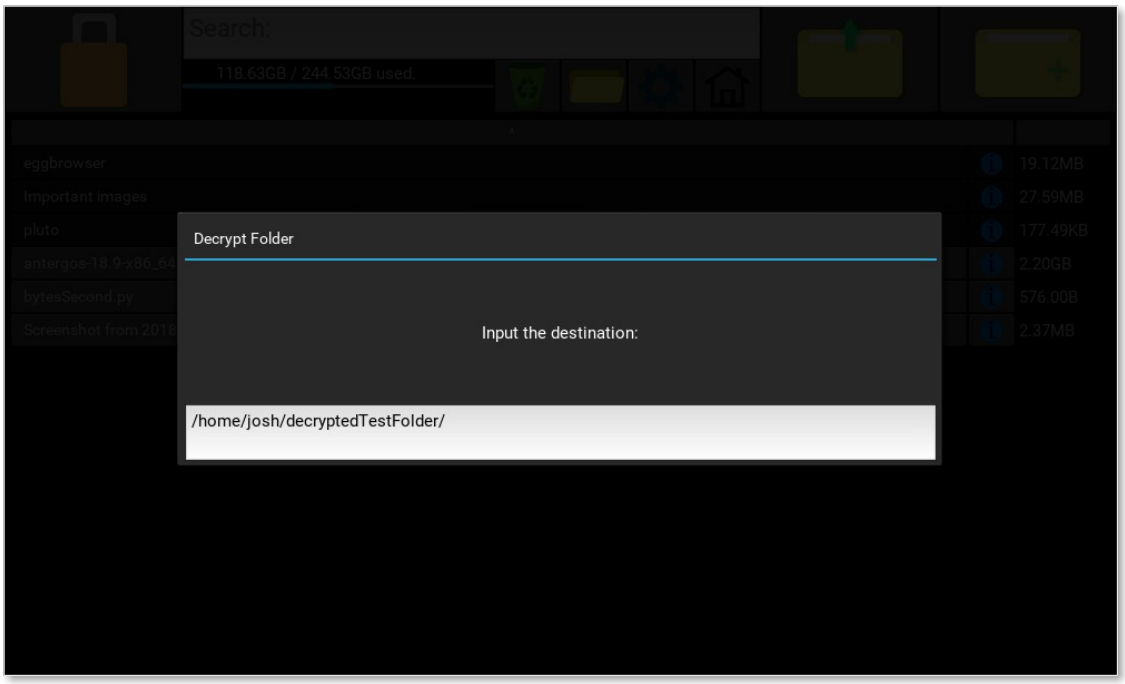
Test Number	15
Relevant Objective	3.i
Description	Decrypt a folder to a location outside of the vault.

Purpose	To check it works normally.
Expected Outcome	`Folder should be decrypted successfully, with all files and folders in the correct place.`
Actual Outcome	`Pass`

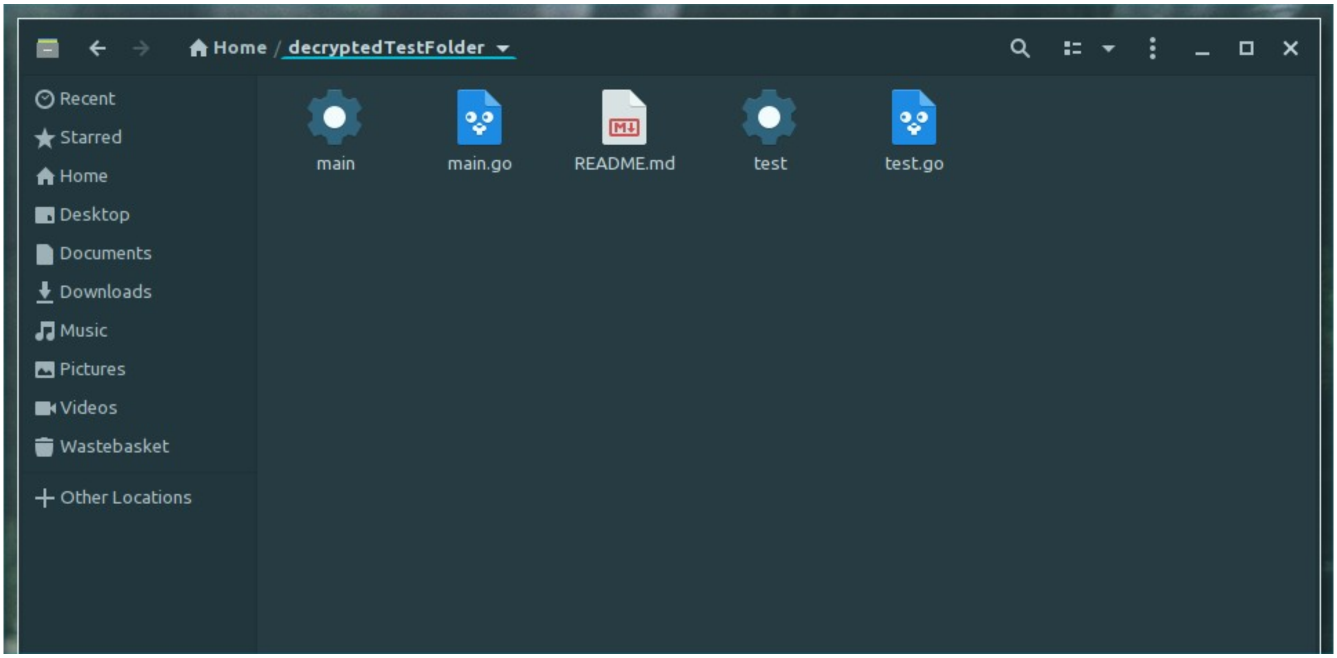
Evidence:

Before:

Input:



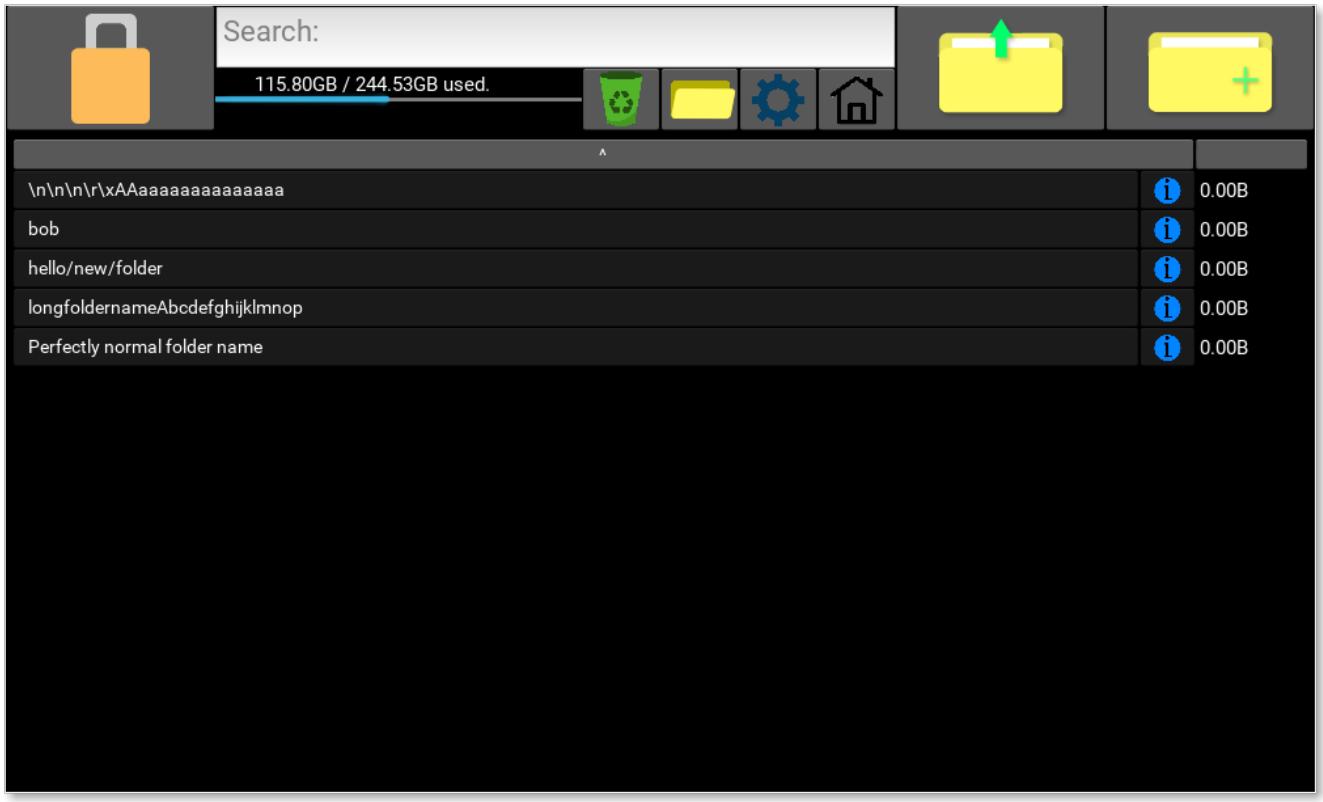
After:



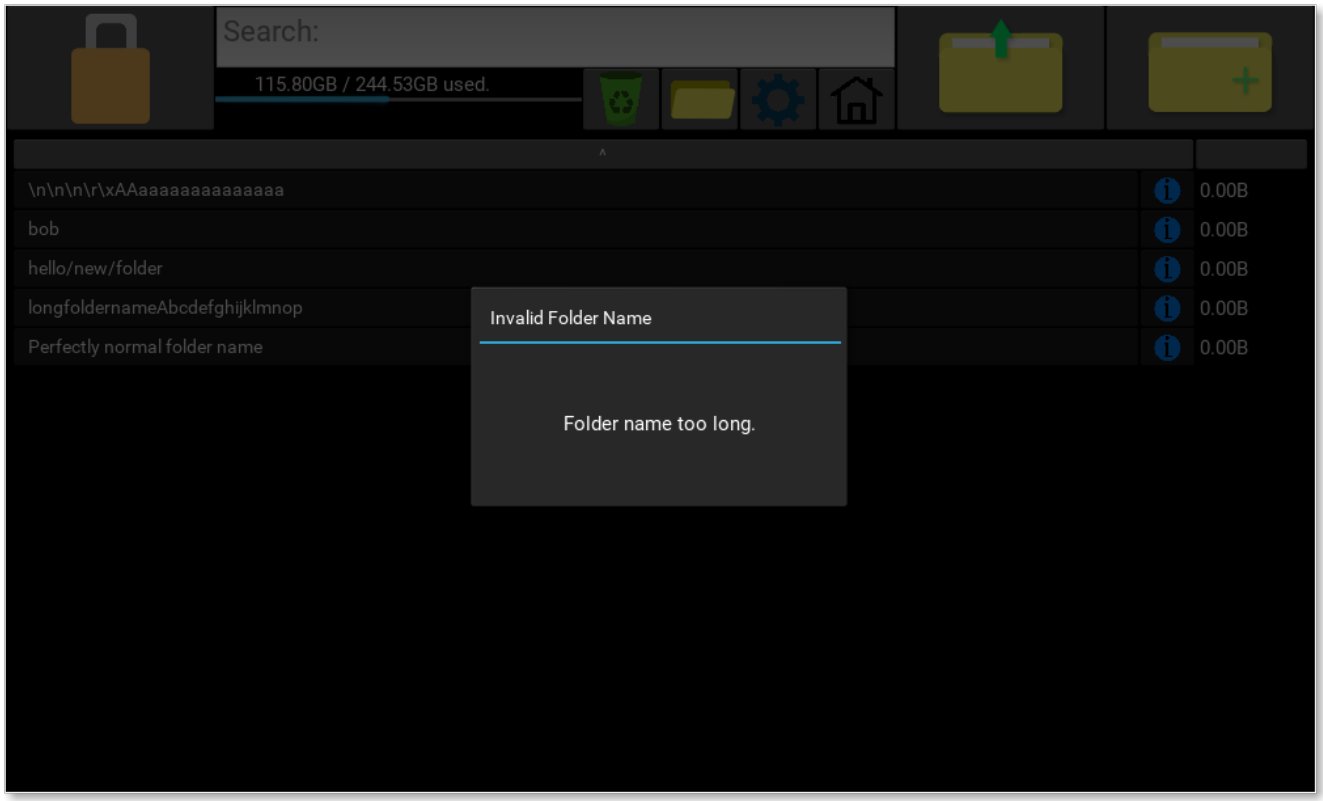
Test Number	16
Relevant Objective	1.f
Description	Create a new folder inside the vault.
Purpose	Make sure that it can be created.
Test Data	T: [1]: “bob” [2]: “longfoldernameAbcdefghijklmnop” [3]: “Perfectly normal folder name” (Possibly Erroneous) E: [4]: “\n\n\n\r\xAAaaaaaaaaaaaaaa” [5]: “FOLDER NAME THAT IS WAY TOO LONG aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa aaaaaaaaaaaaaaaaaaaaaa” [6]: “hello/new/folder”
Expected Outcome	[1-4, 6]: Folder should be created with no issues. [5]: A popup should show telling the user that the file name is too long.
Actual Outcome	[All]: Pass

