Using Facial Recognition to Gather Social Media Intelligence

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1 Abstract

Social Media Intelligence is an emergent sector in Open Source Intelligence that examines gathering information via publicly available social network profiles. It is viewed by many to be an extremely important aspect of information gathering - several intelligence agencies including the UK Ministry of Defence and the US Federal Bureau of Investigation have recently invested in tools to gather and analyse Social Media Intelligence (Antonius and Rich, 2013).

A relatively unexplored method of gathering social media intelligence is by using facial recognition. By allowing a search using a person's face, a completely unknown person of interest could be identified and several important pieces of personal information obtained.

Keywords: SOCMINT; Facial Recognition; OSINT; Social Media; Artificial Intelligence

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3 Introduction

3.1 Overview

Social media intelligence (SOCMINT) is an emergent field in intelligence gathering where data is gathered from social media profiles. Massive amounts of data are added to social media services every day (Omand et al., 2012), much of it personal, making social media sites a potentially valuable resource when gathering information about groups or individuals (Ruiz, 2018). Social networks have also been used as a means of communication between persons of interest to the security services, making mining intelligence from their profiles a high priority (Omand et al., 2012)(Kilburn and Krieger, 2014).

Social media intelligence has been shown to have many uses, from detecting potential insider threads (Kandias and Stavrou, 2015) to increasing the effectiveness of prior knowledge attacks. The second point is particularly relevant, as it allows an adversary with no privileged information (OSINT only) to potentially gain access to networks or sensitive information by means of a spearphishing or social engineering attack.

Although the usefulness of social media intelligence has been established, gathering and analysing it may not be as easy as it first appears. The problem for would-be analysts is the sheer amount of data contained within social media platforms for example, 250 million photos are added to Facebook every day (Omand et. al., 2012). To find useful information about a single person of interest in such a large data set is extremely challenging. Success rates increase dramatically if some starting point is known, such as a first name, a date of birth, or a place of work.

There has been little speculation on the use of artificial intelligence when gathering or analysing SOCMINT, particularly in the case of gathering information about a single person of interest. Being able to restrict a search for such a subject by their face has a high potential for intelligence agencies, e.g. when the only information they may have is a mugshot. The following paper investigates the feasibility of implementing such a system.

3.2 Aims and Objectives

The main aim of this project is to implement a system that allows a user to search a social networking service by a test image, through facial recognition. A list of objectives may be found below:

Implement a system that can search social networks using face mappings generated from a test image.

1. Gather requirements for the system

2. Implement basic matching functionality using a facial recognition library
3. Generate a test data set
4. Implement a RESTful server to serve test data
5. Implement basic client functionality to retrieve data from the server
6. Implement face matching functionality using test data retrieved from the server
7. Refactor current system into a thread-based architecture

3.3 Key Findings

3.3.1 RGB vs. Greyscale Images

While comparing images stored as Red-Green-Blue, accuracy rates were consistently over 90

3.3.2 Time Taken

When searching over the entire data set, tests took over 2 hours to complete. The data set is meant to simulate a social networking service, however it is a fraction of the size. The time taken to search the dataset was reduced by several orders of magnitude when the search was restricted by some identifying information, in this case a subject's first name. To obtain results in a reasonable timescale in real-world applications the data set must be restricted in some way, or vastly more processing power must be utilised.

3.3.3 Accuracy

The application managned to achieve a high accuracy rate (over 90%) when searching the test data with full-colour images. While the rates shown may be optimistic for real-world use, they certainly demonstrate the efficacy of facial recognition when searching social networking services.

3.4 Structure

The report includes a literature review which presents an overview of the current state of the art in both social media intelligence and facial recognition, as well as holes in functionality that could potentially be filled by this project. It then moves on to a description of the methodology used when researching, designing and implementing. Following this is a discussion of the ethical implications of the project, then a section

describing the implementation of the design and problems that arose. The testing strategy and results are then described, followed by an evaluation of each part of the project. Finally, a conclusion which summarises the project is provided before a list of references and appendices.

4 Literature Review

4.1 Background

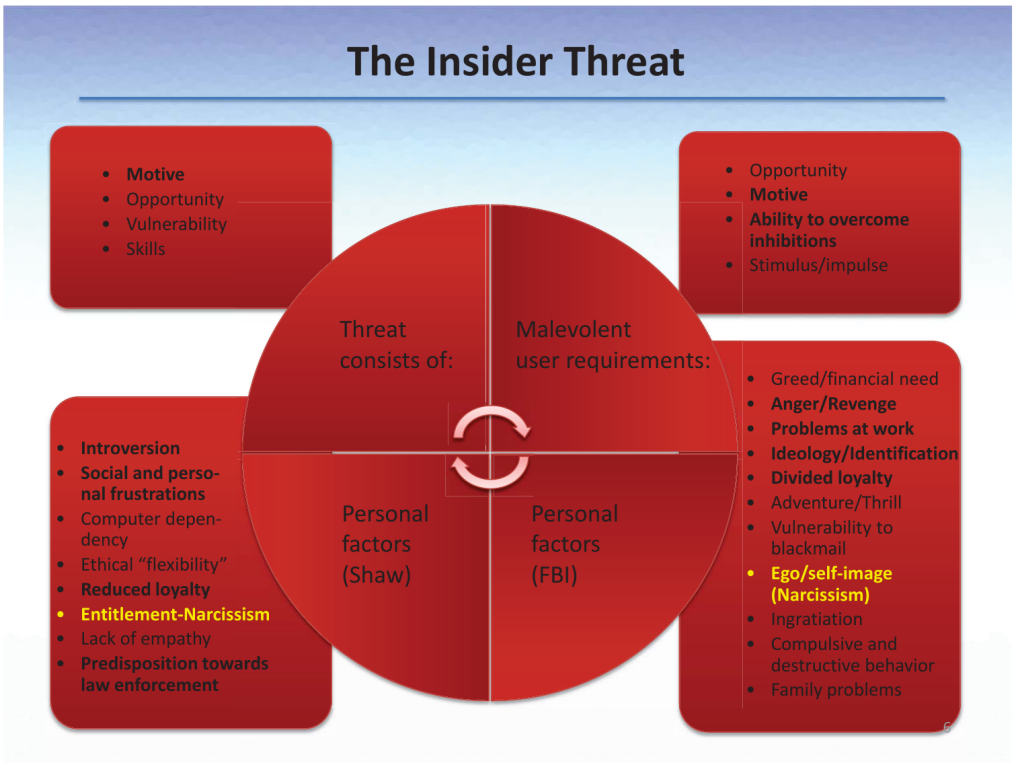
4.1.1 SOCMINT

After the 2011 riots in London which were organised in large part on social media, Her Majesty's Inspectorate of Constabulary stated that the police services were "insufficiently equipped" to effectively use SOCMINT in their response (Antonius and Rich, 2013), which suggests that social media intelligence sources may be woefully underutilised (Omand et al., 2012). This is not to say that the value of SOCMINT is not realised however, as many intelligence agencies are investing in tools to effectively gather and analyse SOCMINT (Antonius and Rich, 2013) or are performing case studies into potential uses (Klontz and Jain, 2013).

While traditional human intelligence (HUMINT) focuses on building rapport and a foundation of trust in order to extract information from people of interest (Russano et al., 2014), users of social networking websites are much more likely to divulge personal information due to a misplaced senes of privacy (Livingstone, 2008). This makes SOCMINT attractive when attempting to gather data with little investment. The amount of data available to gather is vast in comparison to HUMINT sources (Omand et al., 2012), making mass collection and analysis viable (*PRISM Slides*, 2013). The nature of SOCMINT makes it easier to analyse than HUMINT, which relies on "tells" and small social cues (Russano et al., 2014).

4.1.2 Uses of SOCMINT

As previously stated SOCMINT has seen some emergent use, particularly in the security services. The Greek Ministry of Defence has developed a framework to identify individuals fitting certain psychiatric profiles from their social media accounts to allow for early identification of potential insider threats (Kandias and Stavrou, 2015). By identifying factors which multiple intelligence agencies agree make a person more likely to pose an insider threat or negatively influence society (See appendix A), they were able to map usage habits (intensity, content, popularity) to these factors to draw conclusions about clusters of users. So far, the research has been helpful in insider threat prevention, delinquent behaviour prediction and forensic analysis support.



Graph of insider threat factors (Kandias and Stavrou, 2015).

4.1.3 Facial Recognition

Facial recognition is a much more mature area of research than SOCMINT with many examples of industry usage. Facebook uses facial recognition to automate "tagging" photos with the identity of the persons pictured (Becker and Ortiz, 2008), and large companies are now releasing datasets such as YouTube Faces (Cui et al., 2013) in an effort to advance the field.

This is not to say that facial recognition is not without controversy however, as many privacy advocates have pointed out that accurate face recognition could infringe on individuals' right to privacy (Ruiz, 2018). David Wood and Lucas Introne have posed that accurate facial recognition could lead to increased levels of surveillance, with no way to "opt out" (Introna and Wood, 2002)(Bowyer, 2004).

4.1.4 Uses of Facial Recognition

Facial recognition has many practical applications that are already being realised. As noted previously, Facebook uses facial recognition when "tagging" photos. This is

presumably done to allow advertisers to more effectively target individual users - for example, a person identified in a photo with a barbeque may receive adverts for propane gas.

Facial recognition is also enjoying a heavy amount of attention from the security services due to it's use in identifying persons of interest. Case studies have been performed using images released to the public to ascertain how effective facial recognition is when looking for a specific person. In particular, Joshua Klontz and Anil Jain performed a case study using the images of the "Boston Bombers" against a set of test data (Klontz and Jain, 2013). Their approach was successful in recognising one of the perpetrators from a picture taken from his social media account (See appendix B).

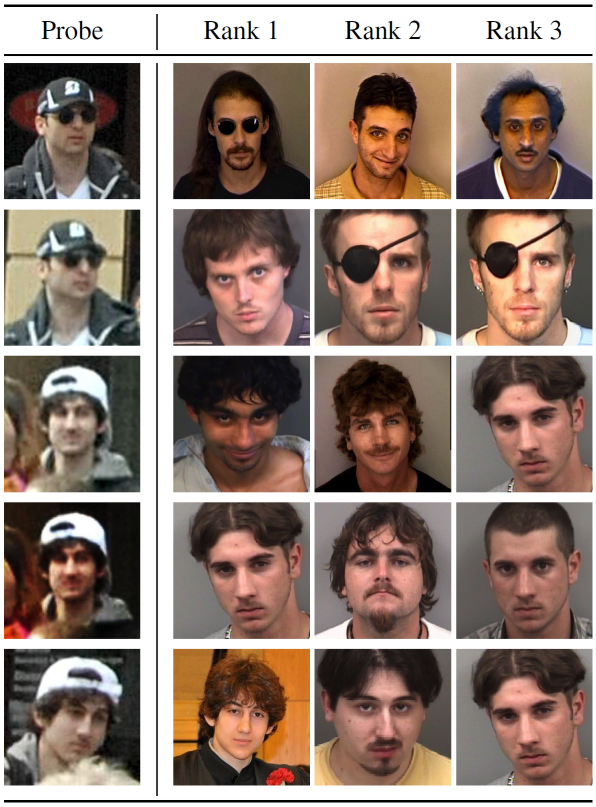


Table of potential matches, note the correct identification from the picture taken from social media with similar pose and lighting (Klontz and Jain, 2013).

4.1.5 Constrained vs Unconstrained

While facial recognition software has come a long way, achieving accuracy rates of up to 99% on small, consistent data sets (Best-Rowden et al., 2014), it is still in it's infancy when it comes to identifying people in "unconstrained" images. Images taken in the wild may have large variations in pose, facial occlusion and ambient lighting. This makes

it difficult to identify facial features or markers (such as iris distance, nasal distance, blemishes) which in turn has a negative impact on accuracy rates (Klare et al., 2015). When looking at applications of face recognition software with unconstrained datasets, matches are typically achieved when the test image has similar pose, facial occlusion and lighting as the sample image (See appendix B).

4.2 Prior Knowledge Attacks

4.2.1 Social Engineering

Social engineering in the context of information security refers to the ability of a person to gain access to information or control systems through a user or administrator, rather than through any technical oversight (Bakhshi, 2008). It is a popular technique against "hardened" targets as technical prevention measures have proven to be ineffective (Krombholz et al., 2015) making the human users and administrators the weakest link in the proverbial chain. In addition, it is difficult to train users in defenses against social engineering attacks. People believe they would not fall for such a trick despite research showing that humans perform poorly when attempting to detect deception (Krombholz et al., 2015)(Bakhshi, 2008).

Social engineering using e-mail as a medium is ubiquitous (Bakhshi, 2008). As a generel strategy, the person wishing to gather information will send one or more people an e-mail in hopes of a response (whether that be in the form of visiting a website, replying with their username or password, opening a file etc). Recent studies in realistic environments have had success rates of up to 23% (Bakhshi, 2008). This is especially worrying given that even one respondant could compromise an entire company.

Examples of social engineering are not hard to find. In his book *The Art of Deception* Kevin Mitnick describes a young Stanley Rifkin using social engineering to make the biggest bank heist of all time, stealing over 10,000,000 USD (Mitnick and Simon, 2011). Social engineering attacks are certainly not difficult to perform - recently, a 13 year old child used social engineering to breach the private e-mail of the then-chief of the CIA, John Brennen (Timm, 2015)

4.2.2 Spearphishing

Spearphish attacks are a subsection of social engineering attacks wherein an attacker sends a malicous e-mail to a user that has been crafted using information that would make it seem authentic (Caputo et al., 2014). For example, a normal social engineering attack using e-mail might send boilerplate messages to all personnel in a department to attempt to gain access to a network account. By contrast, a spearphish attack may use the names of specific people in the department, the location of the department, a spoofed

e-mail header to make it seem as if the message came from within the department, and so on.

Social engineering attacks have proven to be effective at accessing sensitive information even when significant effort has been expended to secure it. A recent spearphishing campaign was conducted against 500 US military cadets - over 80% clicked the link in the e-mail (Caputo et al., 2014). Spearphish attacks are even more effective than "blind" phishing because of the additional information included in the e-mail which lulls the user into a false sense of security (particularly when the information could be wrongfully considered "sensitive", for example including a manager's name and phone number).

Spearphish attacks in particular are difficult to mitigate against. They target the human element in information security making technological defenses insufficient (Caputo et al., 2014). Education on spearphishing is not adequate to mitigate the potential threat either, as shown by William Pelgrin's exercise. He sent 10,000 New York State employees a phishing e-mail, and had a success rate of 15% (that is, 15% of users clicked the link in the e-mail then attempted to enter their passwords). The experiment was repeated after four months, with some success shown as the experiment had a success rate of 8% (Parmar, 2012). It must be remembered however that even a single successful spearphish attack could lead to a breach of information security.

4.3 Intelligence Gathering

4.3.1 SOCMINT

Social media intelligence (SOCMINT) refers to information gathered from social media profiles hosted on social networks. It is an emergent field in open-source intelligence (OSINT), which relies on gathering information users divulge about themselves in the public domain. It is characterised by the massive amount of data available (Omand et al., 2012) and the difficulty of analysis (Bartlett and Reynolds, 2015). An overview of subjects relating to social media intelligence gathering follows below.

4.3.2 HUMINT

Human intelligence (HUMINT) pertains to the gathering of intelligence from individual human subjects. Information may be divulged non-consensually e.g. in the case of interrogation (Evans et al., 2010), or consensually in the case of clandestine information gathering (Musco, 2017).

Non-consensual information gathering via interview or interrogation has only recently become a subject of study for the general public (Russano et al., 2014).

Consensual information gathering sits in a much more grey area. Presenting yourself as somebody else may not be illegal depending on the circumstances, however it poses several moral questions. Clandestine intelligence gathering is still an extremely effective strategy, particularly when attempting to gather sensitive information which may be more heavily protected - for example, networks which have been airgapped or firewalled (Musco, 2017). This makes it attractive during wartime or times of civil unrest (Charters, 2018)(Gioe, 2017).

Using a human intelligence approach when gathering information has several downsides. It is a high risk strategy, as should a person be found out the consequences can be severe (Charters, 2018). The potential reward of sensitive information may be deemed to not be worth the risk. It goes without saying that HUMINT does not scale particularly well - it is a useful tool when attempting to extract information from a single person or small group, but it is much less useful when gathering information about larger groups. It relies on trust being built and may be ineffective when attempting to gather information from targets trained in tradecraft (Charters, 2018)(Musco, 2017)(Gioe, 2017).

4.3.3 Individual vs Group Data

Much of the research done on social media intelligence has focused on group trends or finding subsets of a population (Antonius and Rich, 2013)(Omand et al., 2012). Comparatively, fairly little research has been done on identifying a single person of interest from a social network service.

A practical example of where SOCMINT has been used in the real world is the framework created by Kandias and Stavrou, in which features of a social media profile such as number of friends, "friend hops" standard deviation, psychiatric profiling and usage intensity are used to predict groups of interest that may become radicalised (Kandias and Stavrou, 2015). While this is certainly very useful, it focuses more on identifying groups by some common factor rather than identifying a single person of interest for further analysis.

4.3.4 Quantity of Information

Having limited information is not a problem when gathering social media intelligence. Rather, the opposite is true - 250,000,000 photos are added to Facebook every day (Omand et al., 2012). The vast amount of data is what makes searching for social media so difficult (and nigh on impossible in real time).

While the total amount of data added to social networking websites is extremely large, the information about a single user may be fairly small, especially if the user has been trained to release as little information as possible (Kandias and Stavrou, 2015). This may make targeting single persons of interest less valuable, however should information

"leakage" occur the potential payoff is high. It should be remembered that scanning social media profiles incurs little or no risk, something that cannot be said of human intelligence.

4.3.5 Accessibility of Data

As discussed previously the amount of data pushed to social networking websites is massive. This does not mean that all social networking data is readily accessible. Users may set privacy settings to disallow unauthorised parties from viewing their profile, or particular parts of it. This can be mitigated by having the service allow access, however acquiring access as a party of one may prove difficult.

Several social networking services also impose rate limits on their interfaces (for example, Facebook imposes a limit of 100 API calls per user of an application as well as limits on CPU time used). These limits obviously make searching through the entire data set of profiles unfeasible without allowances being made on the side of the social network.

4.3.6 Uses

Usage of social media intelligence has been limited in large part due to the difficulty in analysing such large amounts of data for small snippets of useful information (Omand et al., 2012). There are, however, some interesting case studies available.

In April 2013, Edward Snowden leaked a deck of slides used by the National Security Agency (NSA) to brief people on the "PRISM" program (*PRISM Slides*, 2013). These slides detailed how the NSA uses mass surveillance with cooperation from companies including Google, Facebook, and Apple, to conduct covert surveillance of persons of interest. As a government agency enabled by the oversight committee the NSA has the power to require large social networking services, including the ones listed, to allow them access to their data.

As mentioned previously, Kandias and Stavrou have developed a framework for using social media intelligence for predicting and mitigating insider threats while working at the Information Security and Critical Infrastructure Protection Lab at the University of Athens (Kandias and Stavrou, 2015). The framework focuses on analysing the psychology of the subjects using their social media posting habits. It shows that seemingly inconsequential data such as posting frequency may still be useful when analysing social media intelligence. An example graph to find the amount of "klout" a social media user may have in the Nereus framework is referenced in Appendix C.

Category	Influence valuation	Klout score	Usage valuation
Loners	0 - 90	3.55 - 11.07	0 - 500
Individuals	90 - 283	11.07 - 26.0	500 - 4.500
Known users	283 - 1.011	26.0 - 50.0	4.500 - 21.000
Mass Media & Personas	1.011 - 3.604	50.0- 81.99	21.000 - 56.9000

Graph of social media connections and klout score in the Nereus framework(Kandias and Stavrou, 2015).

4.3.7 Challenges and Constraints

There are several challenges to consider when collecting and analysing data for social networking services. First is the issue of privacy. Many people see social media profiles in a similar setting as a meeting between friends, and as such post things which they perhaps would not say or show in public (Livingstone, 2008). The chilling effect of public scrutiny, or even direct surveillance, does not seem to put a damper on this.

There are some who feel that police surveillance of social networks is too pervasive (Mateescu et al., 2015), and encroaches on their right to privacy. Despite the effectiveness of social media intelligence gathering, it may be harmful to law enforcement's public image if it continues to utilise SOCMINT.

As far as the law is concerned, information posted on social networking sites is considered to be in the public domain. This makes it legal for law enforcement to gather social media intelligence, provided they do it the same way an unprivileged user would. Several social networks have clauses against mass data collection in their Terms of Service, however it is theorised that this is to prevent competition from other companies when selling said information to advertisers.

4.4 Facial Recognition

4.4.1 Current Applications

Police and military uptake of face recognition technology is widespread. For instance, police in the United Kingdom recently used cameras to scan people's faces at the "Download" music festival (Gallagher, 2005). These images were then compared with a database of custody images across Europe, to identify known criminals for the purposes of crime prevention and outstanding warrant execution.

Facebook also uses face recognition on photos uploaded to its service (Facebook, 2018*c*). By comparing face mappings to the known face mappings of yourself and immediate

friends, it can suggest "tags" of who is in the image which presumably makes the information contained within the image more valuable to advertisers.

4.4.2 Unconstrained Facial Recognition

Unconstrained facial recognition is a subset of facial recognition which focuses on identifying faces in images with variations in pose, lighting, and facial occlusion. It is significantly more difficult than facial recognition which imposes constraints on these conditions.

Unconstrained facial recognition is typically used in situations where a subject is unaware or unwilling. As already mentioned, it was used in a case study by Klontz and Jain where they compared the images released by the FBI of Tamerlan and Dzhokhar Tsarnaev (the "Boston Bombers"). They found that by comparing the released images taken from security cameras to images on social media in an unconstrained setting, they could positively identify one of the brothers (Klontz and Jain, 2013) (see Appendix B).

4.5 Existing Solutions

4.5.1 pipl

`pipl.com` is a popular web service that allows users to search a database of people by name, e-mail, social media username, phone number, or location. It is aimed at de-anonymising people who use pseudonyms or who do not publicly associate identifying information with their e-mail or social media username by cross-referencing information from several sources. For example, a person may associate their e-mail but not their phone number with a username on a social media service, and then associate the same username with their phone number but not their e-mail address on a different social media service. With this method pipl can effectively collate identifying data about a large sample of people and make it searchable, which is evidently useful for many business applications (particularly within advertising, as it allows for targeted adverts to be sent to the same person over several social media networks). It's list of clients include large companies within the social media and personal data sectors such as Twitter, equifax and Experian (pipl, 2018).

4.5.2 192

`192.com` is a similar service to pipl, however it allows for a more advaced search with more terms to restrict or search on. As well as using social media profiles it uses publicly available information (OSINT) such as the electoral register to enhance its data set. It

claims to have 750 million records, far less than pipl's over 3 billion (although the records kept by 192 are much more detailed). The main feature of 192 is that it allows users to search for details about entities other than people, such as schools or businesses.

4.5.3 Facebook

Facebook itself offers fairly primitive search functionality, allowing users to search for posts, people, photos, videos, pages, places, groups, and events. While this may seem to be fairly extensive, it should be noted that the intended use of the search function is to allow users to make more connections. The searches which users can perform will therefore be tightly restricted - for example, when searching for people the search may only show those people who are indirectly connected through other friends, known connections, or people in close proximity (Facebook, 2018*b*). The Graph API that Facebook exposes allows users to search outside of these restrictions, however as discussed previously it is difficult for a party of one to use the Graph API for large-scale searches due to rate limits and Facebook's privacy settings (Facebook, 2018*a*).

Even with these limitations, Facebook is still a very useful service for enumerating identifiable information about a person of interest provided the user has some basic information such as the person of interest's full name.

4.5.4 Gaps in Functionality

The services listed above are extremely useful when attempting to gather more information about a person of interest. Given some basic identifying information such as username, given name, e-mail address etc., they can be used to effectively build a profile of a searchable person. Where they fall short however is when a person of interest needs to be identified from a collection - the amount of data returned when searching for location or place of residence alone is far too large to sift through. Even Facebook's search falls short when trying to identify a single person from a potentially large collection, as the lack of customisable search restrictions means that the result of a search is unlikely to be able to be processed in a reasonable amount of time.

With the exception of Facebook, the services listed aggregate social media profiles in order to hold as much meaningful information about individuals as is feasible. This necessitates that some information must be omitted when collating from several social media networks. One of the pitfalls of these services is that several of the omitted items can be very useful when restricting searches - for example, a profile picture may prove useful for identification if a user has a reference image of a person of interest.

A potentially large gap in functionality is that lack of "soft" comparisons. The services above perform well when doing direct comparisons, such as having a specific name or a name matching a regular expression. They do not offer search functionality allowing

for some margin of error such as a name matching a regular expression or having a Hebbian distance of 1, or having a face harvested from a profile picture be similar to a test image.

4.6 Objectives

As mentioned in the introduction, the objective of this project is to create a system which allows users to search social network profiles using facial recognition. Should it be successful, it fills the gaps in functionality raised in the previous section. The search can be restricted by personally identifiable information, and since the project is open-source an end user may add search vectors directly. It collects the entire profile (or at least, everything that is exposed publicly). It allows for the seaching of regular expressions, as well as thresholding face comparisons to adjust levels of sensitivity.

5 Methodology

5.1 Overview

The software implemented will be in the form of a Python command line program, which allows users to specify an input image and data set to check it against. Additional identifying information such as name, date of birth etc. should also be utilised if given. The data sets the software references must come from social networking websites (or in the case of this proof of concept, a data set which is an accurate representation).

As its output, the software must show the five most similar faces in the data set to allow for human verification. They should be presented with information that was gained from their social media profiles such as age, gender, name etc., as well as the similarity to the test image. In the case that the software is being ran headlessly, the results should be available in a file format which includes an image of the match and a representation of their social media profile.

5.2 Functional Requirements

5.2.1 Face Recognition

The software must implement a method of facial recognition, to rank a set of faces by similarity to a given test image. The test face must be extracted from the input image. The top 5 matches should be outputted, along with relevant identifying information.

5.2.2 Social Media Integration

The software must have the ability to use social networking websites as it's data set when comparing a test face. It would be desirable for the software to have the capability to use other identifying information alongside the test image to narrow the search space. Due to limited time and resources, test accounts may be used as a proof of concept.

5.3 Non-functional Requirements

5.3.1 Accuracy

The software should have a *relatively* high success rate when identifying a person from a social media collection. Note that typical facial reocgnition performance in unconstrained environments achieve a maximum success rate of 30%.

5.3.2 Usefulness

The information gained by using the software should help when crafting prior-knowledge attacks, increasing their effectiveness.

5.3.3 Cross-Platform

The software must be cross-platform to allow for easy deployment to servers or a cloud.

5.3.4 Imprecision Tolerance

The software should attempt a best guess when using an input image with less than ideal pose, facial occlusion or lighting. Inferior results when given a test image like this are acceptable to a degree.

5.3.5 Usability

The software is being developed for use by information security professionals in the form of a command line tool. This is ubiquitous in the industry, so no more than a cursory glance over the usage information should be needed to begin using the tool.

5.3.6 Facial Recognition Libraries

Due to time constrants, reimplementing facial recognition capabilities is not feasible. Therefore, the software should make use of already existing facial recognition libraries, in particular dlib or OpenCV.

5.3.7 Language

The software should be written in Python to allow for easy use of face recognition programs and rapid prototyping.

5.3.8 Time Spent

The software must be able to complete the above task in the same time or less than a human.

5.3.9 Documentation

The software should have at a minimum a man page and usage information. More documentation would be beneficial.

5.3.10 Testing

The software will be tested using a comination of publicly available face recognition datasets including Labeled Faces in the Wild, the Essex Facial Recognition database and the SCFace database.

5.3.11 Headless

The software should be able to function without a GUI, since the requirement of being able to use extremely large data sets may require deployment to a large server cluster or to a cloud.

5.3.12 Multithreaded

Where applicable, the software should make full use of parallelisation to increase its speed and resource utilisation. This is particularly important when working with large data sets.

5.4 Development Methodology

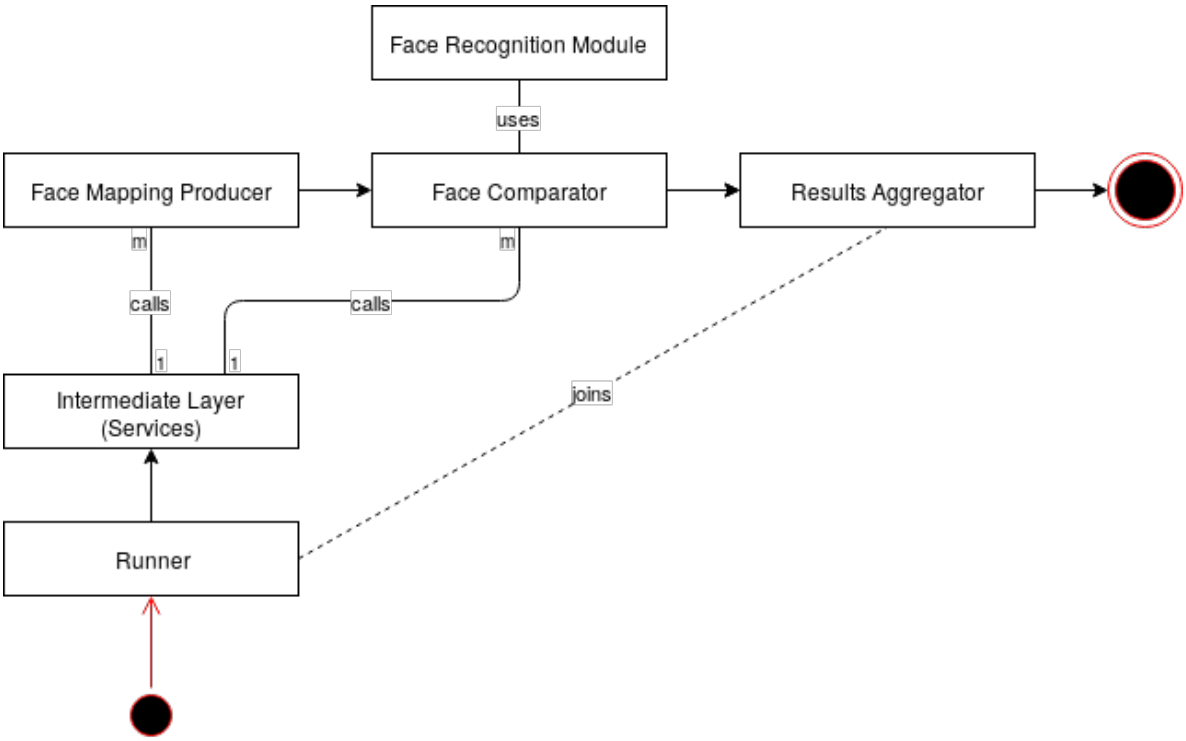
The project will be developed using an agile methodology. The requirements are to be gathered and analysed to create a formal requirements specification. An initial design will then be created from the requirements, and refined as more features are added. After each objective is reached, the design will be reviewed and current functionality tested to ensure no regressions or new bugs enter the code base. This will continue until the first version of the project was complete.

Testing will then be done iteratively to ensure the correctness of the program. Starting with basic functionality (comparing one image against one data set), each requirement will be tested independant of each other. This further ties in to the desire for a modular code base, as each test can be ran against a single part of the program without touching the rest of the code (and that module can then be used with some degree of confidence that it is bug free).

This methodology should continue into the testing used for data gathering. Debug messages will be left in for "dry runs" of the tests to ensure the program was working

as intended, and results will be checked for correctness. Any problems can then be corrected, and the test re-ran. After several of these iterations to remove an error that could be introduced by the program to the results, the test will be ran a final time and the results captured.

5.5 Final Design



6 Impact

6.1 Social

Social media intelligence has recently received a large amount of exposure. In particular, the revelation of consultancy Cambridge Analytica using data obtained through Facebook to influence U.S. elections has focused public attention sharply on what data facebook collects and subsequently shares with advertisers or data analytics firms. As a byproduct, users are becoming acutely more aware of what data they provide Facebook.

The introduction of the General Data Protection Regulation by the EU, a regulation intended to protect the human right to privacy, has also brought SOCMINT to the public attention. Many websites did not comply with the directive when it was introduced but none moreso than social networking websites. Every major social networking service including Facebook, Twitter, Instagram etc. have been forced to refactor their websites to allow users to opt-out of some data gathering practices lest they attract the ire of the European Court.

This project would have the potential for a large social impact if not for a few limiting factors. Should it grant individuals the ability to gather SOCMINT on arbitrary persons of interest, it would allow users to view what information could be gathered about themselves using SOCMINT through facial recognition. It could also having a chilling effect on persons using social media as many would be reticent in broadcasting their thoughts if they knew they could be viewed by anyone with an image of their face. These scenarii are unlikely however, as the resources required to run such searches would be incredibly difficult for a single person to obtain. As well as the significant time and cost required for a search, an individual would have to access the entire data set held by a social media service - no easy task.

6.2 Legal

There are two laws in the UK which may apply to this project; the Computer Misuse Act (1990) and the Data Protection Act (1998). An analysis of how the project may interact with these laws may be found below.

6.2.1 Computer Misuse Act

The Computer Misuse Act prohibits unauthorised access to a computer system (*Computer Misuse Act*, 1990). Some may argue that the program developed as part of this project could breach the computer misuse act as it accesses private data without the authorisation or consent of the subject, however this is simply not the case. The data

analysed by the program has been released to the public by the social media service with the user's consent, and access has been implicitly authorised by the social networking service. In the case of information shared by the social networking service in a privileged context (e.g. advertisers paying for more information) authorisation is granted explicitly, and again the end user has agreed that data gathered about them may be used in such a manner.

6.2.2 Data Protection Act

The Data Protection Act offers several safeguards to consumers to ensure their private data is being used in a responsible way in accordance with their wishes. In particular, it allows users to request a copy of all information a service has stored about them, and request that any incorrect data be corrected (and offers redress in the case that it is not). As well as requiring a data controller to provide these services, the act also mandates that the data stored must not be used in a way which may cause damage or distress, and that the data stored must not be used for direct marketing (*Data Protection Act*, 1998).

There are more detailed principles detailed in the act which have been excluded here for brevity. The main condition of this act that applies to this project is that the data subject has consented to the processing of their data. Again, arguments that this project violates the conditions of this act are unconvincing. All potential data subjects whose data may be analysed must necessarily have agreed to have their information either published in the public domain, or used by a third party.

6.2.3 Terms and Coniditions

In the course of this project no production social networking website was searched. Leaving aside the ethical implications this could have (described in the next section), the use of this application is against many social networking websites terms and conditions. For example, Facebook's terms and conditions states that "You will not collect users' content or information, or otherwise access Facebook, using automated means (such as harvesting bots, robots, spiders or scrapers) without our prior permission" (*Facebook Terms and Conditions*, n.d.). In a real-world application, express permission of the social networking service would need to be obtained before any search was attempted.

6.3 Ethical

There are several ethical issues associated with this project, some of which have been outlined below:

1. Users may not realise information they send to social networking websites may be made public.
2. Users may not realise how much information is exposed about themselves on social networking services, leading to them making sensitive information public.
3. Users may not realise the scale on which exposed information can be gathered and analysed.
4. Users may not realise how much information can be gainend from analysing data they have made available.
5. Users may not realise they are identifiable from specific pieces of information.

Mitigations to these issues exist, however some may not be fully mitigated. The ethical issues are one of the driving reasons behind generating a test data set from publicly available sources that are already in use in the field of computer vision - it allows the efficacy and correctness of the implementation to be tested without the potential for infringing on other persons privacy or the terms and conditions of a social networking service.

There is no way to fully protect against unethical use of the implementation in a real-life scenario. The issues listed above depend on the user being aware of the data they expose about themselves and the impact it may have, which is not possible for the entire population of a social networking service. It is therefore suggested that the use of this tool be restricted to organisations with heavy oversight, such as academic institutions or intelligence agencies.

7 Implementation

7.1 Face Recognition

The application has been developed using the face recognition module created by A. Geitgey:

`https://github.com/ageitgey/face\_recognition/`.

It is an easy to use facial recognition library build on top of dlib. It exposes a python API, making it ideal for this project. It also boasts an accuracy rate of up to 99.38% on the LFW data set.

Alternate libraries (such as dlib) that were investigated were found to either have a much higher barrier to entry, or a much lower accuracy.

7.2 Test Server

7.2.1 nginx

To test the application, nginx is used to serve static content as well as as a reverse proxy. Nginx was chosen over Apache or another native Python webserver due to its capability at handling massive concurrent requests, its flexibility, and its speed at server static content. Since the application makes several connections simultaneusly and requests large amounts of images, nginx was ideal.

7.2.2 cherrypy

To serve a dynamic description of where profiles and their respective images are located, a cherrypy server was implemented which expands a glob from the test directory (which contains the test data sets) then returns a json representation of them. As noted earlier, nginx acts as a reverse proxy to this service

7.3 Portable Module

The application has been developed in a modular fashion. To this end, a run file has been provided alongside a python module. The python module includes the logic for retrieving profiles from a web service and setting up multiple threads to compare face mappings, whereas the run file comes with some pre-processing and default arguments. Ideally, the module should be re-usable for other web services.

7.4 Threading

The application has been developed to make use of multiple threads. The main thread in *facegather.py* controls these threads and their results using locks, thread-safe queues, semaphores, and the thread.join() method.

The producer / consumer consumer model was useful when developing the application. In this context, the producers retrieve profiles from the social networking service and the consumers compare the retrieved profiles to the test data given and store the result.