Evidence:

File names 1-4 and 6:



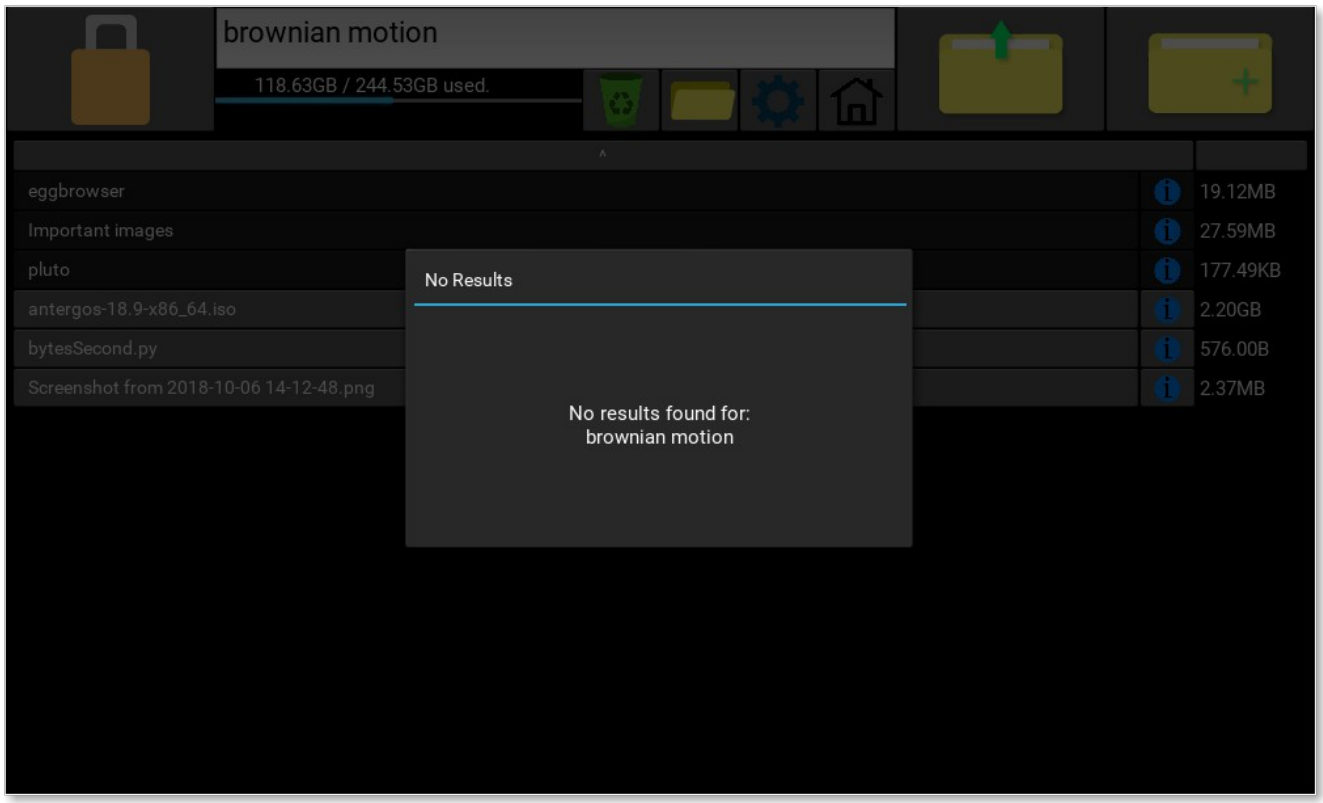
File name 5:



Test Number	17
Relevant Objective	1.r
Description	Attempt to go up one directory while in the root directory of the Vault.
Purpose	Check that the user is confined to the vault, so the program does not try to decrypt file names that are not encrypted.
Expected Outcome	`The displayed files should remain the same when I click to go up.`
Actual Outcome	`Pass`

Test Number	18
Relevant Objective	1.q
Description	Search for an item that is not in the vault.
Purpose	Check that the user is warned when the item is not found.
Test Data	`“brownian motion” - search term (it is not in the vault).`
Expected Outcome	`A popup should open warning the user that the file could not be found.`
Actual Outcome	`Pass`

Evidence:



Test Number	19
Relevant Objective	1.q
Description	Search for an item that is in the vault.
Purpose	To check that the item is found.
Test Data	A lot of files (534 files). Some of them contain the string “processing”, so I will search for the folder “processing-3.4”, which there is only 1 of.
Expected Outcome	Should only show the folder “processing-3.4”
Actual Outcome	Pass

Evidence:

Test Number	20
Relevant Objective	3.g
Description	Open a file then lock the program with the file open.
Purpose	Check that the file is removed regardless of if it is open.
Expected Outcome	File should be removed and should not be in /tmp/FileMate/file.
Actual Outcome	Pass

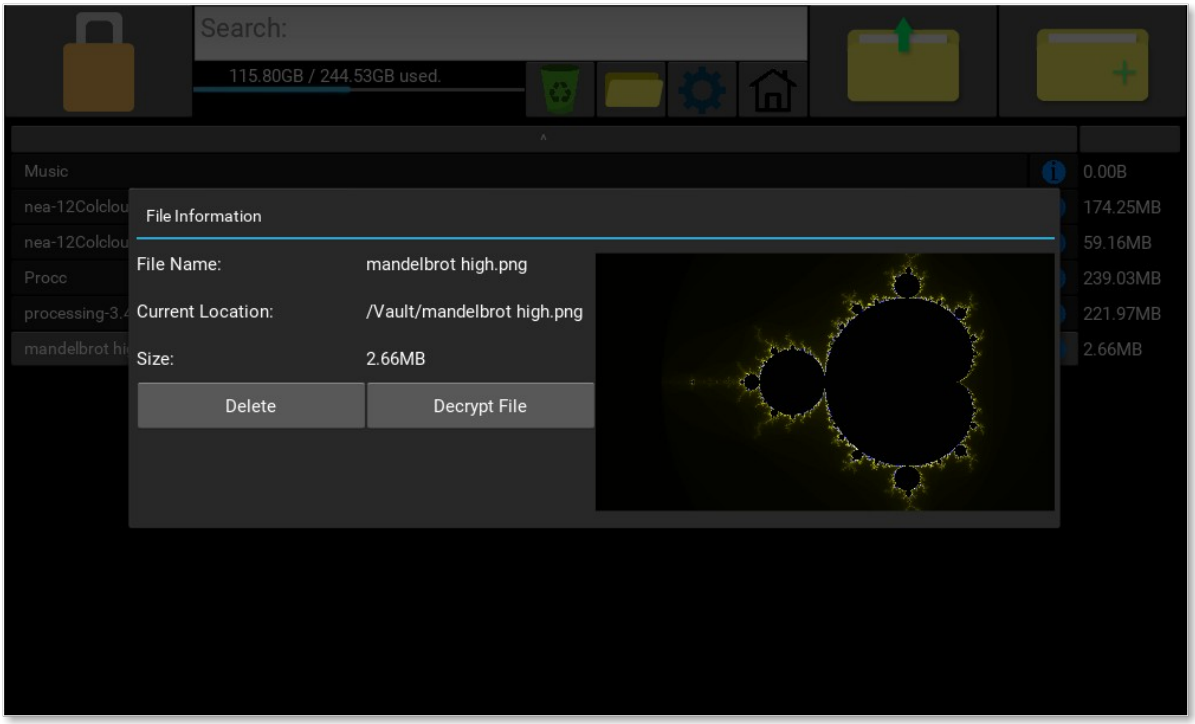
Evidence:

```
~ $ cd /tmp
/tmp $ # File has been opened
/tmp $ ls | grep "FileMate"
FileMate
/tmp $ ls FileMate
test12_3.png
/tmp $ # Vault has been locked
/tmp $ ls | grep "FileMate"
/tmp $
```

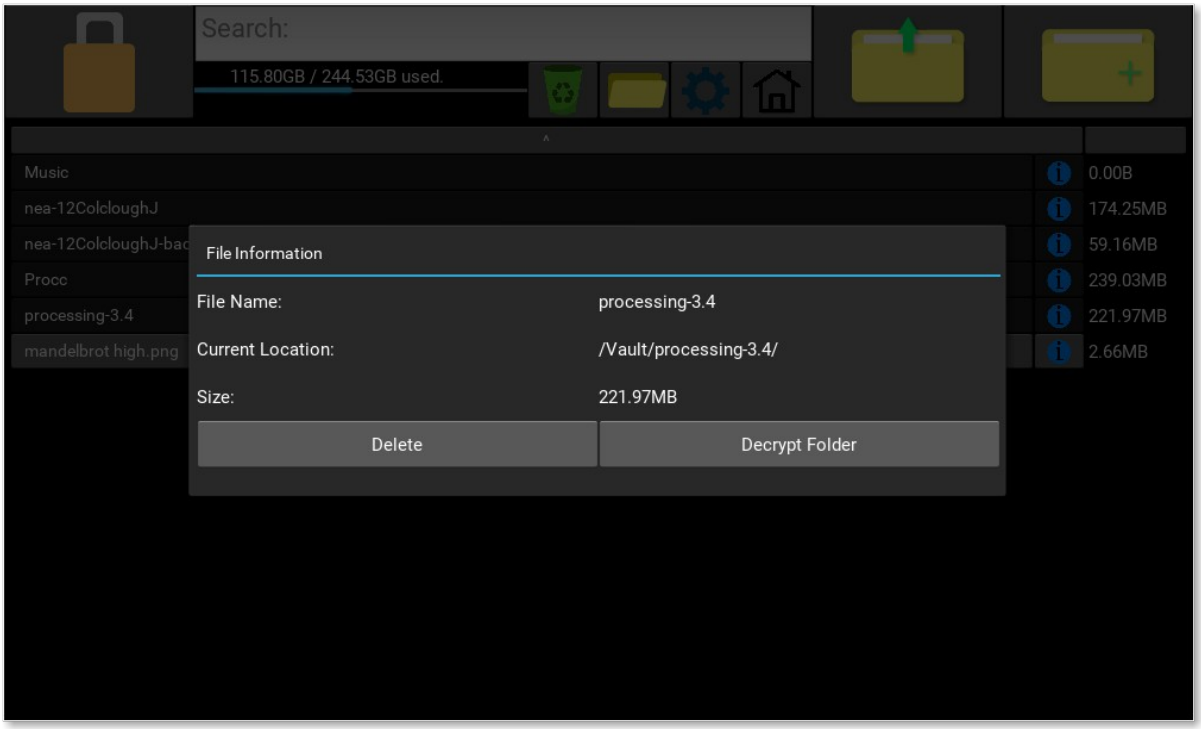
Changed directory to /tmp, which is the temporary folder on my PC. Then I opened the file in the program, then list the files in /tmp, filtering the output for “FileMate” (which is what I ended up calling the program).
Then I listed the contents of /tmp/FileMate/, to view the temporary FileMate files.
Then I locked the app, and checked again for the FileMate folder, and it had been deleted.