7.5 Command Line Interactivity

Rather than use a graphical user interface (GUI), the application makes use of command line arguments (see Appendix D). There are several reasons for this; it cuts down on needless computational cost by eliminating the overhead of a GUI, it allows the OS the application is running on to be "headless" (i.e. run with only a command line or remote connection for user interactivity) again cutting down on overhead, and it allows for easier integration in to scripts (for example, appending logs to a log file using the POSIX >> operator).

```
jack@seven:~/Documents/hons_project$ python3 run.py -h
usage: run.py [-h] [--pthreads PTHREADS] [--cthreads CTHREADS]
              [--maxload MAXLOAD] [--name NAME]
              [--output_location OUTPUT_LOCATION]
              test_face service

A python3 program to gather social media intelligence using facial recognition

positional arguments:
  test_face             Location of the test face
  service               Social network service to search

optional arguments:
  -h, --help            show this help message and exit
  --pthreads PTHREADS   Number of image processing threads
  --cthreads CTHREADS   Number of image comparison threads
  --maxload MAXLOAD     Maximum number of images pre-loaded into memory
  --name NAME           Name of person of interest
  --output_location OUTPUT_LOCATION
                        Location of results file
```

A help page showing the command line arguments that can be supplied.

One potential issue when using an application without a GUI is presenting the results. The application persists its results in a JSON format for use by other applications or for direct consumption by the end user.

7.6 Social Network Interactivity

Since this project has been done on a fairly small scale in a short time frame, it was not possible to gain access to a large social media platform to perform testing (ignoring the obvious ethical issues with such an approach). Instead, the test environment has been set up in such a way as to mirror the way in which a social media API may be presented - with an array of profiles, each one having a link to some related resources.

7.7 Challenges

7.7.1 Loading Images from Memory

Since the application retrieves images remotely over the internet, it makes sense to manipulate the images directly from memory. This avoids filesystem reads and writes, which are several magnitudes slower than memory reads and writes. The time save is massive, especially when repeated over thousands of images.

Unfortunately the face recognition library does not support loading images from memory, instead providing a method (load_image_file(uri)) to load images from the local file system. Upon inspection this method loads an image file from disk in to a Python Imaging Library (PIL) Image object, then casts it to a numpy array to allow for encoding operations. To mirror this method for use with images loaded to memory, the application uses the PIL Image.open() method on the raw response stream from the social network web server to create an Image object, then casts it to a numpy array. This achieves the same result as loading the image from the local file system significantly more efficiently.

```
# Load an image in to memory from local or remote sources
def load_images(uri, remote=True):
    if remote:
        print('Retrieving image from ' + uri)
        resp = requests.get(uri, stream=True)
        resp.raw.decode_content = True
        img = Image.open(resp.raw)
        return fr.face_encodings(numpy.array(img))
    else:
        print('Retrieving image from ' + uri)
        img_array = fr.load_image_file(uri)
    return fr.face_encodings(img_array)
```

Above: A function with an optional keyword parameter to load an image from either a local or remote source.

7.7.2 Maximum Loaded Images

A potential problem when using the producer / consumer model is that producers may produce too much data, filling all available memory and leading to a crash. To solve this a maximum loaded images parameter can be supplied when running the application, which will cap the number of face encodings loaded into memory at that number. This has been implemented using a semaphore initialised with the maximum number of face encodings to be loaded. Each producer thread calls acquire() before loading a set of encodings in to memory, and each consumer thread calls release() when the encoding has been compared and the memory can be freed.

```
# Producer thread
     self.waiting_counter.acquire()
          if profile_queue.empty():
              return
          profile = profile_queue.get()

# Consumer thread
          img = img_queue.get()
          ---
          Comparison happens here
          ---
        self.counter.release()
```

Above: The producer thread calls acquire() on the semaphore before loading mappings in to memory, and the consumer thread calls release() on the semaphore after the memory used for mappings has been freed.

7.7.3 Multiple Threads for Producing and Consuming

As it stands, the application has been developed with mulitple threads in mind. The user can define how many threads should be used for downloading images and producing face mappings via the –cthreads argument, and how many threads should be used to compare face mappings via the –pthreads argument. This allows for much higher processor utilisation than a single threaded application, as all CPU cores can be utilised.

While the application processes images orders of magnitude faster than it would had it been single-threaded, it may still be too inefficient for use on particularly large data sets. It is also difficult to scale due to its singleton nature. In the future it may be worth refactoring to make use of a discrete GPU, or to make use of specialised libraries for big data processing such as MapReduce.

7.7.4 Thread Object Access Control

To control object access between threads two Queue objects are used. One contains a JSON representation of all of the profiles in the search spaces and is only accessed by the producer threads, and the other is used by producer threads to send face mappings of profiles to consumer threads. These objects are guaranteed to be threadsafe, meaning that both the put() and get() operations are atomic. To control access to the result object that multiple consumer threads may try to access, a Lock() is passed in the consumer constructor. Before a consumer accesses the result object it must first call lock.acquire() which will block if another thread has acquired the lock first. After a consumer has finished writing to the result object it releases the lock by calling lock.release(), allowing other consumer threads access.

```
            self.result_lock.acquire()
                self.result.add([distance, img[1]])
                self.result_lock.release()
```

Above: The result object is not thread-safe, so must have a lock around it.

7.7.5 Result Retrieval

Having a "top 5" result as was initially planned would require many comparison and list traversal operations. It would also make having multiple consumers pointless, as only one thread would be able to do comparisons at a time. Rather than having the top 5 matches, the result returned is now all faces that match the test face within a given threshold (by default, face distance < 0.6).

7.7.6 Command Line Arguments

The application can take many command line arguments to customise its use. Having the user fill out and remember every one of these arguments would make the application unintuituve and difficult to use. Therefore, the decision was made to make heavy use of optional keyword arguments both when running the program (e.g. –cthreads=1) and in functions within the application. This allows the user to specify some, all, or none of the optional parameters and still have the application function correctly.

```
def search(test_face_location,
           uri,
           no_producer_threads=None,
           no_consumer_threads=None,
           max_loaded=None,
           threshold=None,
```

```
        name=None):
```

Above: The search function uses several keyword arguments with default arguments, then checks and loads with defaults if not supplied before continuing.

7.7.7 Inter-Thread Communication

The only inter-thread communication required by the application is for the consumer threads to be signalled when there are no more face mappings to compare. To this end, the main thread which spawns both the producer and consumer threads blocks by calling producer.join() on all producer threads. One all producer threads have returned, the main thread pushes a sentinel object on to the end of the face mapping queue. It then blocks by calling consumer.join() on all consumer threads. Once a consumer thread pops the sentinel object, it adds another sentinel to the end of the queue (for further consumer threads to consume) then returns. This guarantees that there is no unconsumed data, and that the consumer threads do not terminate prematurely.

```
# Main thread
for processor in processor_list:
    processor.join()
img_queue.put(sentinels.NOTHING)

for recogniser in recogniser_list:
    recogniser.join()

# Consumer thread
if img == sentinels.NOTHING:
    img_queue.put(sentinels.NOTHING)
    return
```

Above: The main thread blocks until all producer threads are finished, then pushes a sentinel object to the end of the queue, then blocks until all consumer threads are finished.

7.7.8 Loading Greyscale Images

The import function for loading images from memory described above failed when applied to greyscale images that had been converted from the JPG to the PNG format. All JPG images had been stored as RGB images even when they contained no colour, so when they were converted the compression algorithm saved space by converting them to single-channel images. To get around this problem, a special case was added to

convert images in this format to RGB before attempting to generate facial mappings from them.

```
        except:
            # Catch line in case PNG file is encoded as greyscale
            return fr.face_encodings(numpy.array(img.convert('RGB')))
```

7.8 Implementation Methodology

The agile methodology described in the methodology section was continued during implementation. The iterative refinement typical of agile development was applied first to requirements capturing - using gaps in knowledge identified from background research a general set of features could be created and expanded upon, gaining more granularity with each iteration.

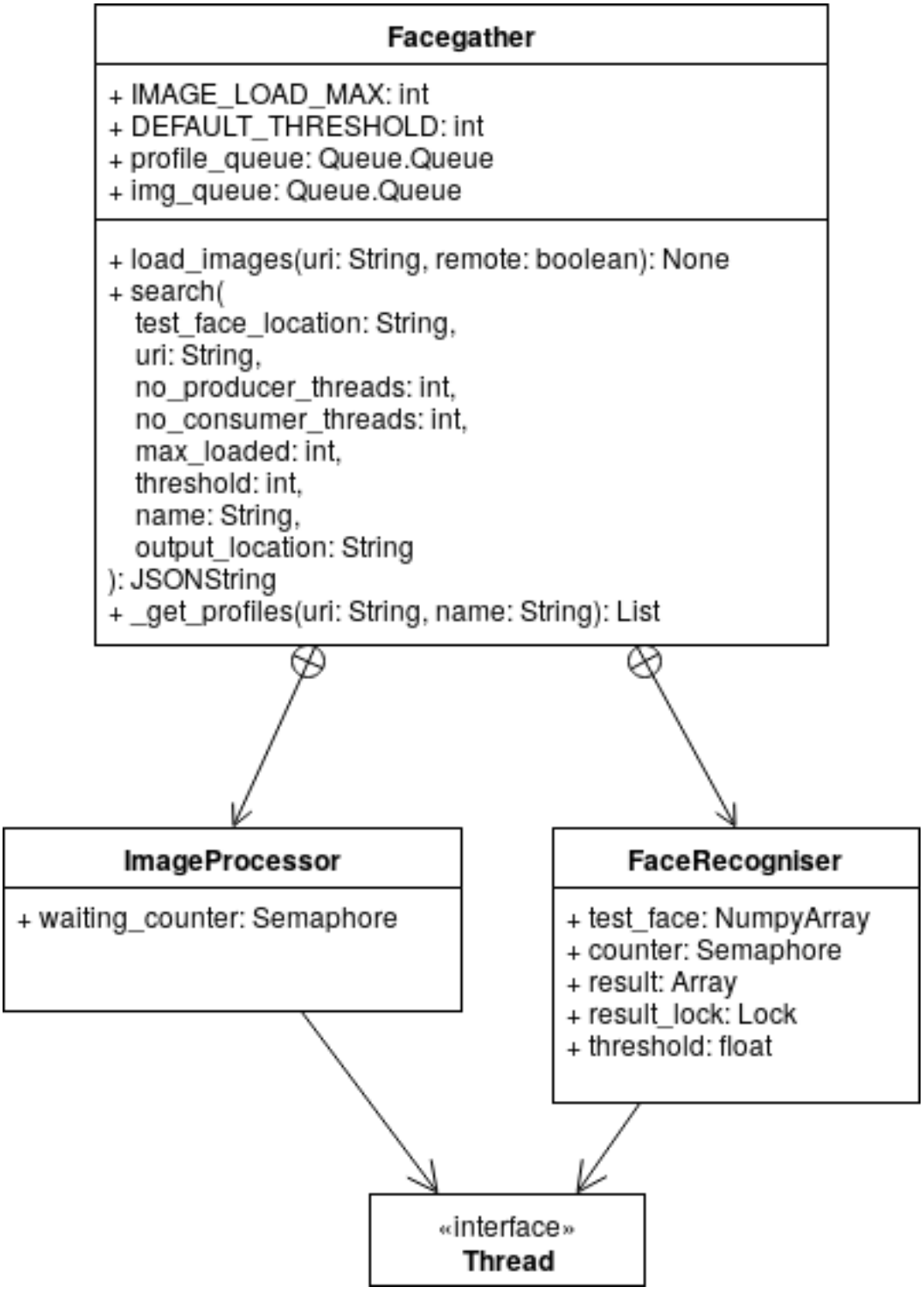
From the requirements specification, an initial concept design was created. It included only a running program, which would use a face recognition module. This design solved all of the essential "must-have" features that were captured in the requirements specification. From here, the design was iterated upon to increase specificity and to include "should-haves" and eventually "could-haves" from the requirements.

This design was then referred to throughout the implementation, and was retroactively modified when it became clear the design would not translate to a successful implementation. Each stage of the implementation was tested for correctness before new functionality was added.

Testing of the program was conducted throughout the implementation, and continued after a fully-featured working version of the program was implemented. The program was tested using a black box methodology, with the requirements specification as a guide. Each requirement was tested against the program, and the results checked for correctness.

The agile nature of this project is evidenced by a git version control repository. Each commit adds some level of functionality, and has a description of what was changed as well as the timestamp of the commit. The full log may be found in appendix E.

7.9 UML Diagram



8 Testing and Results

8.1 Aims

The aim of the application is to allow a user to query a dataset and find the social media profile of a person in a test image. The data sets used for testing are varied so as to allow for testing across a trained data set, testing across an untrained data set, and testing across an abnormal data set (in this case, the IR images taken from the SCFace database). The testing should reflect this, and as such should provide insight into the following areas:

- Even when comparing over multiple data sets that have been generated using different methods, a reasonable accuracy should still be maintained.
- Images that have been compressed with different algorithms should still match, given that they are of the same person.
- Success rates across abnormal data sets - for example, the SCFace IR images - should be tested to gather insight in to how effectively or otherwise these images could be used in facial recognition when gathering social media intelligence.
- The restrictions on search terms should work as expected, and exclude profiles which do not meet the search criteria.
- Testing done across data sets which have not been used in training should have a reasonable accuracy.

8.2 Testing Strategy

8.2.1 Comparing Images from Different Data Sets

To compare images from different data sets five images were selected from the total pool of images. One was taken from each of the seperate categories in the Essex data set, and one was taken from the LFW data set. The number of correct matches was then compared against the number of expected correct matches, and the number of false positives.

8.2.2 Comparing Images with Different Compression Algorithms

A data set that uses a different compression algorithm than JPEG could not be located, so instead a new data set was generated from the LFW data set by compressing the images using the Portable Network Graphic (PNG) algorithm. A comparison was then

made between the accuracy of an image compared with the same compression algorithm, and an image compared using two different compression algorithms.

8.2.3 Comparing Images Taken in the Infra-Red Spectrum

Images taken from the SCFace data set were compared to the IR images contained within the database, and the accuracy rate noted.

8.2.4 Restricting by Identifiable Information

A comparison was done in the accuracy and speed of searches on the LFW data set when restricting the search by first and full name.

8.3 Expected Results

8.3.1 Comparing Images from Different Data Sets

The program should maintain a high accuracy rate even across data sets it has not been trained on.

8.3.2 Comparing Images with Different Compression Algorithms

The PNG compression algorithm that was used is a lossless algorithm. No detail should be lost when compressing the data set, and so the expected accuracy when comparing photos with different compression algorithms is the same.

8.3.3 Comparing Images Taken in the Infra-Red Spectrum

Ideally, photos taken in infra-red should be matched at a similar accuracy as those taken in RGB. This may not be the case due to difficulty identifying facial descriptors.

8.3.4 Restricting by Identifiable Information

Searches against a restricted data set give less opportunities for false positives, and increase the ratio of matching images to non-matching images. Therefore, it is expected that the accuracy and speed of the search should be superior to an unrestricted search.

8.4 Comparing Images from Different Data Sets

The facial recognition algorithm used has been trained against only the LFW data set. By combining this data set with others that it hasn't been trained on, a closer approximation of accuracy to searches in a production social networking service may be obtained. Tests 1 through 4 use a test image from the Essex Computer Vision data set, test 5 uses an image from the LFW data set. All searches were done against a union of theh LFW data set, the SCFace data set and the Essex Computer Vision data set.

Test Number	Accuracy	False Positives	Time Elapsed (Hours)
1	1.0	0	2:06:59
2	1.0	0	2:07:27
3	0.59	13	2:07:50
4	1.0	0	2:06:18
5	1.0	0	2:08:02
Avg	0.92	2.6	2:07:19

8.4.1 Test 1

Test image: essex_cswww/faces94/male/cjsake/cjsake.1.jpg

Image	Distance	False Positive
cjsake.1.jpg	0	No
cjsake.2.jpg	0.12415972564754801	No
cjsake.3.jpg	0.1202683265955043	No
cjsake.4.jpg	0.12056058735503877	No
cjsake.5.jpg	0.15399061544936016	No
cjsake.6.jpg	0.15170091461313734	No
cjsake.7.jpg	0.15761164790252086	No
cjsake.8.jpg	0.18675358283846008	No
cjsake.9.jpg	0.22679627515383244	No
cjsake.10.jpg	0.16498243163116574	No
cjsake.11.jpg	0.2083636000224947	No
cjsake.12.jpg	0.19579060568070747	No
cjsake.13.jpg	0.21036201522486805	No
cjsake.14.jpg	0.16785907543854067	No
cjsake.15.jpg	0.2078185538842606	No
cjsake.16.jpg	0.19772310008051744	No
cjsake.17.jpg	0.18166327218341696	No
cjsake.18.jpg	0.20414891693929105	No
cjsake.19.jpg	0.19693488266700446	No
cjsake.20.jpg	0.1671873443722762	No

8.4.2 Test 2

Test image: essex_cswww/faces95/adhast/adhast.1.jpg

Image	Distance	False Positive
adhast.1.jpg	0	No
adhast.2.jpg	0.2312083988155676	No
adhast.3.jpg	0.25972150326024057	No
adhast.4.jpg	0.21590055493708946	No
adhast.5.jpg	0.24049261224827648	No
adhast.6.jpg	0.23465681660325552	No
adhast.7.jpg	0.24771615139343836	No
adhast.8.jpg	0.2569527085240263	No
adhast.9.jpg	0.2835389426928616	No
adhast.10.jpg	0.2774791080863853	No
adhast.11.jpg	0.2532400849084287	No
adhast.12.jpg	0.28278790526661146	No
adhast.13.jpg	0.2937914096756732	No
adhast.14.jpg	0.2970183349284969	No
adhast.15.jpg	0.29927374807082874	No
adhast.16.jpg	0.2783214797648933	No
adhast.17.jpg	0.2736083238480712	No
adhast.18.jpg	0.2851054856115722	No
adhast.19.jpg	0.2891104254644535	No
adhast.20.jpg	0.2816904095878937	No

8.4.3 Test 3

Test image: essex_cswww/faces96/cjhewi/cjhewi.1.jpg

Image	Distance	False Positive
cjewi.1.jpg	0	No
cjewi.2.jpg	0.19289455983673667	No
cjewi.3.jpg	0.24900325719699287	No
cjewi.4.jpg	0.3291783082081157	No
cjewi.5.jpg	0.31046947257682805	No
cjewi.6.jpg	0.375778847049278	No
cjewi.7.jpg	0.49121008818147793	No
cjewi.8.jpg	0.24928926125340656	No
cjewi.9.jpg	0.2805170839075122	No
cjewi.10.jpg	0.2917877509617489	No
cjewi.12.jpg	0.33383609910398243	No
cjewi.13.jpg	0.3107498407520015	No
cjewi.14.jpg	0.3226220896718056	No
cjewi.15.jpg	0.3315345047726276	No
cjewi.16.jpg	0.29075881781505053	No
cjewi.17.jpg	0.3323513335348239	No
cjewi.18.jpg	0.3216638643477499	No
cjewi.19.jpg	0.310250334339258	No
cjewi.20.jpg	0.338702834726292	No
namull.1.jpg	0.48963088468953936	Yes
namull.6.jpg	0.4842381188636226	Yes
namull.7.jpg	0.4662936114262804	Yes
namull.8.jpg	0.4836512854747962	Yes
namull.9.jpg	0.4696436628368218	Yes
namull.10.jpg	0.4940518896453423	Yes
namull.11.jpg	0.48309837097908737	Yes
namull.12.jpg	0.48312326468475714	Yes
namull.13.jpg	0.486709853926479	Yes
namull.14.jpg	0.49657762085731155	Yes
namull.16.jpg	0.47954763770455816	Yes
namull.17.jpg	0.49958672970235724	Yes
namull.19.jpg	0.49557076522667326	Yes

8.4.4 Test 4

Test image: essex_cswww/grimace/glen/glen_exp.16.jpg

Image	Distance	False Positive
glen_exp.1.jpg	0.34313537619742157	No
glen_exp.2.jpg	0.32513380486202487	No
glen_exp.3.jpg	0.328383372717064	No
glen_exp.4.jpg	0.3491545736970797	No
glen_exp.5.jpg	0.30237431205513626	No
glen_exp.6.jpg	0.29009140244087817	No
glen_exp.7.jpg	0.24115004735784007	No
glen_exp.8.jpg	0.32010274711449116	No
glen_exp.9.jpg	0.24679108112701786	No
glen_exp.10.jpg	0.25755122131334396	No
glen_exp.11.jpg	0.25527497911678315	No
glen_exp.12.jpg	0.2613227017464422	No
glen_exp.13.jpg	0.15115098114591524	No
glen_exp.14.jpg	0.14626106627309007	No
glen_exp.15.jpg	0.12721964956014153	No
glen_exp.16.jpg	0	No
glen_exp.17.jpg	0.1282296546247514	No
glen_exp.18.jpg	0.15230068444806952	No
glen_exp.19.jpg	0.1574033445984365	No
glen_exp.20.jpg	0.171147992496858	No

8.4.5 Test 5

Test image: lfw/Aaron_Peirsol/Aaron_Peirsol_0001.jpg

Image	Distance	False Positive
Aaron_Peirsol_0001.jpg	0	No
Aaron_Peirsol_0002.jpg	0.359368799618006	No
Aaron_Peirsol_0003.jpg	0.3356236792942648	No
Aaron_Peirsol_0004.jpg	0.41244297976804756	No

8.5 Comparing Images with Different Compression Algorithms

Social networks may store images in different formats, typically Portable Network Graphic (PNG). Most commercial cameras store their images a JPEG files. This test compares a JPEG image against a PNG data set, to find if there are any significant differences in accuracy or time taken when comparing images in different formats.

Test Number	Accuracy	False Positives	Time Elapsed (Hours)
1	1.0	0	1:23:20
2	0.25	3	1:22:42
3	0.72	1	1:24:10
4	0.5	2	1:22:46
5	0.82	0	1:23:16
Avg	0.658	1.2	1:23:15

8.5.1 Test 1

Test image: lfw/Aaron_Peirsol/Aaron_Peirsol_0001.jpg

Image	Distance	False Positive
Aaron_Peirsol_0001.png	0.012334246377964656	No
Aaron_Peirsol_0002.png	0.3603868116326761	No
Aaron_Peirsol_0003.png	0.3358269006565544	No
Aaron_Peirsol_0004.png	0.4213942834670981	No

8.5.2 Test 2

Test image: lfw/Doc_Rivers/Doc_Rivers_0001.jpg

Image	Distance	False Positive
Doc_Rivers_0001.png	0.008126612697683498	No
Glenn_Rivers_0001.png	0.4441926835082163	Yes
Maurice_Cheeks_0001.png	0.4755522108329577	Yes
Thabo_Mbeki_0001.png	0.48904588661316073	Yes

8.5.3 Test 3

Test image: lfw/George_HW_Bush_0003.jpg

Image	Distance	False Positive
George_HW_Bush_0001.png	0.43779864167037513	No
George_HW_Bush_0003.png	0.05526240671390998	No
George_HW_Bush_0005.png	0.49556510308006735	No
George_HW_Bush_0006.png	0.49678314589520917	No
George_HW_Bush_0007.png	0.4661770164726044	No
George_HW_Bush_0009.png	0.4343336388504174	No
George_HW_Bush_0011.png	0.41749203800312495	No
George_HW_Bush_0012.png	0.4958857255192459	No
George_HW_Bush_0013.png	0.4970243387404675	No
George_W_Bush_0287.png	0.44049867749481153	Yes

8.5.4 Test 4

Test image: lfw/Joseph_Blatter_0002.jpg

Image	Distance	False Positive
Joseph_Blatter_0001.png	0.47858057359342215	No
Joseph_Blatter_0002.png	0.0336530518133179	No
Sepp_Blatter_0002.png	0.4862694459206191	Yes
Sepp_Blatter_0004.png	0.42559962697675985	Yes

8.5.5 Test 5

Test image: lfw/Tony_Blair_0002.jpg

Image	Distance	False Positive
Tony_Blair_0002.png	0.4771680101285018	No
Tony_Blair_0003.png	0.480985145188809	No
Tony_Blair_0004.png	0.4596974293243147	No
Tony_Blair_0006.png	0.036247002247086095	No
Tony_Blair_0007.png	0.3749530714147472	No
Tony_Blair_0009.png	0.44356856961314667	No
Tony_Blair_0012.png	0.39056265389937056	No
Tony_Blair_0013.png	0.36810087134361	No
Tony_Blair_0015.png	0.47290939486890193	No
Tony_Blair_0016.png	0.4799575413945816	No
Tony_Blair_0017.png	0.3791103058656651	No

Image	Distance	False Positive
Tony_Blair_0019.png	0.47370780408374297	No
Tony_Blair_0020.png	0.4030814376470261	No
Tony_Blair_0022.png	0.3484769600414663	No
Tony_Blair_0024.png	0.4749464761064012	No
Tony_Blair_0025.png	0.37668636275839784	No
Tony_Blair_0026.png	0.4540464799599294	No
Tony_Blair_0027.png	0.4175971449726495	No
Tony_Blair_0028.png	0.45196053604334974	No
Tony_Blair_0029.png	0.4040722828269198	No
Tony_Blair_0030.png	0.4040920514555924	No
Tony_Blair_0032.png	0.4403225959394582	No
Tony_Blair_0033.png	0.47767228365950215	No
Tony_Blair_0035.png	0.4457419703771305	No
Tony_Blair_0036.png	0.45523765642848557	No
Tony_Blair_0037.png	0.47821689320577304	No
Tony_Blair_0039.png	0.46474096062460735	No
Tony_Blair_0040.png	0.45155503656989276	No
Tony_Blair_0042.png	0.4625118053790461	No
Tony_Blair_0041.png	0.47343379679317094	No
Tony_Blair_0043.png	0.46666912378683195	No
Tony_Blair_0046.png	0.4029704245820186	No
Tony_Blair_0047.png	0.42564273287725796	No
Tony_Blair_0048.png	0.47068237137426056	No
Tony_Blair_0049.png	0.42269784320192466	No
Tony_Blair_0050.png	0.498966415423654	No
Tony_Blair_0052.png	0.48711129745936227	No
Tony_Blair_0051.png	0.4863045001385002	No
Tony_Blair_0053.png	0.4878306595340014	No
Tony_Blair_0054.png	0.4547578270562901	No
Tony_Blair_0055.png	0.45477935130613995	No
Tony_Blair_0056.png	0.46440980003212756	No
Tony_Blair_0057.png	0.4044213964481114	No
Tony_Blair_0058.png	0.44105103047407657	No
Tony_Blair_0059.png	0.4572087448490241	No
Tony_Blair_0060.png	0.48874981459517125	No
Tony_Blair_0061.png	0.4259232633107541	No
Tony_Blair_0062.png	0.4312476463279641	No
Tony_Blair_0063.png	0.4539069717684182	No
Tony_Blair_0064.png	0.42503974397901295	No
Tony_Blair_0065.png	0.4034136646600798	No
Tony_Blair_0067.png	0.36800919552842437	No

Image	Distance	False Positive
Tony_Blair_0068.png	0.49371680987282746	No
Tony_Blair_0070.png	0.499827996283155	No
Tony_Blair_0071.png	0.47263084324812427	No
Tony_Blair_0072.png	0.4770663160672075	No
Tony_Blair_0073.png	0.49287495683175353	No
Tony_Blair_0078.png	0.42120037854851483	No
Tony_Blair_0080.png	0.4271619535881904	No
Tony_Blair_0081.png	0.45576621662738687	No
Tony_Blair_0082.png	0.4291947084716399	No
Tony_Blair_0083.png	0.47053749832287933	No
Tony_Blair_0084.png	0.49055603003745324	No
Tony_Blair_0085.png	0.48118130886360233	No
Tony_Blair_0086.png	0.39077778686829673	No
Tony_Blair_0087.png	0.47799662896914624	No
Tony_Blair_0088.png	0.45594586876542087	No
Tony_Blair_0089.png	0.3956468551870259	No
Tony_Blair_0091.png	0.4874395113110329	No
Tony_Blair_0092.png	0.4505891128182158	No
Tony_Blair_0093.png	0.47806026796247597	No
Tony_Blair_0096.png	0.4638839966233622	No
Tony_Blair_0097.png	0.426256451794294	No
Tony_Blair_0099.png	0.4111159768122537	No
Tony_Blair_0101.png	0.4141999990896525	No
Tony_Blair_0102.png	0.4700670088189572	No
Tony_Blair_0103.png	0.46185539009939025	No
Tony_Blair_0104.png	0.44897356154630347	No
Tony_Blair_0106.png	0.47399290771782543	No
Tony_Blair_0107.png	0.49320329875468166	No
Tony_Blair_0109.png	0.497298251309488	No
Tony_Blair_0111.png	0.4658191818926708	No
Tony_Blair_0112.png	0.45226067648954343	No
Tony_Blair_0114.png	0.3888446086340705	No
Tony_Blair_0113.png	0.483735856230772	No
Tony_Blair_0116.png	0.4922189710321329	No
Tony_Blair_0117.png	0.4881579137913724	No
Tony_Blair_0118.png	0.4767777939761526	No
Tony_Blair_0119.png	0.4888145552284681	No
Tony_Blair_0122.png	0.4048638517205401	No
Tony_Blair_0121.png	0.43206610453180183	No
Tony_Blair_0123.png	0.4848490145683085	No
Tony_Blair_0124.png	0.4858565492585873	No

Image	Distance	False Positive
Tony_Blair_0126.png	0.49118102706622646	No
Tony_Blair_0125.png	0.44974738645157736	No
Tony_Blair_0129.png	0.46810588485536203	No
Tony_Blair_0130.png	0.4753108653778671	No
Tony_Blair_0132.png	0.4995327443552532	No
Tony_Blair_0134.png	0.4707471675268031	No
Tony_Blair_0133.png	0.46476424681366074	No
Tony_Blair_0136.png	0.4114815889521775	No
Tony_Blair_0138.png	0.45758562676217934	No
Tony_Blair_0139.png	0.4721173528401837	No
Tony_Blair_0140.png	0.47340721200992797	No
Tony_Blair_0141.png	0.39354676586036913	No
Tony_Blair_0142.png	0.38277308586730685	No
Tony_Blair_0143.png	0.44663782899819965	No

8.6 Comparing Images Taken in the Infra-Red Spectrum

The SCFace includes images of each subject taken in the infra-red spectrum, using a camera without an IR filter. These images may be captured in low-light conditions as they use infra-red radiation as opposed to visible light during exposure. This test compares these images against a data set of RGB images, taken in varied lighting conditions.

Test Number	Accuracy	False Positives	Time Elapsed (Hours)
1	1.0	0	0:01:01
2	0.33	2	0:00:55
3	0.5	1	0:01:56
4	1	0	0:00:57
5	1	0	0:00:58
Avg	0.766	0.6	0:01:09

8.6.1 Test 1

Test image: SCface_database/surveillance_cameras_IR_cam8/001_cam8.jpg

Image	Distance	False Positive
001_cam8.jpg	0	No

8.6.2 Test 2

Test image: SCface_database/surveillance_cameras_IR_cam8/012_cam8.jpg

Image	Distance	False Positive
012_cam8.jpg	0	No
012_cam8.jpg	0.48812956542079605	Yes
012_cam8.jpg	0.4626028092713898	Yes

8.6.3 Test 3

Test image: SCface_database/surveillance_cameras_IR_cam8/018_cam8.jpg

Image	Distance	False Positive
018_cam8.jpg	0	No
106_cam8.jpg	0.4797243721214274	Yes

8.6.4 Test 4

Test image: SCface_database/surveillance_cameras_IR_cam8/050_cam8.jpg

Image	Distance	False Positive
050_cam8.jpg	0	No

8.6.5 Test 5

Test image: SCface_database/surveillance_cameras_IR_cam8/123_cam8.jpg

Image	Distance	False Positive
123_cam8.jpg	0	No

8.7 Restricting by Identifiable Information

It is useful when searching social networking services to restrict the search by multiple vectors, to reduce the search space and thereby increase accuracy of the search and the speed of any following searches. The purpose of this test is to ascertain the improvement in both accuracy and speed when restricting a search by the subject's name.

Test Number	Accuracy	False Positives	Time Elapsed (Hours)
1	0.72	1	0:00:28
2	1	0	0:00:35
3	1	0	0:00:23
4	0.95	0	0:00:35
5	1	0	0:00:11
Avg	0.934	0.2	0:00:26

8.7.1 Test 1

Test image: lfw/George_HW_Bush_0003.jpg

Image	Distance	False Positive
George_HW_Bush_0001.jpg	0.44468805399677747	No
George_HW_Bush_0003.jpg	0	No
George_HW_Bush_0005.jpg	0.49416427819847825	No
George_HW_Bush_0006.jpg	0.497188652920442	No
George_HW_Bush_0007.jpg	0.46536163951784293	No
George_HW_Bush_0009.jpg	0.43531340164790916	No
George_HW_Bush_0011.jpg	0.41985097908792973	No
George_HW_Bush_0012.jpg	0.4960292649139455	No
George_HW_Bush_0013.jpg	0.49746813708113324	No
George_W_Bush_0287.jpg	0.4454600672429446	Yes

8.7.2 Test 2

Test image: essex_cswww/faces94/male/cjsake/cjsake.1.jpg

Image	Distance	False Positive
cjsake.1.jpg	0	No
cjsake.2.jpg	0.12415972564754801	No
cjsake.3.jpg	0.1202683265955043	No
cjsake.4.jpg	0.12056058735503877	No
cjsake.5.jpg	0.15399061544936016	No
cjsake.6.jpg	0.15170091461313734	No
cjsake.7.jpg	0.15761164790252086	No
cjsake.8.jpg	0.18675358283846008	No
cjsake.9.jpg	0.22679627515383244	No
cjsake.10.jpg	0.16498243163116574	No
cjsake.11.jpg	0.2083636000224947	No
cjsake.12.jpg	0.19579060568070747	No
cjsake.13.jpg	0.21036201522486805	No
cjsake.14.jpg	0.16785907543854067	No
cjsake.15.jpg	0.2078185538842606	No
cjsake.16.jpg	0.19772310008051744	No
cjsake.17.jpg	0.18166327218341696	No
cjsake.18.jpg	0.20414891693929105	No
cjsake.19.jpg	0.19693488266700446	No
cjsake.20.jpg	0.1671873443722762	No

8.7.3 Test 3

Test image: essex_cswww/faces95/adhast/adhast.1.jpg

Image	Distance	False Positive
adhast.1.jpg	0	No
adhast.2.jpg	0.2312083988155676	No
adhast.3.jpg	0.25972150326024057	No
adhast.4.jpg	0.21590055493708946	No
adhast.5.jpg	0.24049261224827648	No
adhast.6.jpg	0.23465681660325552	No
adhast.7.jpg	0.24771615139343836	No
adhast.8.jpg	0.2569527085240263	No
adhast.9.jpg	0.2835389426928616	No
adhast.10.jpg	0.2774791080863853	No
adhast.11.jpg	0.2532400849084287	No
adhast.12.jpg	0.28278790526661146	No
adhast.13.jpg	0.2937914096756732	No
adhast.14.jpg	0.2970183349284969	No
adhast.15.jpg	0.29927374807082874	No
adhast.16.jpg	0.2783214797648933	No
adhast.17.jpg	0.2736083238480712	No
adhast.18.jpg	0.2851054856115722	No
adhast.19.jpg	0.2891104254644535	No
adhast.20.jpg	0.2816904095878937	No

8.7.4 Test 4

Test image: essex_cswww/faces96/cjhewi/cjhewi.1.jpg

Image	Distance	False Positive
cjhewi.1.jpg	0	No
cjhewi.2.jpg	0.19289455983673667	No
cjhewi.3.jpg	0.24900325719699287	No
cjhewi.4.jpg	0.3291783082081157	No
cjhewi.5.jpg	0.31046947257682805	No
cjhewi.6.jpg	0.375778847049278	No
cjhewi.7.jpg	0.49121008818147793	No
cjhewi.8.jpg	0.24928926125340656	No
cjhewi.9.jpg	0.2805170839075122	No
cjhewi.10.jpg	0.2917877509617489	No
cjhewi.12.jpg	0.33383609910398243	No
cjhewi.13.jpg	0.3107498407520015	No
cjhewi.14.jpg	0.3226220896718056	No
cjhewi.15.jpg	0.3315345047726276	No
cjhewi.16.jpg	0.29075881781505053	No
cjhewi.17.jpg	0.3323513335348239	No
cjhewi.18.jpg	0.3216638643477499	No
cjhewi.19.jpg	0.310250334339258	No
cjhewi.20.jpg	0.338702834726292	No

8.7.5 Test 5

Test image: essex_cswww/grimace/glen/glen_exp.16.jpg

Image	Distance	False Positive
glen_exp.1.jpg	0.34313537619742157	No
glen_exp.2.jpg	0.32513380486202487	No
glen_exp.3.jpg	0.328383372717064	No
glen_exp.4.jpg	0.3491545736970797	No
glen_exp.5.jpg	0.30237431205513626	No
glen_exp.6.jpg	0.29009140244087817	No
glen_exp.7.jpg	0.24115004735784007	No
glen_exp.8.jpg	0.32010274711449116	No
glen_exp.9.jpg	0.24679108112701786	No
glen_exp.10.jpg	0.25755122131334396	No
glen_exp.11.jpg	0.25527497911678315	No
glen_exp.12.jpg	0.2613227017464422	No
glen_exp.13.jpg	0.15115098114591524	No
glen_exp.14.jpg	0.14626106627309007	No
glen_exp.15.jpg	0.12721964956014153	No
glen_exp.16.jpg	0	No
glen_exp.17.jpg	0.1282296546247514	No
glen_exp.18.jpg	0.15230068444806952	No
glen_exp.19.jpg	0.1574033445984365	No
glen_exp.20.jpg	0.171147992496858	No

An evaluation of these results can be found overleaf.