Test Number	21
Relevant Objective	1.j
Description	View more information on an image, then view more information on a file that is not an image.
Purpose	Check that a preview of the image is shown, and if the file is not an image then a preview is not shown.
Expected Outcome	`The preview should be shown for the image, but not shown for the regular file.`
Actual Outcome	`Pass`

Evidence:
With an image:

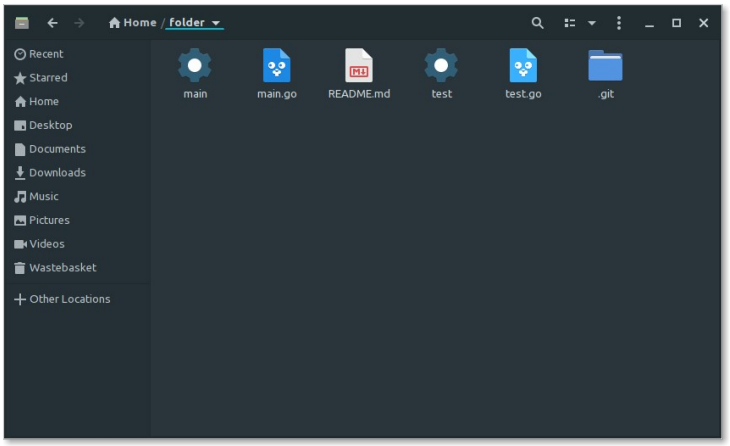


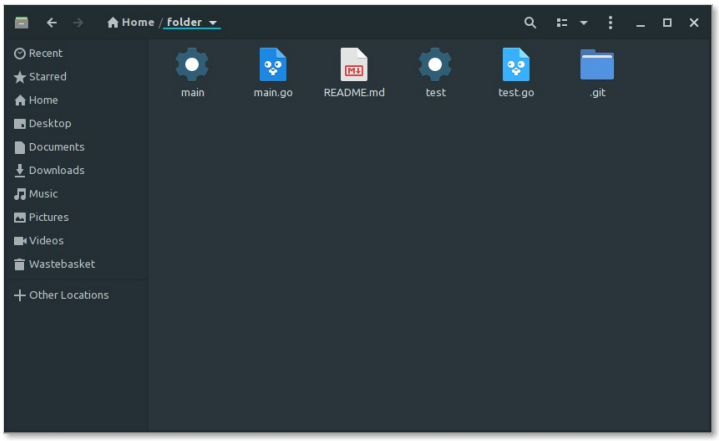
With a folder:



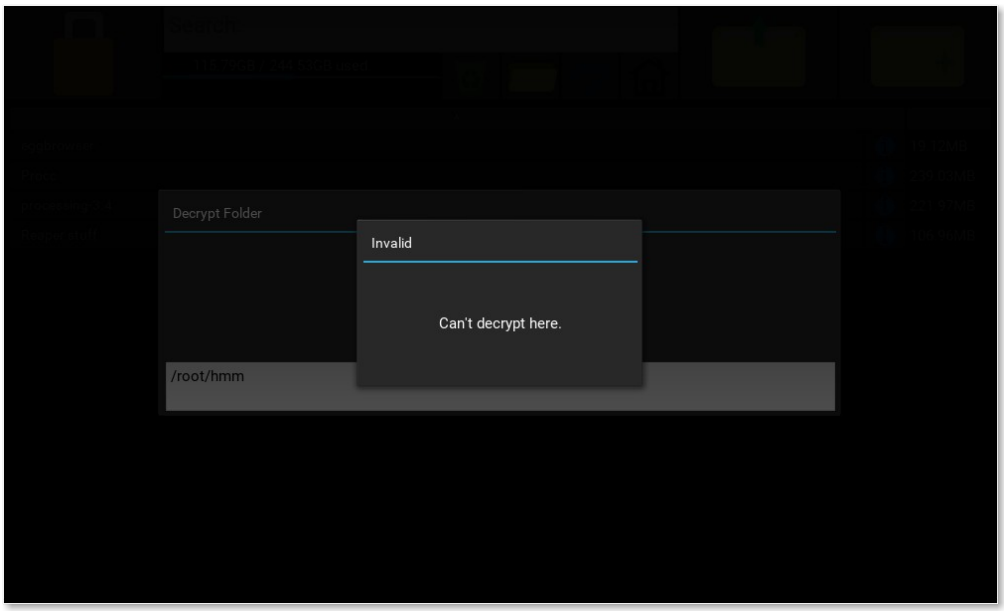
Test Number	22
Relevant Objective	1.d, 3.i
Description	Decrypt folder to different locations.
Purpose	Make sure that the user can't break the input.
Test Data	T : [1]: "/home/josh/folder/" [2]: "/home/josh/folder" [3]: "/home/josh/aaaaaaaaaaaaaaaaaaaaaaaaa/" (Potentially Erroneous) E: [4]: "/root/hmm" (Erroneous if user does not have permission) [5]: "home/josh/folder/" [6]: "/home/josh/////////////////////////////////////folder/" B: [7]: "/home/josh/\n\n\n" [8]: "/home/josh/aaa/a/a/aa/"
Expected Outcome	[1-3]: Should decrypt no problem. [4]: Popup should warn user that it cannot be decrypted here. [5]: Same as [4] [6]: Same as [4] and [5] [7]: May work fine. [8]: Should make the file path correctly then decrypt files to aaa/a/a/aa/.
Actual Outcome	[All]: Pass

Evidence:
[1-3]:

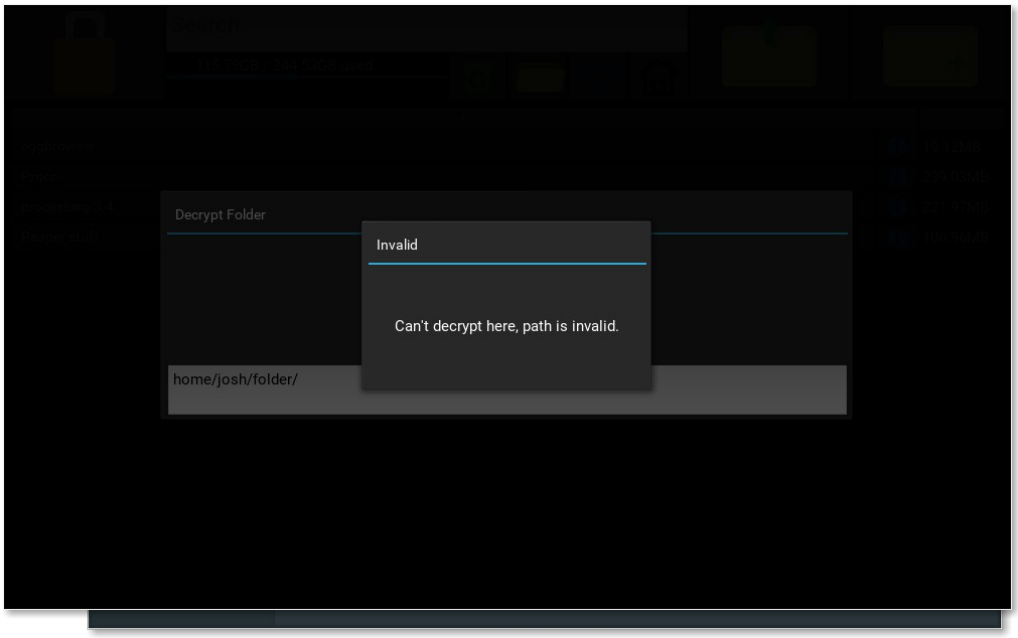




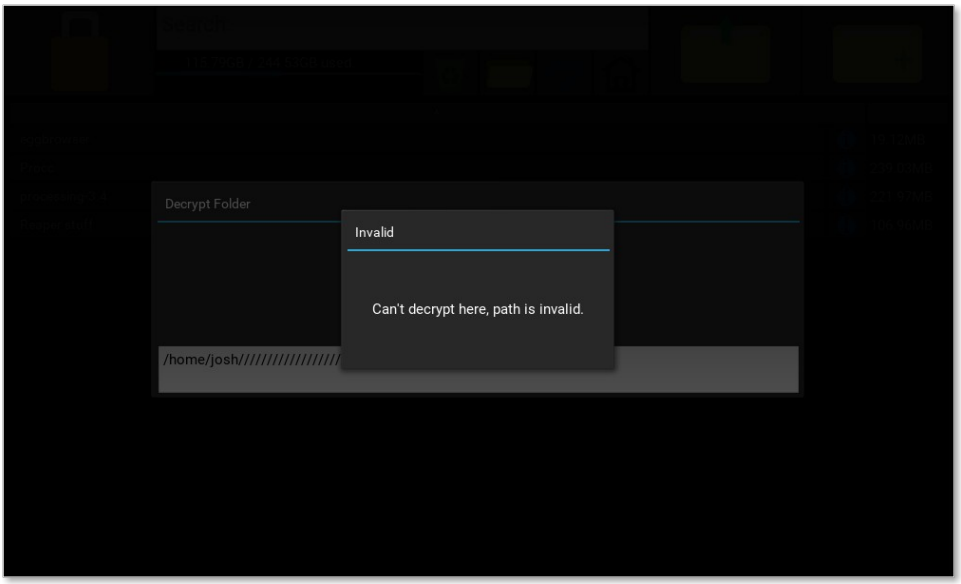
[4]:



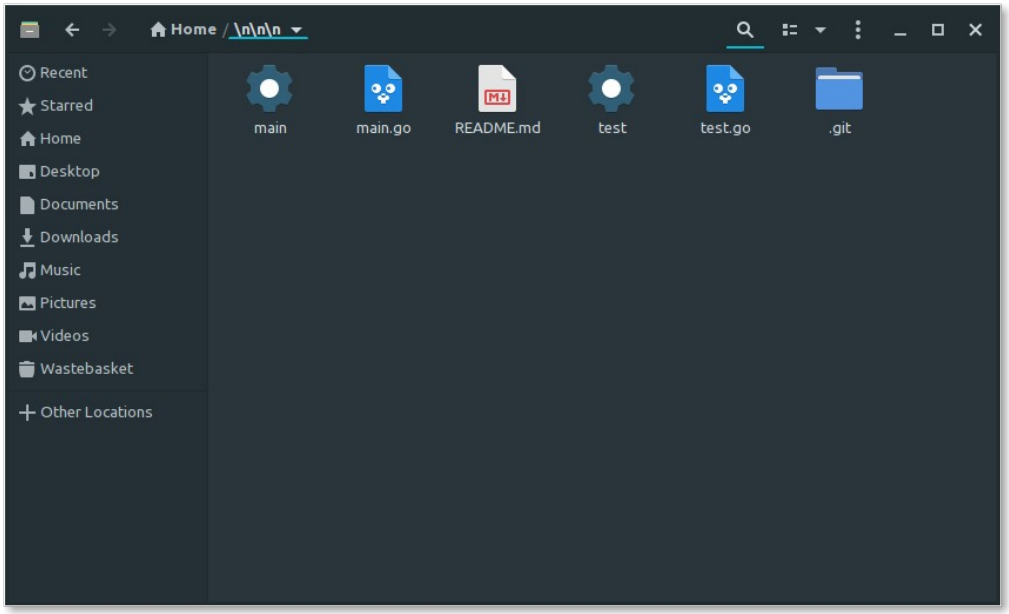
[5]:



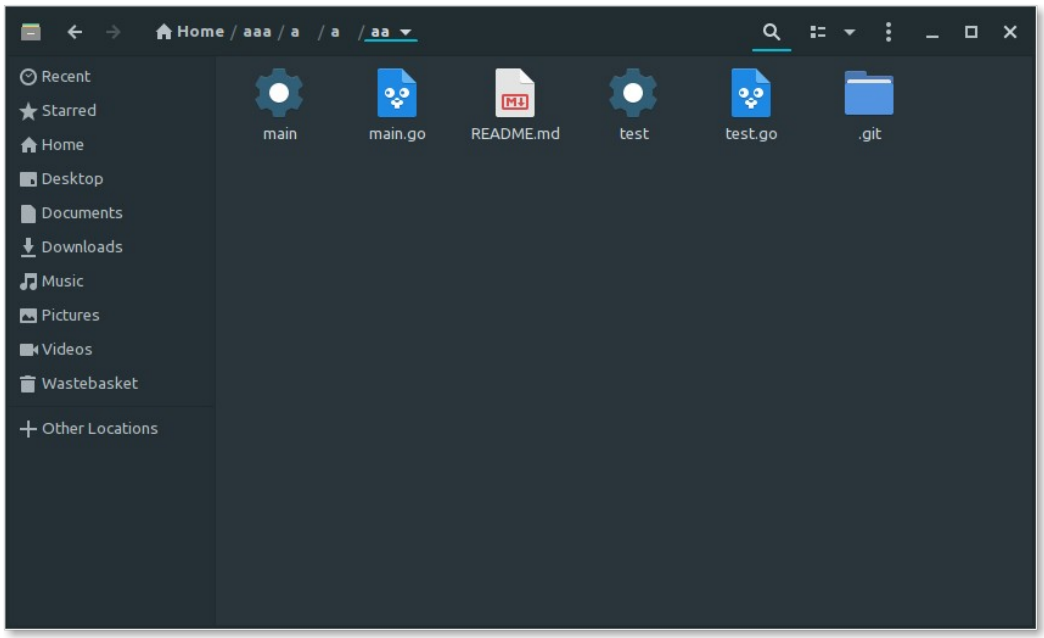
[6]:


Decrypt Folder
Invalid
Can't decrypt here, path is invalid.
/home/josh/

[7]:

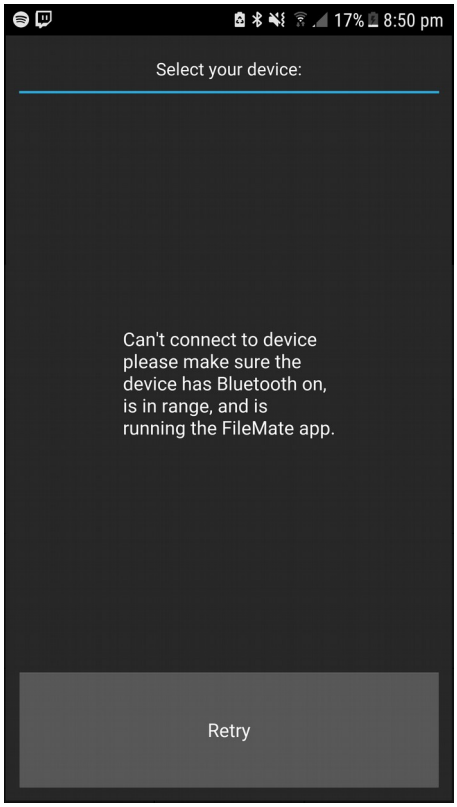

Home / \n\n\n
Recent
Starred
Home
Desktop
Documents
Downloads
Music
Pictures
Videos
Wastebasket
Other Locations
main
main.go
README.md
test
test.go
.git

[8]:


Home / aaa / a / a / aa
Recent
Starred
Home
Desktop
Documents
Downloads
Music
Pictures
Videos
Wastebasket
Other Locations
main
main.go
README.md
test
test.go
.git

Test Number	23
Relevant Objective	2.e
Description	On the mobile app, click to connect to a device that is not running the PC app.
Purpose	To check the user is warned that the program can't connect to the device.
Expected Outcome	A popup should be shown on the mobile telling the user that the app could not connect to the device.
Actual Outcome	Pass

Evidence:

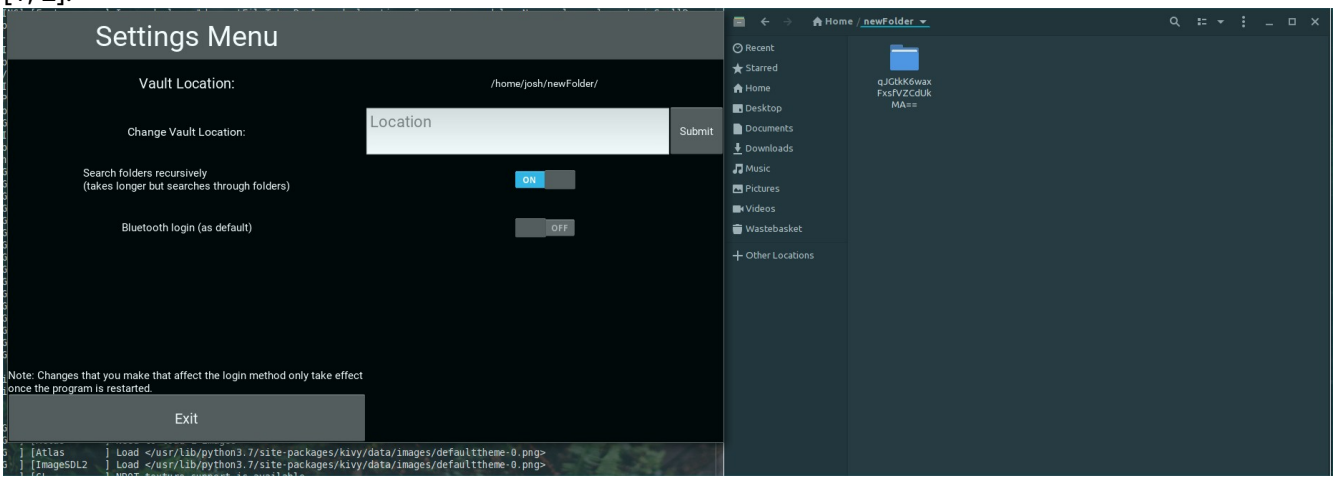


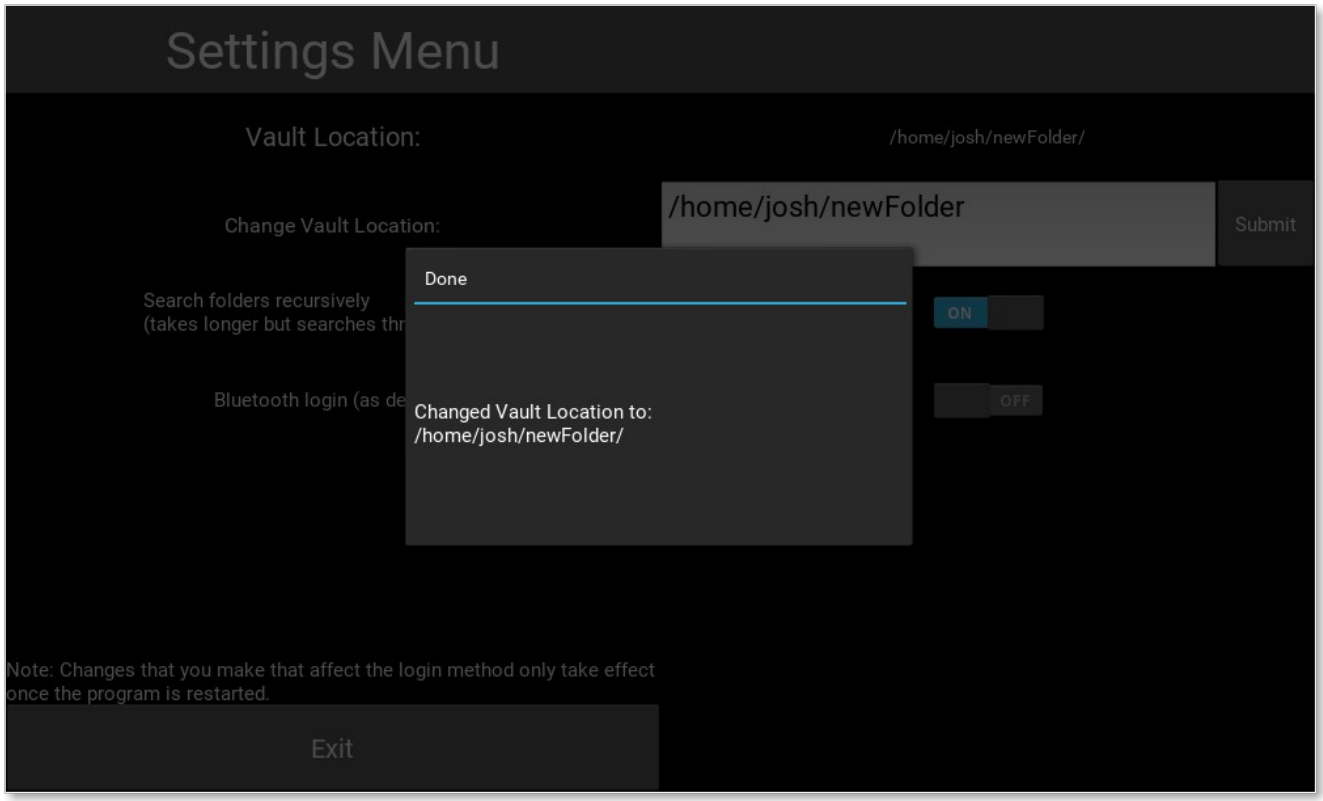
Test Number	24
Relevant Objective	3.a
Description	Change the vault location (using the Settings screen).
Purpose	Make sure the user can easily change vault location.
Test Data	From "/home/josh/EncryptedDir/" to: T: [1]: "/home/josh/newFolder/" [2]: "/home/josh/newFolder" [3]: "newFolder" [4]: "newFolder/subFolder/" [5]: "newFolder/subFolder" B: [6]: "/home/josh/folderWithEncFiles/"

	E: [7]: “/home/josh/folderWithEncFilesDifferentKey/”, log in with the different key, then change vault to “/home/josh/EncryptedDir/”.
Expected Outcome	[1-2]: Should create folder. [3-5]: Should create folder relative to the input. [6]: Has the same key as the original location, so should work just fine. [7]: Hopefuly handles it ok.
Actual Outcome	[1-6]: Pass [7]: Tried to decrypt file names, but showed gibberish.