9 Evaluation

9.1 Overview

The project overall was a success, given its limitations. The design conforms to industry best practices, and was refined iteratively without transforming unrecognisably. The implementation succeeds in fulfilling all requirements set, as well as the primary objective of searching a social networking service by face. It successfully fills the gaps in current functionality outline in the literature review, with the restriction that it is a proof-of-concept raher than a feature complete, production ready system. Testing, while not conclusive, certainly showed promising results and is encouraging should further research be done. By adapting an agile approach throughout the project could be refined several times before completion,

9.2 Design

The overall design of the implementation was sound. In particular the producer-consumer model suited the project well as it allows for a thread-based implementation with multiple queues, allowing the computational cost of searching the data set to be spread across multiple CPU cores.

While the design is fairly modular, as it stands the JSON data containing the list of profiles must be in a particular format and must be sent as a single response). This would be inadequate if the application were to be tested against an actual social media service, as the profile data that can be retrieved from their APIs are in differing formats and are typically sent in chunks. For example, Facebook sends its profiles in chunks of 50 (Facebook, 2018*a*). Ideally this problem would be solved by refactoring the code to include a layer between the calling program (run.py) and the python module (facegather.py) in which formats can be defined, and the module called repeatedly on chunks of results. Alternatively, a proxy server could be placed in between the computer running the search and the social media service which caches API calls to the provider and returns them as a single response in the expected format.

The design allows for a multi-threaded architecture, however to see truly optimal performance a design based around GPU computing should be considered. By utilising thousands of cores rather than 4 it is theorised that the most time consuming part of the search, the facial descriptor comparisons, could be reduced by an order of magnitude.

9.3 Implementation

Although there were several challenges to a successful implementation of the design, the program developed achieves all of the functional and non-functional requirements set out in the specification.

There are some gaps in functionality which are desirable but could not be added due to limitations in time. For example, while the search can be restricted by identifying information other than a person of interest's face, the only information currently searchable on is their name. While this feature is obviously useful, more search restrictions could be implemented such as location, place of work, home address etc. to narrow down the search space. This would be important if the program were to be used in a national security or industry setting, as otherwise the data set would be far too large to search in a timely manner.

The implementation uses a command-line interface to allow users to search services with a test image, specifying search restrictions, threads for producing and consuming data, maximum image load and other parameters. While this is adequate for expert users and is desirable to allow for inter-program communication (for example, search commands being generated by one program and being piped into facegather), non-expert users may struggle to use the program effectively without a GUI.

9.4 Results

9.4.1 Comparing Images from Different Data Sets

The implementation performed admirably when comparing images against multiple data sets, some of which it had not been trained on. It had an average accuracy of 0.92, only marginally less than dlib's advertised performance when searching the Labeled Faces in the Wild data set. The only result that kept it getting a 100% accuracy was test 3, which contained several false positives. All false positives had a distance greater than 0.45, whereas all correct matches had a distance less than 0.35 suggesting that accuracy could be improved by giving a more precise thresholding value. It is unlikely to be a problem with the algorithm itself, as test 4 used a much more difficult data set and was searched with 100% accuracy.

Of particular note is the fact that there was only a single false negative, again in test 3. This is an excellent result, as the intended use of the application is to restrict the search space as much as possible before handing the results to either a secondary program or a human operator. False negatives are therefore much more problematic than false positives, hence why the thresholding value was set to be quite forgiving.

9.4.2 Comparing Images with Different Compression Algorithms

The implementation performed less well when comparing images with different compression algorithms. The accuracy of the search dropped to 0.658, mainly due to the high number of false positives. It should be noted that, even with the substantial drop in accuracy, recall was still fairly high.

The main reason behind the drop in accuracy is most likely due to the changes in the image when compressing greyscale images. The library responsible for facial recognition has been trained mostly on RGB images, so it may have difficulty identifying facial descriptors in greyscale images particularly when faced with a drop in quality.

9.4.3 Comparing Images Taken in the Infra-Red Spectrum

The implementation performed slightly better when comparing images in the infra-red spectrum, achieving an accuracy of 0.766. This is less impressive than the first set of tests however, as there are far fewer potential false positives in the data set - 129 compared to several thousands for the first and second tests. Again, the algorithm may suffer when comparing greyscale images. Compounding this is the fact that the images were taken in the infra-red spectrum. The images taken from this camera show less distinction between facial features, for example the contrast between where the cheek bones end is much less noticable.

9.4.4 Restricting by Identifiable Information

The results obtained by this set of tests are the most promising in the entire project. The implementation achieved an accuracy of 0.934, the highest in any of the sets of tests. This is to be expected, as by supplying a name to restrict the search by the number of false negatives is reduced from several thousand to at most several hundred. Most impressive is the time saved by restricting the search - the average time taken to search was improved from over 2 hours to just 26 seconds, a time save of over 27,000%.

An interesting note is that the false positive in test 1, where the test image provided was of George H.W. Bush, was a picture of George W. Bush - the subject's son. If the application behaves similarly in a real-life applications this could be a useful unintended side-effect as gathering information on family members (sons, fathers etc.) would be valuable.

9.4.5 False Positive vs. False Negative

In the context of this application, false negatives are much less desirable than false positives. Since the application can feed-forward search results to a post-processing

application or to a human operator, the result set should be as complete as possible. Provided the accuracy is above an acceptable baseline, the number of false positives is almost inconsequential so long as recall is high. To that end the threshold for a match is set to be fairly forgiving.

10 Conclusion

10.1 Overview

Overall, the project was succesful in applying machine vision techniques to recognise the faces of persons of interest to gather social media intelligence. The application developed allows users to search a social media service for an image of a person of interest, optionally restricting by name. The underlying facial recognition library is based on dlib trained using the Labeled Faces in the Wild data set.

The emergence of social media intelligence has been helped by several controversies recently. With the new exposure, users of social media services are much more aware of how much information they may potentially be exposing about themselves. Even with this newfound knowledge there are some basic datum which every user must make public - their name and profile photo being examples. This makes the tool developed attractive to intelligence services who may be gathering information about large groups of people, but may lack the tools to single out a person of interest from a population.

10.2 Findings

The application was tested using the Labeled Faces in the Wild, Essex University Computer Vision and SCFace databases. It was tested against datasets it was not trained against, data sets using different compression algorithms, data sets captured in the infra-red spectrum, and data sets that had been restricted using identifiable information (in this case, the person of interest's name).

The results are encouraging overall. The application had accuracy rates of over 90% in tests covering multiple datasets, which closely mirror images representative of typical social media profile photos. Importantly, there was only 1 false negative giving a recall of over 95%. The most realistic text, wherein the search space was restricted by name, had an accuracy of 93.4%.

The tests including different compression algorithms and infra-red images were less succesful, although they do offer areas for improvement. These searches test non-essential functionality of the program, and can be considered important for continued improvement but niche in a real-word setting.

10.3 Future Work

There are several improvements that could be made over the current implementation. While facial recognition technology improves, so too will this application. It can be considered a wrapper for whichever face recogntion implementation is performing best

at the current time. The main improvement that could be made is to have GPUs compare face mappings in batches, rather than the current implementation comparing them one-by-one over multiple CPU cores.

The application certainly warrants further research. The initial findings are promising, but an improved implementation tested against an actual social media service (or a data set truly representative of one) could prove groundbreaking for intelligence gathering communities.

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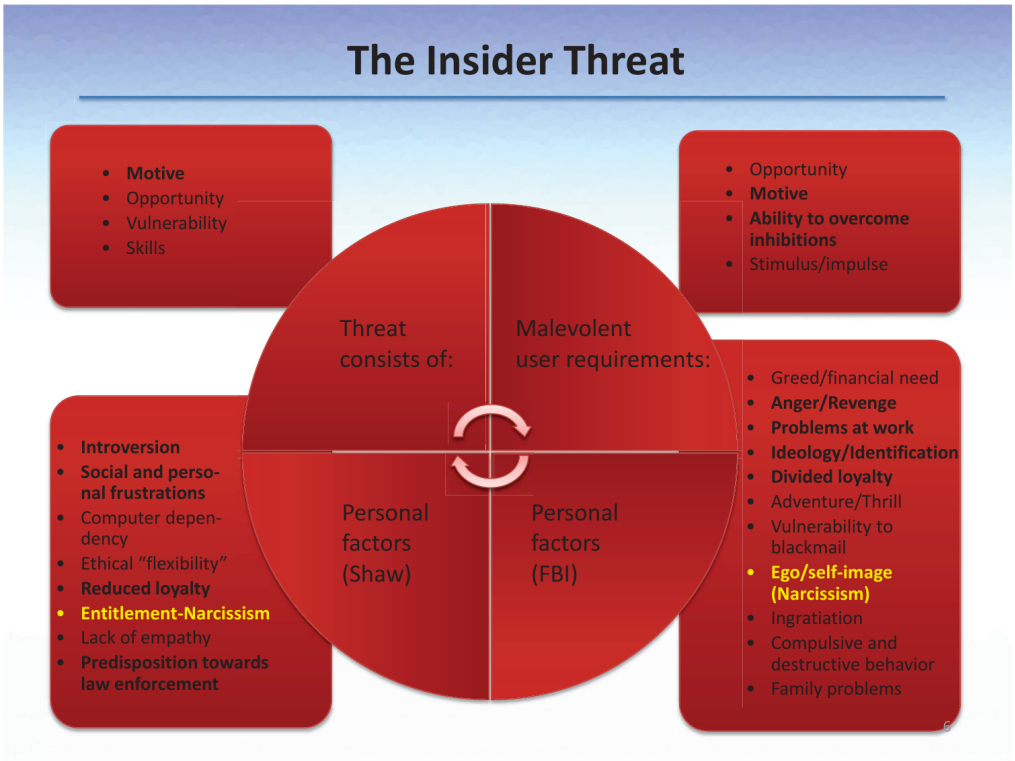
Appendices

A Threat Graph



Graph of insider threat factors (Kandias and Stavrou, 2015).

B "Boston Bomber" Identification

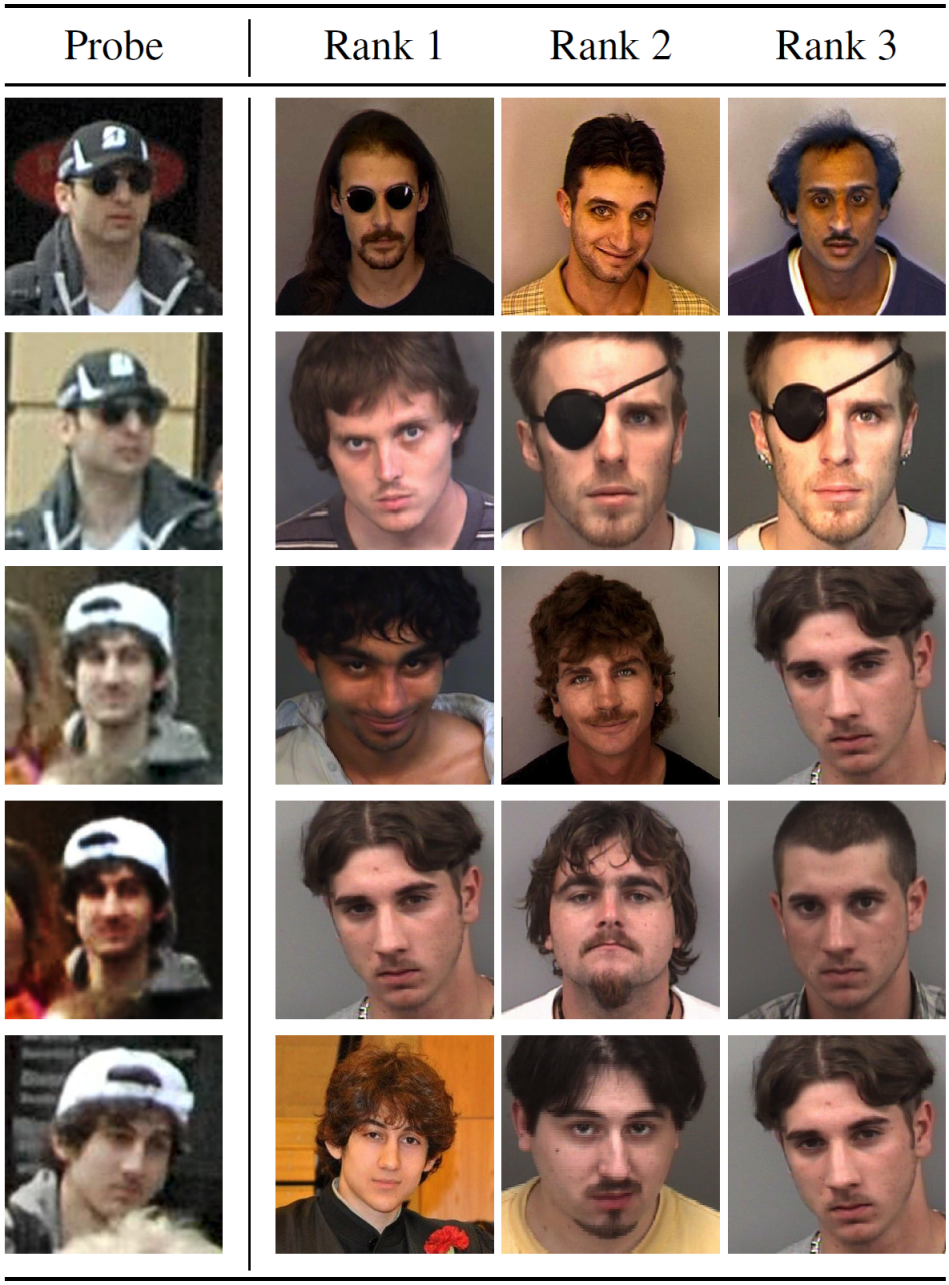


Table of potential matches, note the correct identification from the picture taken from social media with similar pose and lighting (Klontz and Jain, 2013).

C Connection Graph

Category	Influence valuation	Klout score	Usage valuation
Loners	0 - 90	3.55 - 11.07	0 - 500
Individuals	90 - 283	11.07 - 26.0	500 - 4.500
Known users	283 - 1.011	26.0 - 50.0	4.500 - 21.000
Mass Media & Personas	1.011 - 3.604	50.0- 81.99	21.000 - 56.9000

Graph of social media connections and klout score in the Nereus framework(Kandias and Stavrou, 2015).

D Command Line Arguments

```
jack@seven:~/Documents/hons_project$ python3 run.py -h
usage: run.py [-h] [--pthreads PTHREADS] [--cthreads CTHREADS]
              [--maxload MAXLOAD] [--name NAME]
              [--output_location OUTPUT_LOCATION]
              test_face service

A python3 program to gather social media intelligence using facial recognition

positional arguments:
  test_face             Location of the test face
  service               Social network service to search

optional arguments:
  -h, --help            show this help message and exit
  --pthreads PTHREADS   Number of image processing threads
  --cthreads CTHREADS   Number of image comparison threads
  --maxload MAXLOAD     Maximum number of images pre-loaded into memory
  --name NAME           Name of person of interest
  --output_location OUTPUT_LOCATION
                        Location of results file
```

A help page showing the command line arguments that can be supplied.

E GitHub Commit log

```
commit ed9e153d2cd788334bac9b6a238b3cb930a51a91
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Wed Oct 4 17:59:46 2017 +0100

    First Commit

commit 5185a551eaab3f5c2fe00c7c14d16e1aaec3a19f
```

```
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Oct 5 10:14:39 2017 +0100

    Sorted more papers, started record of work

commit e11421915552e1950a27947e4214da8952c750d4
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Oct 5 10:21:16 2017 +0100

    Moved things around, added second lecture

commit 1704c0ee8a0cb79af84abb8c6e955f14721a298b
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Oct 5 16:18:45 2017 +0100

    Added some more relevant papers

commit 0dc39f115e8dc43b7f390fef73aa646d2b93f1c9
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Oct 5 17:28:01 2017 +0100

    Updated diary

commit 556dc5f519da645cea94306ed1c40405683e4825
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Oct 5 17:47:05 2017 +0100

    Added more white papers

commit 7426d82191bae1e14c1679e38fc9a0cf00581387
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Oct 6 12:30:54 2017 +0100

    Updated records

commit 165aee1254176344dd3c1468e323c545c8b3019f
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Oct 12 10:32:39 2017 +0100

    Restructured, added papers on unconstrained facial recognition

commit af33cad06d2abc4d359b5a52b26045d5ab585c11
Author: Jack Neilson <jackdneilson@gmail.com>
```

```
Date:   Fri Oct 13 12:08:29 2017 +0100

    Updated diary and meeting record

commit ce933432026c3182fd97af489b2a373d0866c5be
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Oct 20 12:45:50 2017 +0100

    Updated records

commit 4121cf07f8b60893dd2141e366757ef2761907ce
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Oct 20 18:46:23 2017 +0100

    Updated Records

commit bb0107857cabb86bebd04a6a26d0a8a2b58794d4
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Oct 26 11:02:43 2017 +0100

    Added papers, added beginning of lit review

commit 819959003c5c1668fffd3d6452b9e0a36da6b94f
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Thu Oct 26 13:19:19 2017 +0100

    Added more papers, continued work on lit. review

commit 7baed3ed9455f1274f5b07c0f6e81ff272a84a5c
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Thu Oct 26 20:12:44 2017 +0100

    Added more papers, finished plan, lit. review and bibliography in proposal, update

commit f74e0428b454ec502804a1e41a9b7a52059005f0
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Oct 27 12:26:02 2017 +0100

    ? in proposal, updated diary and meeting record

commit dfc7fcbd7c615c76a73f2da7d92f56249fbfcad4
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Tue Oct 31 17:50:36 2017 +0000
```

```
    Finished first draft of proposal, finished ethics form, updated records

commit d65c794f9fa9e0c449dd0cd1babe0dd247bdf738
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Nov 2 09:34:26 2017 +0000

    Added license

commit b88ce8f3f7e0f207ca5a1d16f45e859cbbfe513d
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Nov 2 10:32:16 2017 +0000

    Rewrote proposal to use Harvard style over Vancouver, updated diary

commit 40a94789ed9d2c0fea8c444ba5253da7aff4016a
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Nov 2 14:11:04 2017 +0000

    Edited proposal, updated records

commit 51543830cea51232af6a0e901f9e59b7aeddca33
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Nov 3 17:28:34 2017 +0000

    Some changes to ethics form, updated records

commit 6d54ad2daebec3e101c6cda267ca4f3aae475225
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Nov 3 17:32:37 2017 +0000

    Added pdf version of proposal

commit 7e795697528af90d4606ad1938eafbb369f1c245
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Fri Nov 10 13:48:08 2017 +0000

    Updated records, added more papers

commit 9093eaa455890cb36c0aa4dc456681307a75c322
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Fri Nov 10 13:51:41 2017 +0000
```

```
    Added project feedback

commit 94aa3da22cb48141a87606ac755c80e8ac4eb368
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Nov 23 16:43:36 2017 +0000

    Added project structure

commit 2a49c1dc5917078c7ea7e8ff8dc27a5550327bd3
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Nov 24 12:37:17 2017 +0000

    Updated records, added literature review structure

commit 81227635a95d9955013f53dcc20d90a1a31e69e4
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Nov 24 12:42:45 2017 +0000

    Updated Records

commit f6a2acfb915d7b0c6376190b777dcf3e2c8b8820
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Nov 30 23:20:11 2017 +0000

    Added full lit review structure

commit a0e04fbf3d7a8dddede51fa9c4b6089450a40cb6
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Dec 1 12:25:42 2017 +0000

    Added report structure, updated records

commit ff2189b3fb381c295377adf3f94b6019c72654c1
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Dec 1 13:05:08 2017 +0000

    Updated records

commit 01d5d78373947e4052adf5eb462c0c5621aaff2e
Author: JACK NEILSON (1506801) <1506801@RG-N519-10.local>
Date:   Mon Dec 11 17:58:06 2017 +0000

    Added gitignore, found more papers
```

```
commit 57780013bd7b2290c539ce0157d14002e19766fd
Author: JACK NEILSON (1506801) <1506801@RG-N519-10.local>
Date:   Mon Dec 11 18:00:31 2017 +0000

    updated diary

commit 5e2006050a48ed50303bac3cace24ae4baf22e73
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Jan 19 17:47:40 2018 +0000

    Started on literature review

commit 5e445ef734992c1c8bca7954ecac12653f47d0d7
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Mon Jan 22 13:28:23 2018 +0000

    Started lit review

commit 71504f933deda0086231be9d12137f561a1e05a2
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Mon Jan 22 18:45:29 2018 +0000

    Added todo

commit aea27588f0ff9e5270dfaee1916c54b47e3db784
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Mon Jan 22 18:47:08 2018 +0000

    Finished added citations

commit daec8b60769c81ba5242c6d8fe91a1172740895a
Merge: aea27588f 71504f933
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Mon Jan 22 18:47:14 2018 +0000

    Merge branch 'master' of https://github.com/jackdneilson/hons_project

    added todos

commit 47b2d89c53de6b19a78e1c9139ca5ef68a9a5ec4
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Mon Jan 22 20:37:00 2018 +0000
```

```
    Finished sources, added intro to lit review

commit 34fe5bad4ba8a387dd48d4b2fbfe22f36917ebc5
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Mon Jan 22 20:47:01 2018 +0000

    Fixed lit review

commit b3d6c475b4f899cd02145b883e04635b00227ea2
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Mon Jan 22 20:49:37 2018 +0000

    No changes

commit 06d1e44958e0877e4afefa9b394f02769ebfc70a
Merge: b3d6c475b 34fe5bad4
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Mon Jan 22 20:49:43 2018 +0000

    Merge branch 'master' of https://github.com/jackdneilson/hons_project

    No changes

commit 86b7692c89792dce3e86ef74bb86a4a4c57868ff
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Mon Jan 22 22:05:26 2018 +0000

    More work on lit review, added papers

commit 825d5810d0f69f52736859def70aa4ba38a736ec
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Tue Jan 23 20:19:08 2018 +0000

    More work on lit review, added folder for resources

commit 05a57e8bc544ed4df60bb2b47d71133b33c3e767
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Wed Jan 24 15:13:25 2018 +0000

    Built lit review

commit 08803fb80218c31f57af0613bd39880e91199f33
```

```
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Wed Jan 24 16:43:15 2018 +0000

    First draft of lit review intro

commit 80bbafa7798cb574a48096697f2f8775cd0ecbdc
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Wed Jan 24 17:05:46 2018 +0000

    Built first draft of intro

commit 9654811e69d0fc06be85c4b4ef9065e7aa08e7e8
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Fri Jan 26 16:00:34 2018 +0000

    Reworded intro

commit 582a452c6db1c1ad908aaafd86fa2680f7a38571
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Jan 30 13:08:52 2018 +0000

    lit review, updated records

commit c63b46f3fced5b7bce2dd3079eadb82fd7fda470
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Tue Jan 30 13:34:41 2018 +0000

    lit review

commit bd78daa9053a04baef9ae97ef57af87b3fa8a124
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Tue Jan 30 17:25:39 2018 +0000

    lit review, papers

commit 7cb504341da44b20dea0ea24e369a76a9351a496
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Wed Jan 31 15:38:07 2018 +0000

    Lit review, papers

commit baf6897c20fa1205c941865f410ec53ac6dce75f
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
```

```
Date:   Wed Jan 31 15:44:36 2018 +0000

    Lit review

commit 5c9a84b2a31b68f6d6ac209c217e34427f2f9c4b
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Wed Jan 31 15:46:30 2018 +0000

    lit review build

commit e961f3df3cb927f4b2df7fad4d729f49a9dcda5c
Author: JACK NEILSON (1506801) <1506801@rgu.ac.uk>
Date:   Wed Jan 31 16:32:45 2018 +0000

    Lit review

commit 7c6934dba01e46f4b43deb5fdea548ed4ef91702
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Mon Feb 5 20:02:17 2018 +0000

    Lit review, updated diary, added papers

commit 38cd014bec8347a05c04dc3fa071633034aca8b1
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Feb 6 17:31:18 2018 +0000

    Added a draft requirements spec to the methodology section

commit 9092a801e6ebcea972c5d7f6179e1e88cde0d104
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Feb 6 17:34:08 2018 +0000

    Small amendment to requirements spec

commit c10d564b53d8879f91b9bef9da8fadb6078213c7
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Feb 6 17:43:10 2018 +0000

    Updated records, built report

commit 43bbf7bb78c08887a0623372e35ff57dbc24955e
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Wed Feb 7 16:48:27 2018 +0000
```

```
    Small edits to report, started implementing

commit 120998f6e83988c6659f672a735c3c785751f7ff
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Feb 8 18:38:35 2018 +0000

    Work on facegather module, fixed imports and dir structure

commit 034294156eacfed42662b4247324cb245441cc47
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Feb 9 12:05:07 2018 +0000

    Added todo

commit 7f73fde5690878f78fd2a4ef37ac31a2ed3fe7d7
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Feb 9 16:09:07 2018 +0000

    Implemented command line args, consumer threads, looping for multiple face images

commit 3a7fc664ebff1af7ba2616c73266eb9d00291329
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Feb 9 16:37:05 2018 +0000

    updated todo

commit 7749622f5bbfadd694d4c63cf77828e42129a131
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Wed Feb 14 16:44:39 2018 +0000

    Fixed server implementation and face recognition, made demo for john.

commit fe7356f468b017fb7263a2d74f108969e93304e8
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Feb 20 16:41:42 2018 +0000

    Added JSON representation of folder structure

commit 21f7c12780cd1f9e7bc13c970c0437d9d51d7d13
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Feb 22 13:13:00 2018 +0000
```

```
    Generated test data, fixed  webservers, started debugging threads

commit 6662d715c9c375ab60bbd517e2fe118145df9727
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Feb 22 17:52:58 2018 +0000

    Basic functionality completed

commit 64d4098508ae8935df0493de5b6d01fa7f7d424e
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Feb 23 15:44:42 2018 +0000

    Fixed deadlock issues by using sentinel

commit dde55f027e89f598e4a0f378feb02f193472421b
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Feb 23 19:49:16 2018 +0000

    More deadlocking bugs solved

commit 7cdb4cc1d0efacd3ab85d24b699a52e5485354fa
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Feb 23 19:57:09 2018 +0000

    Removed redundant imports, added todos in report

commit 6d1bcfbaf2d88b24dadd491d2c150e6c29db81ff
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Mon Feb 26 12:47:50 2018 +0000

    Some work on implementation section of report

commit ddcdb634e4619139497c608e02fbce8c6bc0c048
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Feb 27 14:46:31 2018 +0000

    Code refinements, added implementation section to report

commit f1ac4046117d3a5f2e1df9f68db4e43b35fbbbe8
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Feb 27 15:49:26 2018 +0000

    Meeting record
```

```
commit c427911ae59daea769023e8688d96e687f2a209e
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Mar 1 16:41:23 2018 +0000

    Added information gathering section to lit. review

commit 27059125962b9e5e2caf1d8c3a5d0069ab795532
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Mar 2 16:22:19 2018 +0000

    Added section on facial recognition

commit 343ade2bb5080be1e123ccc9030f5aa04202001d
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 6 11:57:48 2018 +0000

    Added watcher file to visualise results

commit a168f741fc221f80ff604eef1533ab4dce987859
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 6 15:46:36 2018 +0000

    Small changes to demo watcher

commit b17c384a04cba0a53a6fad459e2c694ec3d263cf
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 6 16:59:40 2018 +0000

    Increased font size (I'm SO productive)

commit 9d9f12f90bc674d3dd8b242a68b9ca63573a801b
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 13 11:58:59 2018 +0000

    Added current solutions and missing functionality section to lit. review of report

commit 0b9324bb4f5af70cdb12ec1a6dbd99b4f463a16a
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 13 16:34:18 2018 +0000

    Added UML diagram
```

```
commit 3ac847144446a105b16552799242fa509743ca9d
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Sat Mar 17 19:43:08 2018 +0000

    Annotated report with todos for completed project, found other data sets for compa

commit 3b60168fc9acac20dc52ce777b9b1b4582a2efb6
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 20 09:16:42 2018 +0000

    Added SCFace release agreement

commit 064624d5e6aca28334ec32bf30715e05c3875aaa
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 20 09:29:11 2018 +0000

    Updated records

commit 01b3571bfc6ed6ae3981f85009934b912c04c376
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 20 16:53:59 2018 +0000

    Added to test generator script, now generates for essex dataset

commit cb89cd54a1754d3a30c6696cbd968d58e53efc91
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 20 18:18:51 2018 +0000

    Added placeholder for writing about testing section

commit bcca0143916c9c42dbdfed1d8806646ca76155ad
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Wed Mar 21 16:14:48 2018 +0000

    New build of report

commit a20d4b1d7729d326bfc2e74357acd3a2c99c2fe7
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Mon Mar 26 12:44:12 2018 +0100

    Added capability to compare to essex_cswww dataset

commit 33d9057f0e7808e370b63e53e04218a6a8b7cf3b
```

```
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 27 10:07:51 2018 +0100

    Added SCFace cover letter

commit 770235943f10797e1275f5a00eeb30e243da834c
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 27 14:01:18 2018 +0100

    Added new databases to server, began testing in earnest

commit a5702620d5b7f07f60b368bf3221cca6407723a0
Merge: 770235943 33d9057f0
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 27 14:03:42 2018 +0100

    Merge branch 'master' of https://github.com/jackdneilson/hons_project

    Empty merge

commit 498e3a7049f52ed1e6b07d73288c766b63363b0c
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 27 14:07:00 2018 +0100

    Updated json records

commit 82e7916ff1cdc17d70041005c96667ebdf5b7e77
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 27 14:34:44 2018 +0100

    Bugfixes

commit a7f3c7cdcf164fac398adb9f542566fc501b55d3
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 27 14:46:56 2018 +0100

    Refreshed JSON data

commit 75d097821f4c6434048dee988e981bc2e3e5212e
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 27 14:48:58 2018 +0100

    Forgot http:// scheme
```

```
commit 15d5766e998f6d6f03e3a7e4fa7e5c6f67127a76
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 27 14:49:52 2018 +0100

    Forgot http scheme

commit cd30a3c9e986cbfdba5699320dfc16447990f901
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Mar 27 16:22:12 2018 +0100

    Added SCFace data set, bug fixes

commit fdc1c1c201d1a00adce977d6ae378c9bd4aa7023
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Mon Apr 2 17:12:06 2018 +0100

    Added small section on testing methodology

commit 7c15cc30c82326d7f4c5d28aa6584cc9500be3ac
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Mon Apr 2 17:41:03 2018 +0100

    Added png data set

commit e5634e38502ced7eb2e3baf2e70b0f28cae5645f
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Tue Apr 3 13:52:41 2018 +0100

    Finished draft of testing methodology and expected results, added abstract draft

commit 94fc94f074e7fec6cd94d8a7f7c3e9b8f7e69db4
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Apr 6 12:57:31 2018 +0100

    Added first run of test, requirements file for pip

commit 68d3eeef2ec6fe663161e3b694a2735167fd0c4f
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Apr 6 15:05:14 2018 +0100

    Added PNG files for testing to server
```

```
commit 2a8e32db582fc8cb86607ea053c1ae328da5f079
Merge: 68d3eeef2 94fc94f07
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Apr 6 15:05:26 2018 +0100

    Merge branch 'master' of github.com:jackdneilson/hons_project

    Merging changes with results

commit 9a4c0c334558774c441068c9702092ab10890c9a
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Apr 6 15:19:58 2018 +0100

    Added multiple compression test

commit 9b73d61b6d97a960e349319dfeebdf904def43fb
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Wed Apr 11 17:08:08 2018 +0100

    Misc. bugfixes, added test for restricting by identifiable information

commit a4623ab0c11069807d5662dc974c6c28b53e6fec
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Apr 12 15:25:36 2018 +0100

    Added photo of table of results

commit 9d2345a12a643967a996a98adc520da801a87d8c
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Apr 12 15:34:43 2018 +0100

    Changed text size on demo

commit 2d74d83d65824dbc6df483f2029d71a8fdd53dde
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Apr 12 15:35:58 2018 +0100

    Made table of results more readable

commit 75be085240c5d33eaacd420cf43a798d397b9c70
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Apr 12 16:14:35 2018 +0100
```

```
    Added fake ID using socmint

commit e085078c19deeb1d53d0f754015dbe6647efaa18
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Thu Apr 12 17:47:13 2018 +0100

    Added image of help output

commit ae240de015b3d9b214b2940542d0b1dfa616eecb
Author:  <jack@RG-N519-05.rgu.ac.uk>
Date:   Thu Apr 12 18:53:34 2018 +0100

    Added test results for compression algorithms, poster draft

commit 4b86b0177d61c0c68220023709dcd1816783fedd
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Apr 13 19:11:01 2018 +0100

    Added IR and IR_RGB tests and test data, changes to server to serve SCface databas

commit fd80ea6e394341a4ce0138a21c1ab0ef17a49ad8
Author: root <root@RG-N519-05.rgu.ac.uk>
Date:   Fri Apr 13 19:52:42 2018 +0100

    Added final draft of poster, results for IR_image_test

commit 13df87d1cb4be97d0e863bc3e26f5634deaa33ab
Author: root <root@RG-N519-05.rgu.ac.uk>
Date:   Sat Apr 14 17:10:08 2018 +0100

    Removed IR_RGB test as pointless. Made changes to poster

commit f329bb8e7b61d12ddf24c09544bcef214a4a9013
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Mon Apr 23 18:58:04 2018 +0100

    Added copy of full source code and testing results to report

commit 0b0571e3107aad5280ab82cbdfb3d81ec3d448b3
Merge: f329bb8e7 13df87d1c
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Mon Apr 23 18:59:06 2018 +0100
```

```
    Merge branch 'master' of github.com:jackdneilson/hons_project

    Merged to master

commit 06a35ec20a55af5b0996d54c9e6fa9981a4c6be2
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Mon Apr 23 19:17:48 2018 +0100

    Formatted report

commit 8175240eda02b066092cf5ce6839ce43aa576703
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Apr 27 16:03:28 2018 +0100

    Added demo files

commit b32661f27e7470638c16817a57924d4ee76863f0
Author: Jack Neilson <jackdneilson@gmail.com>
Date:   Fri Apr 27 21:37:22 2018 +0100

    Finished first draft of report
```

F Full Source Code

F.1 facegather.py

```
from PIL import Image
from io import BytesIO
import requests
import face_recognition as fr
import threading
import queue
import numpy
import sentinels
import time
import json

IMAGE_LOAD_MAX = 200
DEFAULT_THRESHOLD = 0.5
profile_queue = queue.Queue()
img_queue = queue.Queue()
```

```
# Load an image in to memory from local or remote sources
def load_images(uri, remote=True):
    if remote:
        resp = requests.get(uri, stream=True)
        try:
            img = Image.open(BytesIO(resp.content))
            return fr.face_encodings(numpy.array(img))
        except:
            # Catch line in case PNG file is encoded as greyscale
            return fr.face_encodings(numpy.array(img.convert('RGB')))
    else:
        img_array = fr.load_image_file(uri)
    return fr.face_encodings(img_array)


# Search a data set at the given URI for the best matches to the test face
def search(test_face_location,
           uri,
           no_producer_threads=None,
           no_consumer_threads=None,
           max_loaded=None,
           threshold=None,
           name=None,
           output_location=None):
    # Load default values in case called with "None"
    if no_producer_threads is None:
        no_producer_threads = 1
    if no_consumer_threads is None:
        no_consumer_threads = 1
    if max_loaded is None:
        max_loaded = IMAGE_LOAD_MAX
    if threshold is None:
        threshold = DEFAULT_THRESHOLD

    result = []
    result_lock = threading.Lock()

    profile_queue_counter = threading.Semaphore(int(max_loaded))
    print('Getting profile information...')
    if name is None:
        print(uri)
        profiles = _get_profiles(uri)
    else:
        print(uri + '?name=' + name)
        profiles = _get_profiles(uri + '?name=' + name)
```

```
    for profile in profiles:
        profile_queue.put([profile['image_location'], profile])
    print('Done')

    print('Processing images...')
    processor_list = []
    for i in range(0, int(no_producer_threads)):
        processor = ImageProcessor(profile_queue_counter)
        processor.start()
        processor_list.append(processor)

    recogniser_list = []
    for i in range(0, int(no_consumer_threads)):
        recogniser = FaceRecogniser(test_face_location,
            profile_queue_counter, result, result_lock, threshold)
        recogniser.start()
        recogniser_list.append(recogniser)

    for processor in processor_list:
        processor.join()
    img_queue.put(sentinels.NOTHING)

    for recogniser in recogniser_list:
        recogniser.join()

    print('Done')
    if output_location is None:
        return result
    else:
        output_file = open(output_location + '/facegather_' +
            str(time.time()) + '.txt', 'w')
        output_file.write(json.dumps(result))
        return result


def _get_profiles(uri, name=None):
    if name is not None:
        uri += '?name='
        uri += name
    resp = requests.get(uri)
    return resp.json()


# Class based thread to take a profile from the queue, download the profile
    photo, and pre-process it to be ready for
# facial recognition by 1 or more FaceRecogniser threads
```

```
class ImageProcessor(threading.Thread):
    def __init__(self, counter):
        threading.Thread.__init__(self)
        self.waiting_counter = counter

    # Take a URI from the queue, download image from that location then add
        face mappings and profile uri to the queue
    # to be consumed by a FaceRecogniser
    def run(self):
        while True:
            self.waiting_counter.acquire()
            if profile_queue.empty():
                return
            profile = profile_queue.get()

            img_array = load_images(profile[0])
            for img in img_array:
                img_queue.put([img, profile[1]])


# Class based thread to take images loaded in to memory and rank them in
    terms of similarity to the test image.
class FaceRecogniser(threading.Thread):
    finished_flag = False

    def __init__(self, test_face_location, waiting_counter, result,
        result_lock, threshold):
        threading.Thread.__init__(self)
        self.test_face =
            fr.face_encodings(fr.load_image_file(test_face_location))[0]
        self.counter = waiting_counter
        self.result = result
        self.result_lock = result_lock
        self.threshold = threshold

    # Take a face mapping from the queue, then test for similarity.
    def run(self):
        while True:
            img = img_queue.get()
            if img == sentinels.NOTHING:
                img_queue.put(sentinels.NOTHING)
                return

            if fr.face_distance([self.test_face], img[0]) < self.threshold:
                distance = fr.face_distance([self.test_face], img[0])
                img[1]['distance'] = distance[0]
```

```
                self.result_lock.acquire()
                self.result.append(img[1])
                self.result_lock.release()
            self.counter.release()
```