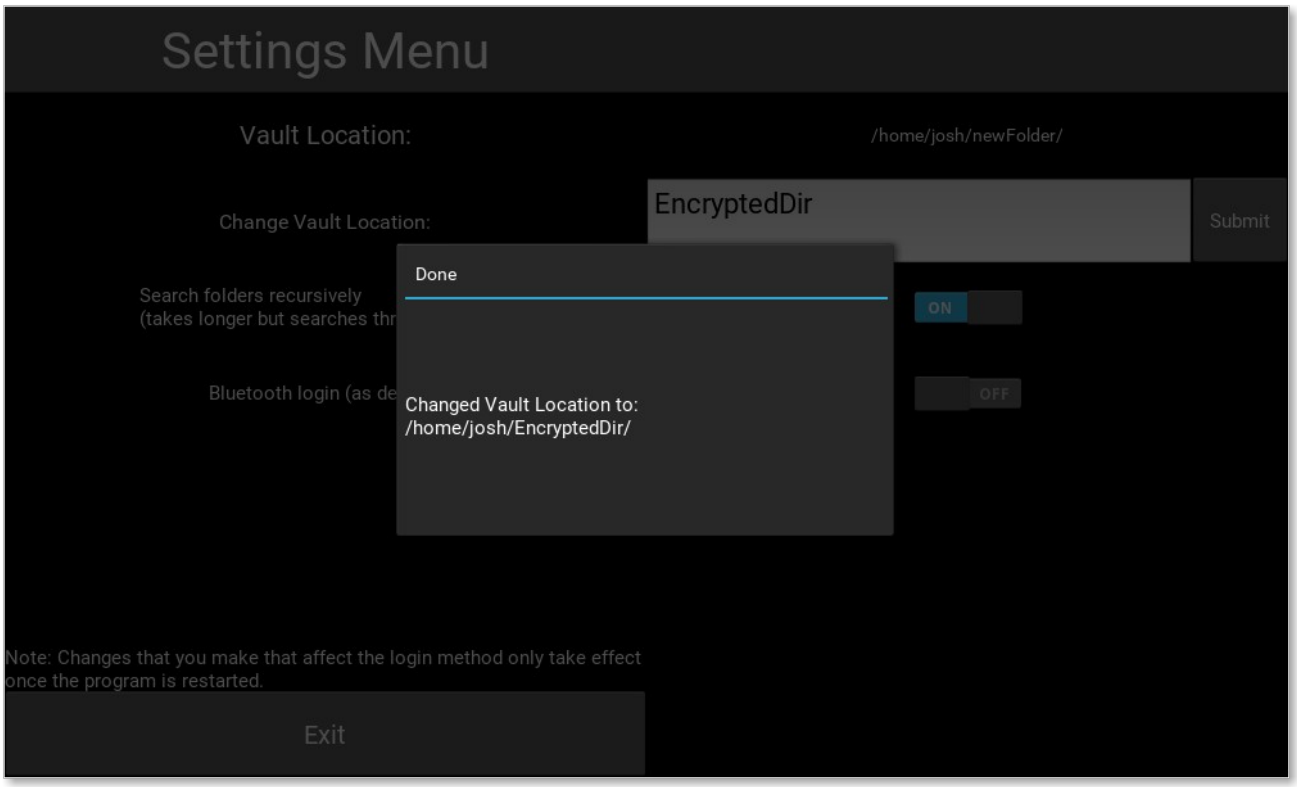
Evidence:

[1, 2]:

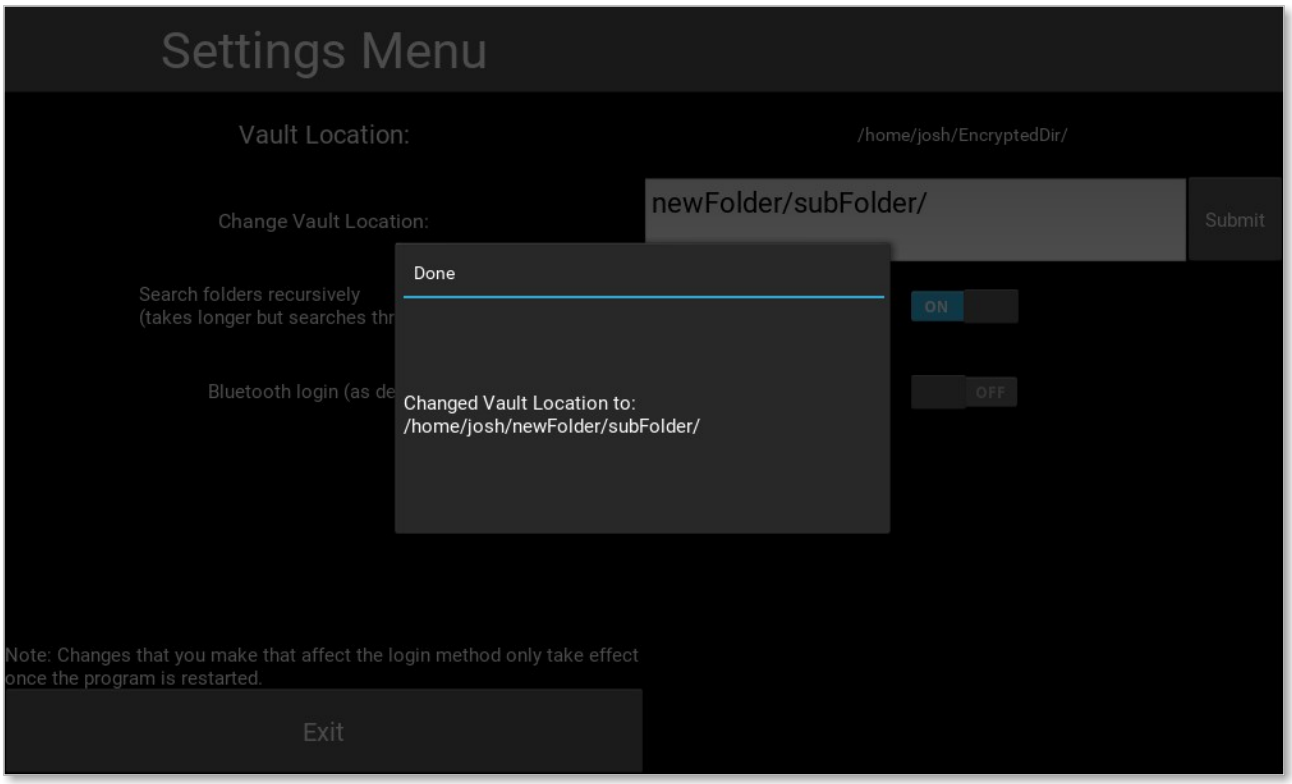




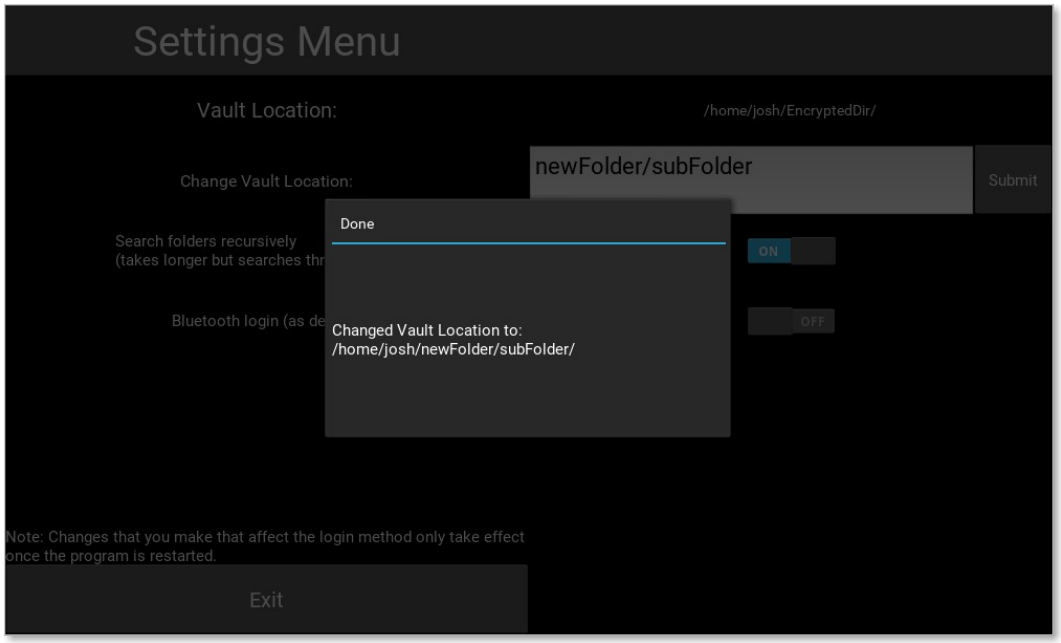
[3]:


Settings Menu
Vault Location:
/home/josh/newFolder/
Change Vault Location:
EncryptedDir
Submit
Done
Search folders recursively
(takes longer but searches thr
ON
Bluetooth login (as de
OFF
Changed Vault Location to:
/home/josh/EncryptedDir/
Note: Changes that you make that affect the login method only take effect
once the program is restarted.
Exit

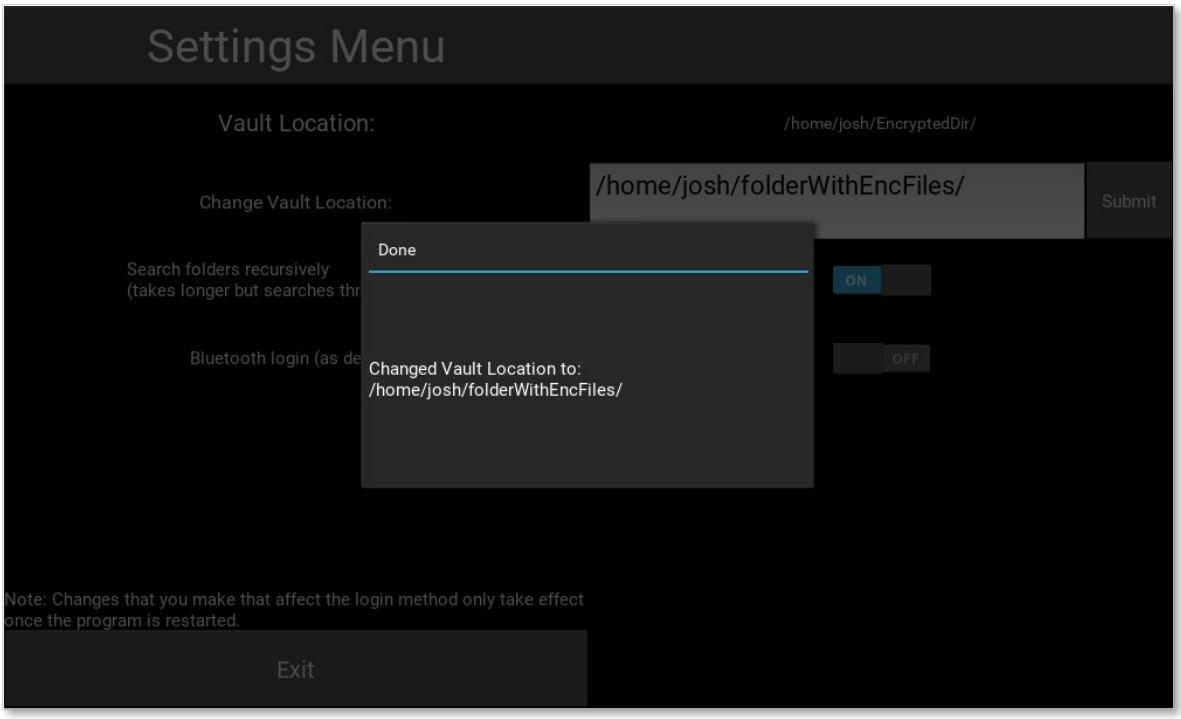
[4]:


Settings Menu
Vault Location:
/home/josh/EncryptedDir/
Change Vault Location:
newFolder/subFolder/
Submit
Done
Search folders recursively
(takes longer but searches thr
ON
Bluetooth login (as de
OFF
Changed Vault Location to:
/home/josh/newFolder/subFolder/
Note: Changes that you make that affect the login method only take effect
once the program is restarted.
Exit

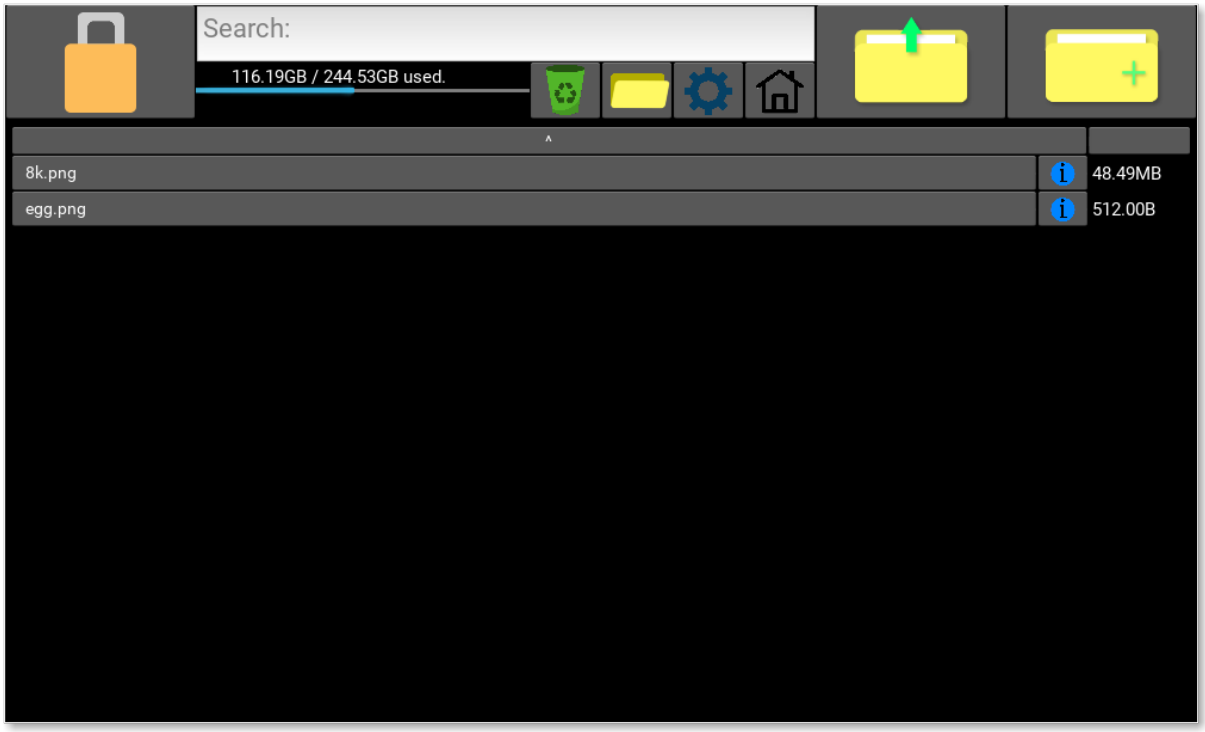
[5]:



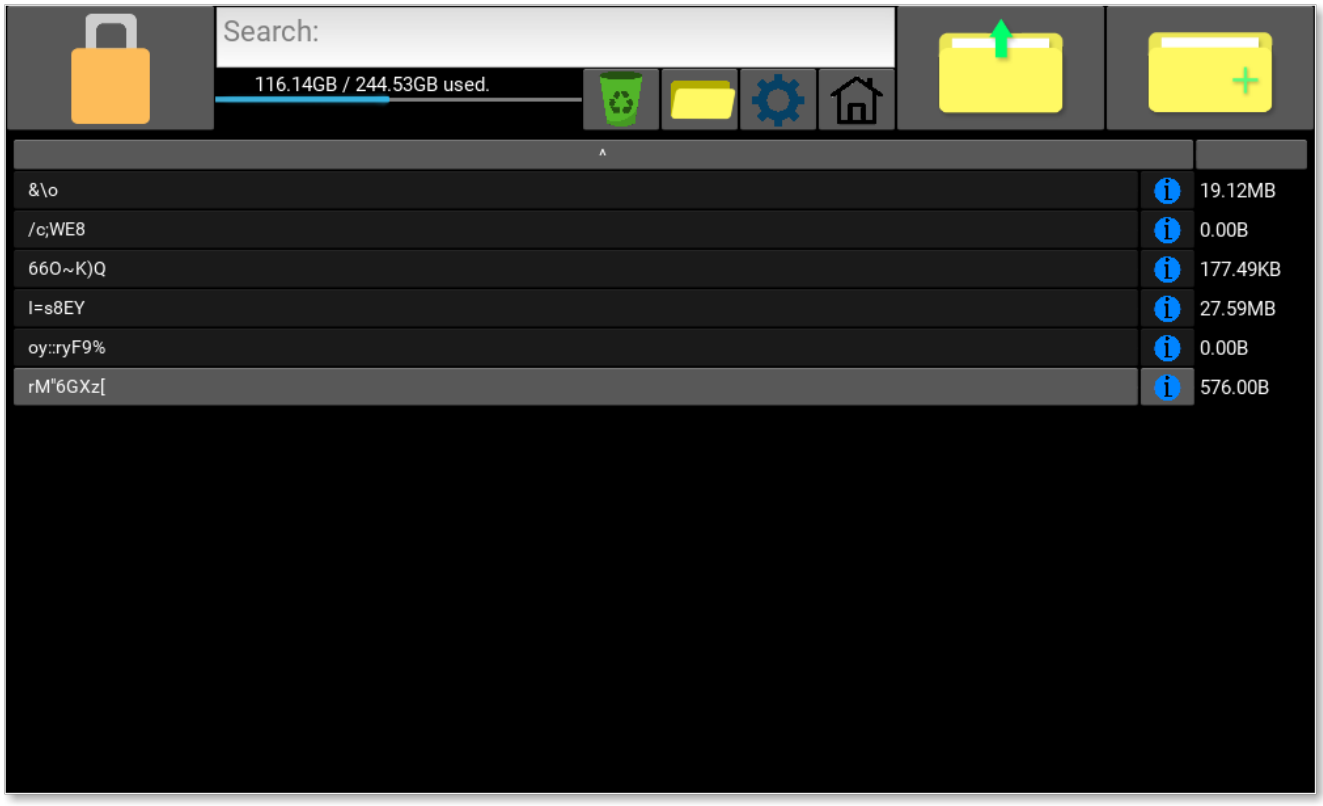
[6 (in 2 parts)]:
Change vault to /home/josh/folderWithEncFiles/



View vault:



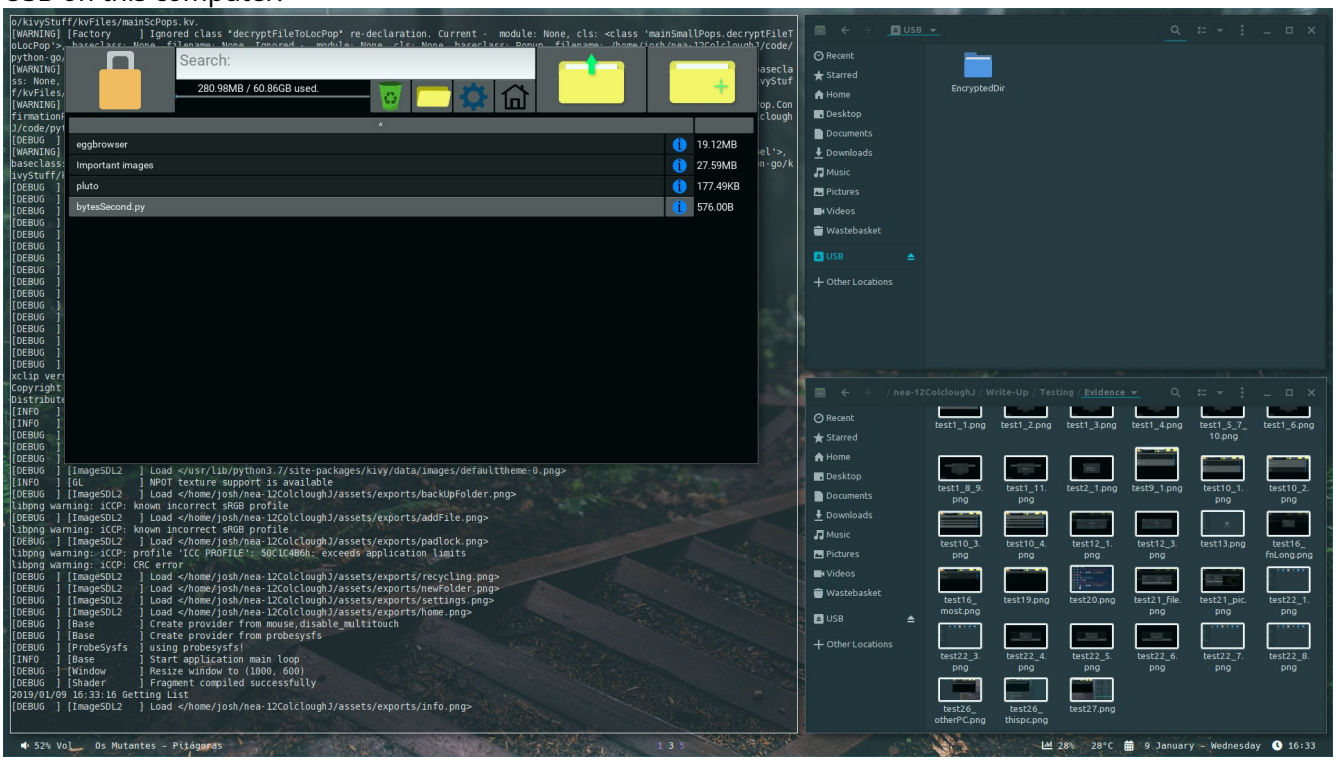
[7]: (The one that broke)



Test Number	25
Relevant Objective	3.a
Description	Move a vault onto a USB stick, and access it on another computer.
Purpose	To make sure that use case is possible.
Expected Outcome	`The user should be able to access all files in the vault using my program, if they enter the key correctly and if the vault location is set correctly in the configuration files.`
Actual Outcome	`Pass`