F.2 run.py

```
from facegather import facegather
import face_recognition
import argparse

parser = argparse.ArgumentParser(
    description='A python3 program to gather social media intelligence using
        facial recognition')
parser.add_argument("test_face", help='Location of the test face')
parser.add_argument("service", help='Social network service to search')

parser.add_argument("--pthreads", help='Number of image processing threads')
parser.add_argument("--cthreads", help='Number of image comparison threads')
parser.add_argument("--maxload", help='Maximum number of images pre-loaded
    into memory')
parser.add_argument("--name", help='Name of person of interest')
parser.add_argument("--output_location", help='Location of results file')

args = parser.parse_args()

uri = ''
if args.service == 'demo':
    uri = 'http://localhost:8081/static'

    test_face = facegather.load_images(uri +
        '/lfw/Aaron_Peirsol/Aaron_Peirsol_0001.jpg')[0]
    test_face2 = facegather.load_images(uri +
        '/lfw/Aaron_Peirsol/Aaron_Peirsol_0002.jpg')[0]
    result = face_recognition.face_distance([test_face], test_face2)
    print(result)

    test_face = facegather.load_images(
        '/home/jack/Documents/hons_project/test/lfw/Aaron_Peirsol/Aaron_Peirsol_0001.jpg',
        remote=False)[0]
    test_face2 = facegather.load_images(
        '/home/jack/Documents/hons_project/test/lfw/Aaron_Peirsol/Aaron_Peirsol_0002.jpg',
        remote=False)[0]
```

```
    result = face_recognition.face_distance([test_face], test_face2)
    print(result)

elif args.service == 'test':
    uri = 'http://localhost:8081/'
    result = ''
    if args.name is not None:
        if args.output_location is not None:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                name=args.name,
                output_location=args.output_location
            )
        else:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                name=args.name
            )
    else:
        if args.output_location is not None:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                output_location=args.output_location
            )
        else:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
            )
    print(result)
```

```
elif args.service == 'test_multiple_db':
    uri = 'http://localhost:8081/test_multiple_datasets/'
    result = ''
    if args.name is not None:
        if args.output_location is not None:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                name=args.name,
                output_location=args.output_location
            )
        else:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                name=args.name
            )
    else:
        if args.output_location is not None:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,https://www.facebook.com/
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                output_location=args.output_location
            )
        else:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
            )
    print(result)

elif args.service == 'test_image_compression':
    uri = 'http://localhost:8081/test_image_compression/'
    result = ''
```

```
    if args.name is not None:
        if args.output_location is not None:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                name=args.name,
                output_location=args.output_location
            )https://www.facebook.com/
        else:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                name=args.name
            )
    else:
        if args.output_location is not None:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                output_location=args.output_location
            )
        else:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
            )
    print(result)

elif args.service == 'test_IR_RGB':
    uri = 'http://localhost:8081/test_IR_RGB/'
    result = ''
    if args.name is not None:
        if args.output_location is not None:
            result = facegather.search(
```

```
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                name=args.name,
                output_location=args.output_location
            )
        else:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                name=args.name
            )
    else:
        if args.output_location is not None:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                output_location=args.output_location
            )
        else:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
            )
    print(result)

elif args.service == 'test_IR_images':
    uri = 'http://localhost:8081/test_IR_images/'
    result = ''
    if args.name is not None:
        if args.output_location is not None:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
```

```
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                name=args.name,
                output_location=args.output_location
            )
        else:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                name=args.name
            )
    else:
        if args.output_location is not None:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
                output_location=args.output_location
            )
        else:
            result = facegather.search(
                args.test_face,
                uri,
                no_producer_threads=args.pthreads,
                no_consumer_threads=args.cthreads,
                max_loaded=args.maxload,
            )
    print(result)
```

F.3 server.py

```
import cherrypy as cp
import glob


class EnumerateFiles:
    @cp.expose
    def index(self, **kwargs):
```

```
        directory = 'test/**'
        if 'name' in kwargs:
            directory = 'test/**/' + kwargs['name']

        sb = '['
        for location in glob.glob(directory + '/*.json', recursive=True):
            if not location[-9:] == '_png.json':
                f = open(location, 'r')
                sb += f.read()
                sb += ','https://www.facebook.com/
                f.close()
        if sb.endswith('['):
            return '[]'
        else:
            return sb[:-1] + ']'


class TestMultipleDB:
    @cp.expose
    def index(self, **kwargs):
        directories = ['test/lfw/', 'test/essex_cswww/']
        sb = '['
        for directory in directories:
            if 'name' in kwargs:
                directory = directory + kwargs['name'] + '/'
            for location in glob.glob(directory + '**/*.json',
                recursive=True):
                f = open(location, 'r')
                sb += f.read()
                sb += ','
                f.close()
        sb = sb[:-1] + ']'
        return sb


class TestImageCompression:
    @cp.expose
    def index(self):
        sb = '['
        for location in glob.glob('test/lfw/**/*_png.json', recursive=True):
            f = open(location, 'r')
            sb += f.read()
            sb += ','
            f.close()
        sb = sb[:-1] + ']'
        return sb
```

```
class TestIRImages:
    @cp.expose
    def index(self):
        sb = '['
        for location in
            glob.glob('test/SCface/SCface_database/surveillance_cameras_IR_cam8/*.json'):
            f = open(location, 'r')
            sb += f.read()
            sb += ','
            f.close()
        sb = sb[:-1] + ']'
        return sb


if __name__ == '__main__':
    cp.config.update({
        'server.socket_port': 8080,
        'tools.proxy.on': True,
        'tools.proxy.base': 'localhost'
    })

    home = EnumerateFiles()

    cp.tree.mount(EnumerateFiles(), '/', None)
    cp.tree.mount(TestMultipleDB(), '/test_multiple_datasets', None)
    cp.tree.mount(TestImageCompression(), '/test_image_compression', None)
    cp.tree.mount(TestIRImages(), '/test_IR_images', None)

    cp.engine.start()
    cp.engine.block()
```

F.4 compression_algorithm_test.sh

```
#!/bin/sh
python3 run.py ./test/lfw/Aaron_Peirsol/Aaron_Peirsol_0001.jpg
    test_image_compression --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/compression_algorithm_test;
python3 run.py ./test/lfw/Doc_Rivers/Doc_Rivers_0001.jpg
    test_image_compression --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/compression_algorithm_test;
```

```
python3 run.py ./test/lfw/George_HW_Bush/George_HW_Bush_0003.jpg
    test_image_compression --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/compression_algorithm_test;
python3 run.py ./test/lfw/Joseph_Blatter/Joseph_Blatter_0002.jpg
    test_image_compression --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/compression_algorithm_test;
python3 run.py ./test/lfw/Tony_Blair/Tony_Blair_0006.jpg
    test_image_compression --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/compression_algorithm_test;
```

F.5 identifying_information_restriction_test.sh

```
#!/bin/sh
python3 run.py ./test/lfw/George_HW_Bush/George_HW_Bush_0003.jpg test
    --pthreads=2 --cthreads=2 --maxload=200 --name="George*"
    --output_location=./test/results/identifying_information_restriction_test;
python3 run.py ./test/essex_cswww/faces94/male/cjsake/cjsake.1.jpg test
    --pthreads=2 --cthreads=2 --maxload=200 --name="cj*"
    --output_location=./test/results/identifying_information_restriction_test;
python3 run.py ./test/essex_cswww/faces95/adhast/adhast.1.jpg test
    --pthreads=2 --cthreads=2 --maxload=200 --name="ad*"
    --output_location=./test/results/identifying_information_restriction_test;
python3 run.py ./test/essex_cswww/faces96/cjhewi/cjhewi.1.jpg test
    --pthreads=2 --cthreads=2 --maxload=200 --name="cj*"
    --output_location=./test/results/identifying_information_restriction_test;
python3 run.py ./test/essex_cswww/grimace/glen/glen_exp.16.jpg test
    --pthreads=2 --cthreads=2 --maxload=200 --name="glen*"
    --output_location=./test/results/identifying_information_restriction_test;
```

F.6 IR_image_test.sh

```
#!/bin/sh
python3 run.py
    ./test/SCface/SCface_database/surveillance_cameras_IR_cam8/001_cam8.jpg
    test_IR_images --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/IR_image_test;
python3 run.py
    ./test/SCface/SCface_database/surveillance_cameras_IR_cam8/012_cam8.jpg
    test_IR_images --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/IR_image_test;
```

```
python3 run.py
    ./test/SCface/SCface_database/surveillance_cameras_IR_cam8/018_cam8.jpg
    test_IR_images --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/IR_image_test;
python3 run.py
    ./test/SCface/SCface_database/surveillance_cameras_IR_cam8/050_cam8.jpg
    test_IR_images --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/IR_image_test;
python3 run.py
    ./test/SCface/SCface_database/surveillance_cameras_IR_cam8/123_cam8.jpg
    test_IR_images --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/IR_image_test;
```

F.7 multiple_dataset_test.sh

```
#!/bin/sh
python3 run.py ./test/essex_cswww/faces94/male/cjsake/cjsake.1.jpg
    test_multiple_db --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/multiple_dataset_test;
python3 run.py ./test/essex_cswww/faces95/adhast/adhast.1.jpg
    test_multiple_db --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/multiple_dataset_test;
python3 run.py ./test/essex_cswww/faces96/cjhewi/cjhewi.1.jpg
    test_multiple_db --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/multiple_dataset_test;
python3 run.py ./test/essex_cswww/grimace/glen/glen_exp.16.jpg
    test_multiple_db --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/multiple_dataset_test;
python3 run.py ./test/lfw/Aaron_Peirsol/Aaron_Peirsol_0001.jpg
    test_multiple_db --pthreads=2 --cthreads=2 --maxload=200
    --output_location=./test/results/multiple_dataset_test;
```

F.8 generate_test_data.py

```
import glob


def generate_data(root_dir):
    for location in glob.glob(root_dir + '/lfw/**/*.jpg', recursive=True):
        file = open(location[:-3] + 'json', 'w')
```

```
    towrite = '{"name":"%s", "image_location":"%s"}' %
        (location.split('/')[-2],
        'http://localhost:8081/static'+location[1:])
    file.write(towrite)
    file.close()

# for location in glob.glob(root_dir + '/lfw/**/*.jpg', recursive=True):
#    print(location)
#    subprocess.run(["convert", location, "-colorspace", "sRGB", "-type",
    "truecolor", location[:-3] + "png"])

for location in glob.glob(root_dir + '/lfw/**/*.png', recursive=True):
    file = open(location[:-4] + '_png.json', 'w')
    towrite = '{"name":"%s", "image_location":"%s"}' %
        (location.split('/')[-2],
        'http://localhost:8081/static'+location[1:])
    file.write(towrite)
    file.close()

for location in glob.glob(root_dir + '/essex_cswww/**/*.jpg',
    recursive=True):
    file = open(location[:-3] + 'json', 'w')
    towrite = '{"name":"%s", "image_location":"%s"}' %
        (location.split('/')[-2],
        'http://localhost:8081/static'+location[1:])
    file.write(towrite)
    file.close()

# SCface db has several formats, need to be specific
for location in glob.glob(root_dir +
    '/SCface/SCface_database/mugshot_frontal_cropped_all/*.JPG',
    recursive=True):
    file = open(location[:-12] + '.json', 'w')
    towrite = '{"name":"%s", "image_location":"%s"}' %
        (location.split('/')[-1][:3],
        'http://localhost:8081/static'+location[1:])
    file.write(towrite)
    file.close()

for location in glob.glob(root_dir +
    '/SCface/SCface_database/mugshot_frontal_original_all/*.jpg',
    recursive=True):
    file = open(location[:-12] + '.json', 'w')
    towrite = '{"name":"%s", "image_location":"%s"}' %
        (location.split('/')[-1][:3],
        'http://localhost:8081/static'+location[1:])
```

```
        file.write(towrite)
        file.close()

    for location in glob.glob(root_dir +
        '/SCface/SCface_database/mugshot_rotation_all/*.jpg', recursive=True):
        name = location.split('/')[-1][:-4]
        towrite = '{"name":"%s", "image_location":"%s"}' % (name,
            'http://localhost:8081/static' + location[1:])
        file = open(location[:-3] + 'json', 'w')
        file.write(towrite)
        file.close()

    for location in glob.glob(root_dir +
        '/SCface/SCface_database/surveillance_cameras_*/**/*.jpg',
        recursive=True):
        name = location.split('/')[-1][:-4]
        towrite = '{"name":"%s", "image_location":"%s"}' % (name,
            'http://localhost:8081/static' + location[1:])
        file = open(location[:-3] + 'json', 'w')
        file.write(towrite)
        file.close()


generate_data('.')
```

G Example nginx configuration file

```
  upstream app_server {
     server localhost:8080;
  }

  gzip_http_version 1.0;
  gzip_proxied    any;
  gzip_min_length    500;
  gzip_disable    "MSIE [1-6]\.";
  gzip_types    text/plain text/xml text/css
          text/javascript
          application/json;

  server {
     listen 8081;
     location ^~ /static {
        alias /home/jack/Documents/hons_project/test/;
```

```
    }

    location / {
       proxy_pass http://app_server;
       proxy_redirect off;
       proxy_set_header Host $host;
       proxy_set_header X-Real-IP $remote_addr;
       proxy_set_header X-Forwarded-For $proxy_add_x_forwarded_for;
       proxy_set_header X-Forwarded-Host $server_name;
    }
  }
```

H Poster

USING FACIAL RECOGNITION TO GATHER SOCIAL MEDIA INTELLIGENCE

Abstract

Social Media Intelligence (SOCMINT) is a relatively unexplored source of intelligence, examining data contained within social media profiles. It is a subset of Open Source Information, where data on a subject is gathered using publicly available resources. Many see it as a vital aspect of modern information gathering – both the US FBI and the UK MOD have invested heavily in tools to utilize SOCMINT (Antonius and Rich, 2013)

There are very few examples of facial recognition being applied to SOCMINT to assist in gathering or analysis. It is therefore my aim to develop a tool will assist human operators in gathering social media intelligence by searching a database of faces to find potential matches to a face in a test image.

Introduction

Social media intelligence has been shown to have many uses, from detecting potential insider threads (Kandias and Stavrou, 2015) to increasing the effectiveness of prior knowledge attacks. The second point is particularly relevant, as it allows an adversary with no privileged information (OSINT only) to potentially gain access to networks or sensitive information by means of a spearphishing or social engineering attack.

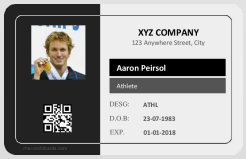


Figure 1. An example of a fake ID card that could be created with a person of interest's name, date of birth and picture. Created by template from msword.dcards.com.

Although the usefulness of social media intelligence has been established, gathering and analysing it may not be as easy as it first appears. The problem for would-be analysts is the sheer amount of data contained within social media platforms – for example, 250 million photos are added to Facebook every day (Omand et. al., 2012).

To find useful information about a single person of interest in such a large data set is extremely challenging. Success rates increase dramatically if some starting point is known, such as a first name, a date of birth, or in this case the person's face. These factors may also be used in combination to increase accuracy and search speed.

Methods and Materials

Rather than search against actual social networks with real people, a database of test profiles was generated using the Labeled Faces in the Wild data set (Huang et. al., 2007), the Essex Face Recognition data set (Hond and Spacek, 1997), and the Security Camera Face data set (Grgic, Delac and Grgic, 2009). The tool used to search the data set was developed using Python version 3, using the face-recognition module with dlib as the underlying face recognition implementation. It includes a requirements.txt file to allow for easy installation of all pre-requisites using pip, and is used from the command line. A small demo file has been included that watches for results, and creates a HTML page that may be viewed for visualisation purposes.

The software was tested using data sets with different compression algorithms (JPG vs PNG), untrained data sets, data sets containing infra-red images, and data sets that were restricting by a piece of personally identifying information.

```
jack@seven:~/Documents/hons_projects$ python3 run.py -h
usage: run.py [-h] [--pthreads PTHREADS] [--cthreads CTHREADS]
              [--maxload MAXLOAD] [--name NAME]
              [--output_location OUTPUT_LOCATION]
              test_face service

A python3 program to gather social media intelligence using facial recognition

positional arguments:
  test_face             Location of the test face
  service               Social network service to search

optional arguments:
  -h, --help            show this help message and exit
  --pthreads PTHREADS   Number of image processing threads
  --cthreads CTHREADS   Number of image comparison threads
  --maxload MAXLOAD     Maximum number of images pre-loaded into memory
  --name NAME           Name of person of interest
  --output_location OUTPUT_LOCATION
                        Location of results file
```

Figure 2. The "help" message that shows all positional and optional arguments that may be used with the program.

Results

The software performed excellently on both the untrained data set and the restricted data set, achieving 100% accuracy with 0 false positives over 5 tests in both cases. Of particular note is the restricted data set – by massively reducing the number of images to compare, the average length of each search was reduced to just 25 seconds.

When searching across a data set with a different compression algorithm, the same results were noted. However, the distance between two otherwise identical images was non-0 suggesting that the compression algorithm may produce some baseline error during comparison.

Searching across the SCFace data set with the infra-red images produced much worse results. While the original image was always compared with a distance of 0, the accuracy was negatively impacted by the presence of several false positives. It is theorised that the IR images lack facial detail, and are difficult to place descriptors on due to the lack of colour.

Name	Distance	Image
Aaron_Peirsol	0.3356236792042648	
Aaron_Peirsol	0.41244297976804756	
Aaron_Peirsol	0.0	
Aaron_Peirsol	0.3593687996180006	

Table 1. Results when using searching with the test image Aaron_Peirsol_0001.jpg, restricted with the term "Aaron*" (i.e. search for all people named "Aaron").

Conclusions

The program implemented shows that, yes, it is possible to use facial recognition to assist in the gathering and analysis of social media intelligence. The automation of this task could be greatly beneficial to intelligence services, private firms wishing to gather intelligence, or private citizens wishing to see their SOCMINT footprint. There are however several caveats:

While testing showed promising results in terms of accuracy, the time taken for each search is excessive. The program can undoubtedly search large data sets faster than a human could, but having searches last over an hour over a small data set (in comparison to all profile photos on a social networking service) means that it is unlikely to be able to scale well.

As a corollary, since the time taken for each search is so long only limited testing could be performed. It is likely that the 100% accuracy rating achieved over the tests is close to the true accuracy that the program could achieve, the small sample size of tests makes it difficult to say this definitively.

Finally, the service this program provides may not be accessible to all. Using it against a real social network rather than a test data set would require setting up a proxy server to present data in the expected manner, as well as having the service in question allow access to the full (or at least, a sizeable portion) collection of profile images. This is feasible for security services and large corporations but is likely outside the scope of what a single person could acquire.

References

Antonius, N. and Rich, L. (2013), 'Discovering collection and analysis techniques for social media to improve public safety', 3, 42.

Kandias, M. and Stavrou, V. (2015), 'Personal traits analysis as a means to predict insiders'.

Omand, S. D., Bartlett, J. and Miller, C. (2012), 'Introducing social media intelligence (socmint)', *Intelligence and National Security* 27(6), 801-823.

Huang, G., Ramesh, M., Berg, T. and Learned-Miller, E. (2007), 'Labeled Faces in the Wild: A Database for Studying Face Recognition in Unconstrained Environments'.

Hond, D. and Spacek, L. (1997), 'Distinctive Descriptions for Face Processing'.

Grgic, M., Delac, K. and Grgic, S. (2011), 'SCFace – surveillance cameras face database'.

ROBERT GORDON UNIVERSITY ABERDEEN

Jack Neilson; 1506801

I Ethics Form

STUDENT PROJECT ETHICAL REVIEW (SPER) FORM

The aim of the University's *Research Ethics Policy* is to establish and promote good ethical practice in the conduct of academic research. The questionnaire is intended to enable researchers to undertake an initial self-assessment of ethical issues in their research. Ethical conduct is not primarily a matter of following fixed rules; it depends on researchers developing a considered, flexible and thoughtful practice.

The questionnaire aims to engage researchers discursively with the ethical dimensions of their work and potential ethical issues, and the main focus of any subsequent review is not to 'approve' or 'disapprove' of a project but to make sure that this process has taken place.

The *Research Ethics Policy* is available at www.intranet.rgu.ac.uk/credo/staff/page.cfm?pge=7060

Student Name	Jack Neilson
Supervisor	Dr. John Isaacs
Project Title	Using Facial Recognition to gather Social Media Intelligence
Course of Study	Computer Science
School/Department	Computer Science and Digital Media

Part 1 : Descriptive Questions			
1	Does the research involve, or does information in the research relate to:	Yes	No
	(a) individual human subjects		x
	(b) groups (e.g. families, communities, crowds)		x
	(c) organisations		x
	(d) animals?		x
	Please provide further details:		
2	Will the research deal with information which is private or confidential?	Yes	No
			x
	Please provide further details:		
	The research will use publicly available images from the YouTube Faces repository within the limits of it's terms and conditions.		

Part 2: The Impact of the Research			
3	In the process of doing the research, is there any potential for harm to be done to, or costs to be imposed on	Yes	No
	(a) research participants?		x
	(b) research subjects?		x
	(c) you, as the researcher?		x
	(d) third parties?		x
	Please state what you believe are the implications of the research:		
4	When the research is complete, could negative consequences follow:	Yes	No
	(a) for research subjects		x
	(b) or elsewhere?	x	
	Please state what you believe are the consequences of the research:		
	When it is finished, the research could be applied to actual data on a social media website and could gather potentially damaging information about a single person. The licensing agreement should make clear that the research is for personal use only, unless the informed consent of all participants can be obtained.		

Part 3: Ethical Procedures			
5	Does the research require informed consent or approval from:	Yes	No
	(a) research participants?		x
	(b) research subjects		x
	(c) external bodies		x
	If you answered yes to any of the above, please explain your answer:		
6	Are there reasons why research subjects may need safeguards or protection?	Yes	No
			x
	If you answered yes to the above, please state the reasons and indicate the measures to be		
7	Has PVG membership status been considered?	x	
	(a) PVG membership is not required.	x	
	(b) PVG membership is required for working with children.		
	(c) PVG membership is required for working with protected adults.		
	(d) PVG membership is required for working with both children and protected		
	If you answered yes to (b), (c) or (d) above, please give details:		
8	Are specified procedures or safeguards required for recording, management, or storage of data?	Yes	No
			x
	If you answered yes to the above, please outline the likely undertakings: No private or confidential data will be recorded or stored. Any data that is recorded or stored will be anonymised and will follow RGU's data protection policy.		

Part 4: The Research Relationship			
9	Does the research require you to give or make undertakings to research participants or subjects about the use of data?	Yes	No
			x
	If you answered yes to the above, please outline the likely undertakings:		
10	Is the research likely to be affected by the relationship with a sponsor, funder or employer?	Yes	No
			x
	If you answered yes to the above, please identify how the research may be affected:		

Part 5: Other Issues			
11	Are there any other ethical issues not covered by this form which you believe you should raise?	Yes	No
			x

Statement by Student			
I believe that the information I have given in this form is correct, and that I have addressed the ethical issues as fully as possible at this stage.			
Signature	J. Neilson	Date	03/11/2017

If any ethical issues arise during the course of the research, students should complete a further Student Project Ethical Review (SPER) form.

The *Research Ethics Policy* is available at www.intranet.rgu.ac.uk/credo/staff/page.cfm?pge=7060

J Proposal

Appendix C - Detailed Project Proposal

First Name:	Jack
Last Name:	Neilson
Student Number:	1506801
Supervisor:	Dr. John Isaacs

1.
2. Defining your Project

1.1 Detailed research question/problem

Help: Your detailed research question is the statement of a problem within the computing domain, which you will address in your project. Refining the research question involves narrowing down an initial question until it is answerable using a primary research method(s) that you will conduct during the time of your project. The refined research question must not be so general that it is answerable with a yes or no answer. It must not be so broad that you would be unable to achieve a solution during your project. The key to this is BEING SPECIFIC: Narrow down the method or technology you will use, narrow down the group that the question refers to (localize a general question) If the project is still 'too big', can you think of a way to work on a part of the problem? Avoid using words that cannot be measured, by you, without a huge research budget e.g. 'effects on society', 'effects on business'. *Example:* The initial question "Does cloud computing effect business" needs narrowing down *(for a start the answer is yes) W*hat is meant by cloud computing? Or 'effect'? Or 'business', in this question? Refining this first question will involve narrowing it down to something you, personally, can measure. A refined version of this question might be: "Does implementing a cloud based voting system improve the speed of decision making in a small company in Aberdeen?" This refined question is implementable: You can now identify a small company to work with, document their current decision making processes, implement a cloud based voting system, compare decision making speeds over a limited time period (say 1 month) and evaluate your findings. *A small piece of genuinely new knowledge is produced*.

Is it possible for an entity with extremely limited resources to develop a system that uses facial recognition to assist in the gathering of open source intelligent from social media?

1.2 Keywords

Help: Include up to 6 keywords separated by a semi-colon; what keywords are appropriate to describe your project in an online database like Google Scholar? Keywords should include the general research area and the specific technologies you will be working with. *Example.* A project that proposes a novel way of visualising large amounts of twitter feed data may have the keywords: Data visualisation; twitter; hashtags; database design; graphics libraries.

SOCMINT; Facial Recognition; OSINT; Social Media; Artificial Intelligence

1.3 Project title

Help: The project title is a statement based on your detailed research question. For example, the research question *'to what extent does a mobile application reduce the number of errors made in class registers at RGU in comparison to current paper based registers'* may be stated in the project title: *"A Wi-Fi driven mobile application for large group registers using iBeacons"*.

Using Facial Recognition to gather Social Media Intelligence

1.4 Client, Audience and Motivation:

Help: Why is this project important? To whom is this project important? A project must address a question/problem that generates a small piece of new knowledge/solution. This new knowledge/solution must be important to a named group or to a specific client (such as a company, an academic audience, policy makers, people with disabilities) to make it worthwhile carrying out. This is the ***motivation*** for your project. In this section you should address who will benefit from your findings and how they will benefit. Example: If you intend to demonstrate that a mobile application that automates class registers at RGU will be more efficient than paper based registers - the group who would be interested in knowing/applying these findings would be both academic and administrative staff at RGU and they would benefit by time saved and a reduction in their administrative workload. If you are making a business case for an organization explain how the organisation will benefit from your findings.

The main beneficiaries of this project are security analysts / researchers who wish to protect their employers from attacks that utilise SOCMINT, as well as members of the general public who are concerned about how their privacy may be infringed by automated scanning of social media (in particular the ACLU, as the tool to be developed mirrors some of the capabilities of the NSA's social media scanning tool). The tool will allow users to see what information hostile actors can gather from their social media, allowing redaction or mitigation of potential threats e.g. spearphish attacks, social engineering attacks. Additionally, it may be of use to security services in the field of anti-terrorism when trying to identify suspects.

1.5 Project Plan

Help: This is the project plan as to how you will go about achieving the objectives of the project. It must include the methods you plan to use such as for example experiments, applications or software demonstrators, process models, surveys, analysis of generated data ...

Example: In the class register example above "to what extent does a mobile application reduce the number of errors made in class registers at RGU in comparison to current paper based registers" - the research plan may involve: 1) Collecting and analysing paper based registers in a given class on five occasions. 2) Identifying the error rate average on these occasions 3) Designing and implementing a mobile application that automatically records attendance in class. 4) Deploying the application in the class on five occasions. 5) Identifying the error rate average of the mobile application on these occasions. 6) Comparison of data and summary of findings.

1. Gathering papers, background research
    - 1.1. Literature review
    - 1.2. Project proposal
    - 1.3. Timescale
    - 1.4. Background gathering on technical implementation
2. Review prior work in depth
    - 2.1. Find examples of SOCMINT using data other than faces
    - 2.2. Find examples of large-scale unconstrained facial recognition not applied to social media
    - 2.3. Find practical uses of social media intelligence
3. Design
    - 3.1. Requirements gathering
    - 3.2. Success metrics
    - 3.3. Initial design of program (data structures, class diagrams etc.)
    - 3.4. Choose libraries etc. to use
4. Implementation
    - 4.1. Create test accounts (YTF, PFW for large-scale face data set)
    - 4.2. Start facial recognition element
    - 4.3. Test facial recognition element (unit, baseline results)
    - 4.4. Implement other vectors for identification (name, DOB, location etc.)
5. Testing
    - 5.1. Test program for correctness
    - 5.2. Test program for efficacy against small data set (IARPA Janus)
    - 5.3. Test program for efficacy against real-world or close simulated data set
6. Report

6.1. Record results of testing

6.2. Full literature review

6.3. Changes made to initial plan

6.4. Efficacy of program

7. Presentation

7.1. Visualise results

7.2. Condense subject matter

7.3. Create presentation

This is the end of section one.

3. Section Two: abstract and initial literature review

2.1 Abstract

Help: An abstract is a short summary of the project that enables others to know if your report is relevant to them without reading the whole report. It is usually written retrospectively so that it can include findings and results. It is fully expected that you will rewrite your abstract when you come to write your final paper. For now, you should write an abstract of about 250 words that define the project described in section one. Before writing your abstract you MUST read some abstracts from conference or journal papers on *Google Scholar* or from *portal.acm.org* (to understand their style) and then provide your own abstract that outlines what your question is and what you 'did' to answer it.

For some people social networking websites are a large part of social life. Many of these people may not realise how much sensitive information they are sharing on these sites, and how easily identifiable they are from a starting point of as little as a picture of their face. This paper will examine the viability of unconstrained facial recognition in tandem with other open source information to identify social media users. This capability mirrors the work done by the NSA and GCHQ, and should provide some insight in to how difficult (or otherwise) it is to identify a person given minimal information. The program developed is a command line tool which takes multiple inputs and will return a list of the closest matches to be sifted through manually. Since this paper has obvious ethical implications, test accounts will be generated to provide statistics on accuracy.

Unconstrained facial recognition has proven to be an exceptionally difficult problem in computing. While some success has been achieved using controlled samples with cooperative subjects, facial recognition in the context of social media has not been significantly explored in academia. Several confounding factors exist which make this problem much harder, such as variance in subjects' pose, ambient light and facial occlusion. To increase the accuracy of the tool developed, other identifying information has been used e.g. subject's name, home town etc.

2.2 Initial/Mini Literature Review (500 words maximum)

Help: A literature review is a select analysis of current existing research, which is relevant to your topic, showing how it relates to your investigation. It explains and justifies how your investigation may help answer some of the questions or gaps in this area of research. A literature review is not a straightforward summary of everything you have read on the topic and it is not a chronological description of what was discovered in your field. Use your literature review to:

- compare and contrast different authors' views on an issue
- criticise aspects of methodology, note areas in which authors are in disagreement
- highlight exemplary studies
- highlight gaps in research
- show how your study relates to previous studies

Little public work has been done in the field of facial recognition with respect to social networks. Most research in this area has been on the techniques used to analyse images, rather than the applications that could come from being able to recognise people's faces on social media (Becker et. al. 2008). A large part of the work done in the practical application of facial recognition in social media has been done by the security services and is appropriately classified.

Much more work has been done in the field of unconstrained facial recognition. Some of this work is particularly relevant as it relates to identifying people from a large data set (Best-Rowden et. al. 2014; Klontz

et. al. 2013; Stone et. al. 2010; Cui et. al. 2013), sometimes in adverse conditions such as side pose, low lighting and facial occlusion (Biswas et. al. 2013). By using these techniques in conjunction with other identifying information, it may be possible to positively identify a person's social media account. Although it is particularly challenging, some practical applications of unconstrained facial recognition have begun to emerge. For example, a group of researchers used the images of the "Boston Bombings" perpetrators that were released to the public and tested them against a database to find the efficacy of several approaches (Klontz et. al. 2013).

A relatively new area of research is Social Media Intelligence (SOCMINT). It involves using data gathered from social networks to learn more about a subject, and to make inferences about them from this information (Omand et. al. 2012). Because social media is so ubiquitous, information gathered this way poses a large security and privacy risk. For example, intelligence gathered through social media could be used to personalise a highly effective spearphishing attack (Parmar 2012).

Several methods have been proposed for face recognition in the wild. The papers "Pushing the Frontiers of Unconstrained Face Detection and Recognition" (Klare et. al. 2015) and "Fusing Robust Face Region Descriptors via Multiple Metric Learning for Face Recognition in the Wild" (Cui et. al. 2013) are of particular interest as they deal with faces in less than ideal poses and lighting, similar to what would be found in a social media profile. The first of these papers uses an open-source facial recognition library "OpenBR" against the IARPA Janus data set (Klare et. al. 2015, p137 s3.4) as a baseline with a success rate of 0.627 ± 0.012 at a false acceptance rate of 0.1 (Klare et. al. 2015, p137 table 3). This shows the difficulty of unconstrained facial recognition even with a small sample size - many of the images used could not be enrolled successfully as the pose used showed only one eye (Klare et. al. 2015, p137 s3.4).

The second paper is much more promising, and it achieves state of the art performance on two real world data sets (Labeled Faces in the Wild[LFW] and YouTube Faces[YTF]) (Cui et. al. 2013, p3554 s1). It takes a novel approach to placing facial descriptors which are used for comparison, allowing for a much more robust detection of facial features in images where the face is partially occluded or in a side pose.

These recent advances in unconstrained facial recognition could be applied to social media networks to gather large amounts of SOCMINT.

2.3 Relevant professional, social, ethical, security and legal issues to the project

Because the project has the capability to infringe upon an individual's privacy and threaten their security, strict countermeasures must be taken to ensure that no harm comes of the research. During the testing phase test accounts will be generated using publicly available images of faces (YTF etc.) and randomly generated strings of text to act as placeholders for names, dates of birth etc. The aim of the project is to allow users and security professionals to increase safety, as such the end product will be released under the GNU AGPL 3.0 license to provide maximum transparency. It will also be released with the understanding that it is for personal use, or use on those who have given informed contest, only. Although some may consider the tool to breach their privacy, it should be noted that it only makes use of publicly available information.

Some social media website's terms and conditions would forbid the use of this program against their website. The responsibility here is on the end user to use the program in

accordance with these terms and conditions.

2.4 Bibliography (key texts for your literature review)

Help: Please provide references, in correct Harvard style, for at least three key texts that have informed your literature review. If you are implementing an application, select texts, which demonstrate how other researchers have tackled similar implementations? The references should be recent and sufficiently technical or academic. Your markers will be looking for you to identify technical reports, conference papers, journal papers, and recent textbooks. Avoid *Wikipedia* entries, newspaper reports that do not cite sources, and general or introductory texts.

"Evaluation of Face Recognition Techniques for Application to Facebook" - Brian C. Becker, Enrique G. Ortiz c. 2008

"Unconstrained Face Recognition: Identifying a Person of Interest From a Media Collection" – Lacy Best-Rowden, Hu Han, Charles Otto, Brendan F. Klare, Anil K. Jain; IEEE Transactions on Information Forensics and Security vol. 9 no. 12 c. 2014

"A Case Study on Unconstrained Facial Recognition Using the Boston Marathon Bombings Suspects" – Joshua C. Klontz, Anil K. Jain; Technical Report MSU-CSE-13-4 c. 2013

"Toward Large-Scale Face Recognition using Social Network Context" – Zak Stone, Todd Zickler, Trevor Darrell; Proceedings of the IEEE vol. 98 no. 8 c. 2010

"Pose-Robust Recognition of Low-Resolution Face Images" – Soma Biswas, Gaurav Aggarwal, Patrick J. Flynn, Kevin W. Bowyer; IEEE Transactions on Pattern Analysis and Machine Intelligence vol. 35 no. 12 c. 2013

"Introducing Social Media Intelligence" – David Omand, Jamie Bartlett, Carl Miller; Intelligence and National Security vol. 27, no. 6 c. 2012

"Protecting Against Spear-Phishing" – Bimal Parmar; Computer Fraud & Security c. 2012

"Pushing the Frontiers of Unconstrained Face Detection and Recognition" – Brendan F. Klare, Ben Klein, Emma Taborsky et al., c. 2015

"A Literature Review of Social Media Intelligence Capabilities for Counter Terrorism" – Jamie Bartlett, Louis Reynolds c. 2015

"Accessorize to a Crime: Real and Stealthy Attacks on State-of-the-Art Face Recognition" – Mamood Sharif, Sruti Bhagavatula, Lujo Bauer c. 2016

This is the end of section two.