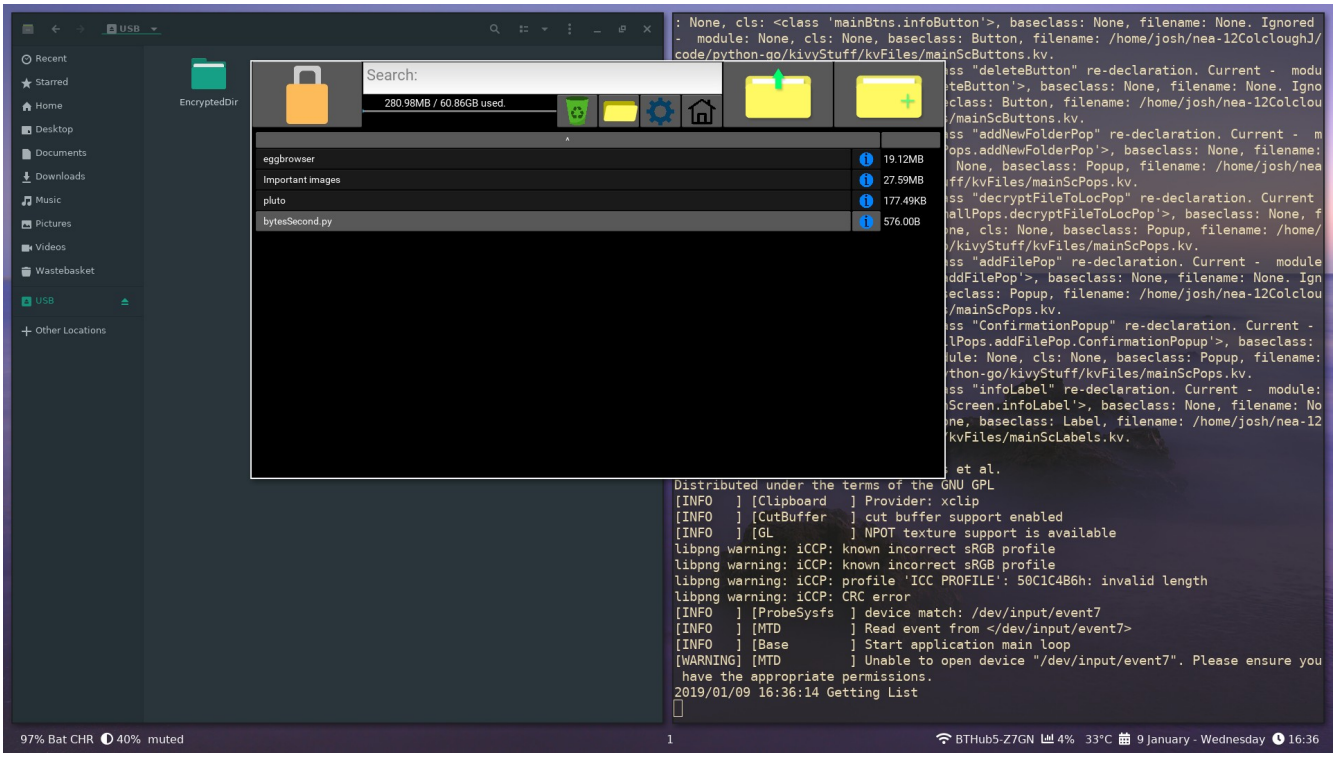
Evidence:

USB on this computer:



Left is the program, top right is the contents of the USB (= EncryptedDir).

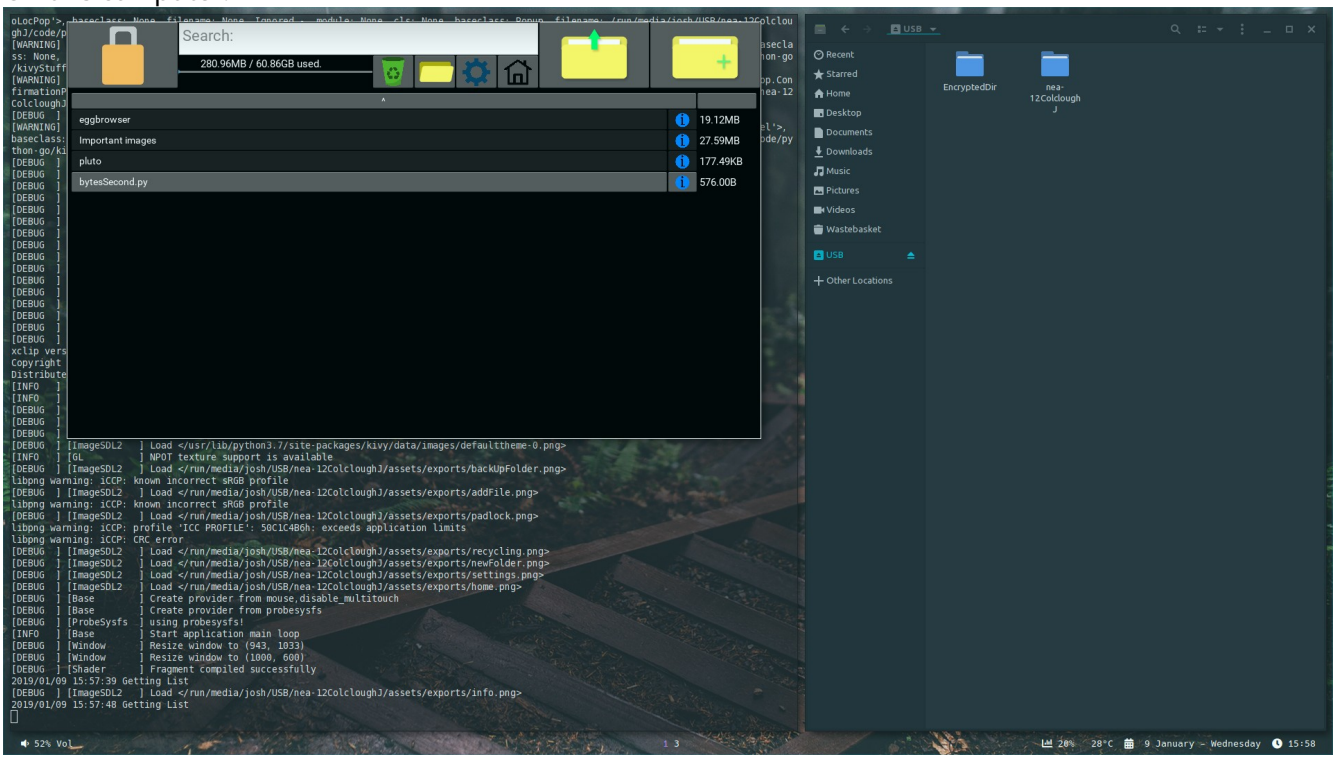
USB on another computer:



Test Number	26
Relevant Objective	3.a
Description	Move the vault AND the program onto a USB stick, and run the program from the USB stick on multiple computers.
Purpose	Check that the use case is possible, and working on different machines is smooth.
Expected Outcome	The user should be able to access all files in the vault using my program, if they enter the key correctly and if the vault location is set correctly in the configuration files, using a relative vault location.
Actual Outcome	Pass

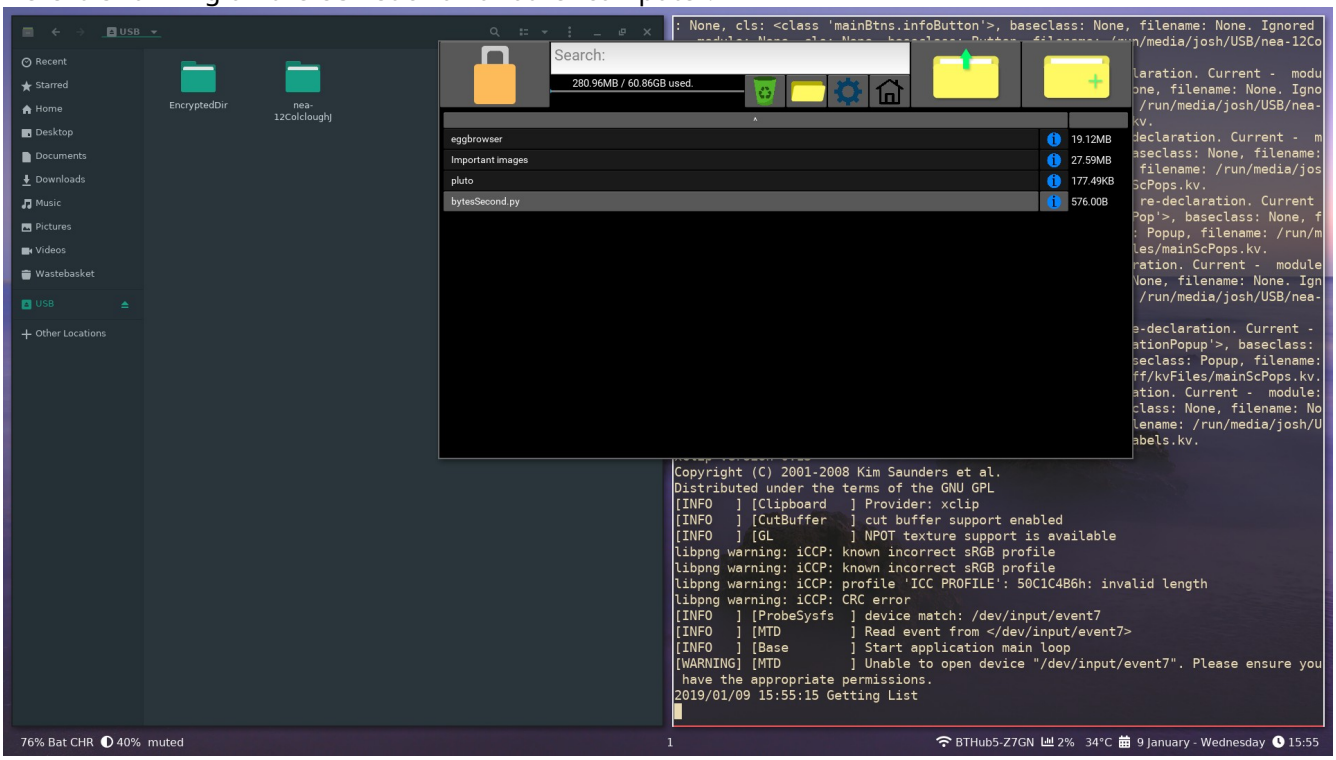
Evidence:

On this computer:



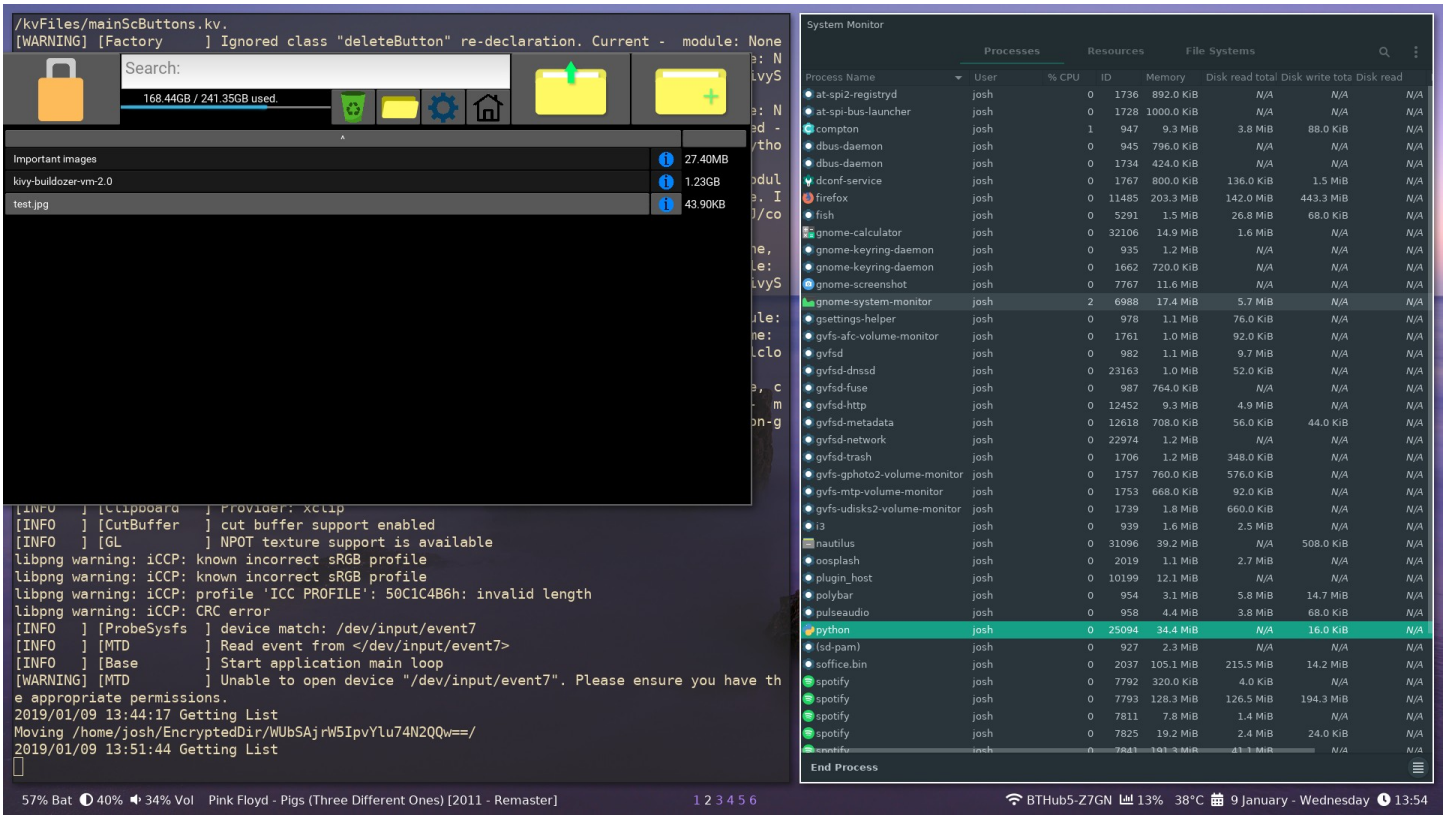
Right tile shows contents of USB stick, left is the program running showing the contents of USB/EncryptedDir.

Here it is running off the USB stick on another computer:



Test Number	27
Relevant Objective	1.h.i
Description	Check my program is not using too much CPU time when idle (<5%), and not too much memory (<100 MiB).
Purpose	To make sure that my program is not using up CPU time when it is really doesn't need to be doing anything, and that it is not too memory hungry.
Expected Outcome	`Should be below 5% CPU usage and 100 MiB of memory, as it isn't a huge program.`
Actual Outcome	`Pass- 0% CPU usage and 34.4 MiB memory usage.` `The memory usage is still a bit high (comparable to my file manager at 35 Mib), and I believe this is due to the loading of images for the info button on files, when it could probably be loaded once instead of once for every button.`

Evidence:



Here I have my program sitting idle, with a task manager open (the `python` task is highlighted).

Evaluation

Objectives

In this section I will go through each of my objectives and comment on their completeness.

---

1. GUI should:

   a. Be easy to use:

   i. Logically laid out.

   ii. Have simple options.

   I feel that my program is quite easy to use due to the layout, the important buttons are the largest, and the file browser fills most of the screen, which is the most important part of the main screen. The settings screen is also quite easy to use, as the switches for the True/False configuration values are very straiht forward to change, and it is clear what each setting changes.

   b. Display the files currently stored in the vault, along with the file extension and the size of the file.

   Works fine. The file extension is at the end of the file name anyway. The size is read from the file in the vault.

   c. Display the storage space remaining on the storage device the program is running on.

   Works fine.

   d. The user should be able to easily encrypt and decrypt files:

   i. Using easy to access buttons in the UI.

   ii. Using drag and drop from outside of the program.

   iii. Decrypt to a directory specified.

   All of the above work, as long as you have drag+drop on your machine.

   e. Have an options menu, including the options to:

   i. Change from 128 bit security to 256 security. 128 bit is the bare minimum.

   Didn't end up adding this, as it would require a lot more code and time for a feature that very few people would probably use.

   ii. Change the location of the vault.

   Can be changed relative to the program, or as an absolute path.

   iii. Set the default login method (Bluetooth or no Bluetooth).

   Also done using a switch in the settings screen.

   iiii. Change if the search in the file browser is recursive or not.

   Done using a switch in the settings screen.

   f. Make it easy to manage the files in the vault (move to other folders in the vault, rename, delete, etc).

I ran out of time to implement this, as Kivy buttons by default do not have a right click, and it is quite hard to implement. If I were to implement this, I would show a bubble above where the user right clicked, with multiple options to carry out on that file/folder. Alternatively, I could use the information popup to hold each of these options.

g. Have a secure login screen.

i. Ask the user to either input the key via their keyboard (no Bluetooth for that session), or connect via the app.

ii. Tell the user if the key is invalid or not, and smoothly transition into the main program.

iii. Validate all input.

All tested to be working.

h. Look relatively good without being bloated.

i. Allow the user to easily read file names, and easily tell folders and files apart.

Files are coloured in a darker shade than regular files, and the file names are in medium-sized font (relative to the window).

j. Let the user preview images without opening them (using thumbnails or an information screen).

Works well, as AES decrypts the image quickly, then it is displayed in the information screen. I did not add thumbnails as I thought that it would probably drastically increase the loading time when opening folders containing images.

k. Be resizeable, and all items on the screen should look ok.

Also looked at in testing. Each widget uses a relative layout, so that when the window is resized, the widgets also resize themselves based on the proportions they were given.

l. Allow the user to switch between using Bluetooth and using regular login.

Works good.

m. Make it easy for the user to return to the root folder of the Vault in case they get lost (a "panic" button).

A home button is included on the main screen, and takes the user back to the root folder.

n. Give the user statistics during files being enc/decrypted, including:

Works well. I cover how this works in the Technical Solution, and it is tested to give accurate readings in Testing. Gives the user a nice readable output, displaying all useful information.

o. Allow the user to sort the files by name or by size.

The user can do this using the two buttons above the list of files on the main screen.

p. Allow the user to configure default settings using a configuration file that is easy to use.

The configuration is relatively simple, and easy to edit manually in case of an issue.

q. Allow the user to search for file names in the vault.

Works well, however is quite slow because it is done in Python. I would have liked to do this in Go, however passing the file objects into Go would have been a pain, as they are not all in the same directory like the sorting buttons are (which is why I could do those in Go).

r. Not break when doing arbitrary tasks such as browsing the files.

See Testing.

2. App should:

   a. Be easy to use.

   The GUI could be improved on the mobile side, as the flow of the program is quite weird, going from the device screen, into the pad screen (this part is fine), and then into a blank screen with only one option. This last screen is a good idea if you have multiple options, however I only supply one, so it is a bit redundant. If I were to continue working on this project I would leave it in for future functionality. However, other than this each screen works well individually. The pad screen has large buttons with quite large font. The main screen is basic, but functional.

   b. Connect via Bluetooth to the PC.

   Connects seamlessly to the PC using pyjnius java classes.

   c. Allow the user to input their pin code easily.

   The Pad Screen is easy to use.

   d. Tell the user if the pin code is invalid or not.

   (b, c, d) Works fine.

   e. Make it easy to recover from mistakes (e.g invalid pin code, or if they make a typo).

   In the pad screen, the key input is reset to be empty if it is incorrect, and the user can easily delete the last digit while entering the key. If the user does get the key incorrect, a small popup shows up telling them, and then they can easily dismiss it.

   f. Allow the user to see a list of files currently in the vault, and let the user download those files onto their mobile device.

   The file browser is quite good, with a large scrollable list of files, however there is no way of distinguishing between files and folders at the moment. This is due to the protocol, as I decided against sending pickled objects between the PC and phone. I decided not to do this because I was using Python 2 for the mobile app, and Python 3 for the PC app. The way Python 2 handles bytes is quite different to Python 3, and so pickle had quite a few differences. If I was to continue working on this I would build the mobile app in Python 3, however at the time I was having issues building the app for Python 3. Other than this, the download feature is pretty good, as it is quite reliable (as far as I have tested).

3. File handling:

   a. Store the encrypted contents in the location specified by the user.

   Works fine.

   b. Encrypt and decrypt relatively quickly, while still being secure.

   In Testing, I benchmark AES, and the speed is adequate. I have also tested my implementation against test vectors to ensure it has been implemented correctly.

   c. When the Bluetooth device goes out of range or disconnects (if using Bluetooth), delete all decrypted files and lock the program until the pin code is input correctly again.

   Works fine.

   e. Have a recycling bin so that the user can recover their files.

There is a recycling bin and it works fine, however it cannot restore files back to their original place in the vault. If I were to continue working on this project, I would save a pickled Python object in the recycling bin, that contains a class with attributes listing each file in the recycling bin with where they came from originally.

f. When a file is opened, check for changes once it is closed.

Works well, and BLAKE is of adequate speed, as tested in Testing. I also tested my implementation of BLAKE against official test vectors, so that my implementation is accurate to avoid hash collisions.

g. Files stored in the vault should not be accessible from outside of the app.

Could not open a file in the vault from my normal file manager (it worked).

h. Names of the files stored in the vault should also not be view-able from outside of the app (encrypt the name).

Each file and folder name is encrypted, and encoded to base64. When the files are listed within the app, they are decoded, decrypted and then encoded into string again, and displayed.

i. Allow the files/folders to be decrypted to an external location.

Works fine. Files can be decrypted to a new folder, with their original name, or they can be renamed when decrypting.

4. Overall system should work on Windows, MacOS and Linux.

Works great on Linux, so it should work on MacOS too, however I have no way of checking this as I do not own a computer that runs MacOS. The program works well on Windows as well, however I had issues installing PyBluez for the Bluetooth capability (it was asking for the Windows SDK, and even after I installed it, it still asked for it...). The rest of the program worked fine, as you can see in this video (type the link into the top bar on your web browser): https://youtu.be/2dcJAWGE_IE

Things I would do to improve the project

- Parallelise BLAKE (use multiple CPU cores)
  - Would improve overall speed, which is essential for editing very large files.
  - Would make editing smaller files more seamless too, as the waiting time would be reduced by a small amount, but it will be slightly noticeable.
- Make it so you can right click on files to view more options, those being:
  - Move the file to another location in the vault.
  - Copy the file to another location in the vault.
  - Delete the file (move to recycling).
- Improve the recycling bin so that it recovers files to their original location using a pickled class (serialised object), that contains information about each of the files in the recycling bin.
- Change the Bluetooth protocol I made to use serialised objects, to reduce the likelyhood that a pattern used in the protocol will appear in the file, and to also send more data more reliably, such as file metadata.
- Make it so that when you change vault location, you can enter a key you would like to set, or if there are files that already exist, logout and ask the user to log in again.
- Display the current status of file transfer in the mobile app while downloading.
- Be able to send files from your phone to the PC app to encrypt to the vault.