National College of Ireland

Project Submission Sheet

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Programme:	MSc/PGD in Cybersecurity **Year:** 1
Module:	Forensics and eDiscovery
Lecturer:	Michael Prior MSc/PGD
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I hereby certify that the information contained in this (my submission) is information pertaining to research I conducted for this project. All information other than my own contribution will be fully referenced and listed in the relevant bibliography section at the rear of the project.
ALL internet material must be referenced in the references section. Students are encouraged to use the Harvard Referencing Standard supplied by the Library. To use other author's written or electronic work is illegal (plagiarism) and may result in disciplinary action. Students may be required to undergo a viva (oral examination) if there is suspicion about the validity of their submitted work.

Signature:	Matthew Browne
Date:	16th April 2025

PLEASE READ THE FOLLOWING INSTRUCTIONS:

1. Please attach a completed copy of this sheet to each project (including multiple copies).
2. Projects should be submitted to your Programme Coordinator.
3. **You must ensure that you retain a HARD COPY of ALL projects**, both for your own reference and in case a project is lost or mislaid. It is not sufficient to keep a copy on computer. Please do not bind projects or place in covers unless specifically requested.
4. You must ensure that all projects are submitted to your Programme Coordinator on or before the required submission date. **Late submissions will incur penalties.**
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AI Acknowledgement Supplement

Your Name/Student Number Course		Date
Name: Matthew Browne Student Number : x21174415	MSc/PGD in Cybersecurity	16/04/2025

This section is a supplement to the main assignment, to be used if AI was used in any capacity in the creation of your assignment; if you have queries about how to do this, please contact your lecturer. For an example of how to fill these sections out, please click here.

AI Acknowledgment

This section acknowledges the AI tools that were utilized in the process of completing this assignment.

Tool Name	Brief Description	Link to tool

Description of AI Usage

This section provides a more detailed description of how the AI tools were used in the assignment. It includes information about the prompts given to the AI tool, the responses received, and how these responses were utilized or modified in the assignment. **One table should be used for each tool used**.

Free Harvard Referencing Generator	

Evidence of AI Usage

This section includes evidence of significant prompts and responses used or generated through the AI tool. It should provide a clear understanding of the extent to which the AI tool was used in the assignment. Evidence may be attached via screenshots or text.

Additional Evidence:

[Place evidence here]

Additional Evidence:

[Place evidence here]

CA2, Application of Data Analytics and Machine Learning in CCTV Footage Analysis for Criminal Investigations

Matthew Browne
Student ID: x21174415

Executive Summary

Requirement 1: {Description of the objectives of the investigation}

{10 Marks}

For my assignment I will be looking at and exploring the Application of Data Analytics and Machine Learning within Digital Forensics , the requirements are to understand how data analytics and machine learning are utilised to automate processes and procedures in real world scenarios my assignment will be focused on looking at how these technologies and techniques can be applied in the areas of close circuit television recordings as part of an investigation such as a criminal one.

The key requirement of my assignment will be to look how these tools and techniques make it more accessible and cut down time on mundane tasks like identifying , tracking and understanding video evidence which may be given in a court of law. I'll also be able to look at how video evidence is processed in terms of artificial intelligence and how this can also be used for activities like detecting everyday objects , action's taken and looking for anomalies.

By undertaking and literature review ill be looking at , analysing how an algorithm for machine learning helps with everyday tasks like identifying people , tracking movement , and understanding video footage with a microscopic lens minus the microscope. As part of this ill be using a form of analytics (wikipedia.org, 2019) to tell me more about the evidence.

Machine learning is known for its ability to complete mundane tasks such as analysing images in camera footage , anomaly detection (wikipedia.org, 2019) is the art of detecting these anomalies in forensics. It should be noted that Artificial intelligence and Machine Learning still have many issues and challenges in terms of being able to accurately define results and can sometimes lead to mistakes caution should be applied where necessary.

Methodology & Literature Review

Requirement 2: {Details and justifications , with references of the research methods that were used}

My methodology for this paper was to try use a small quantity of open access easy to find documentation , whitepaper's . research review's , online journals and technical papers from companies like NVidia Deep Stream , IEEE and Computer Vision Foundation. For this I will be look through the lens of a forensic specialist as to how an individual or company may use machine learning as part of a data analytics process when looking at or reviewing some camera footage.

The Key to Understanding Machine Learning
Requirement 3:

{Provide description of the process you followed to understand how the Data Analytics and Machine Learning works in CCTV Footage Analysis for Criminal Investigations}

Machine Learning Definition
I started my journey by trying to understand what the definition of Machine Learning is , the best way I could describe machine learning is it essentially tries to understand its "surrounding environment" , by doing this it can showcase how it could represent human responses to questions and answers where's previously it was very computer orientated usually being performed by programming and coding language's , machine learning has now changed and touches every part of our lives and it formally belongs to what's known as the Big Data group. (I & M.J. , 2015)

So, what is Supervised Learning ?.

I continued my journey by trying to understand some of the key terminology these were words like Supervised learning this focused on the idea of training large sets of data for a specific requirement such as camera's looking to identify an individuals face or even detecting an object within a piece of footage. As part of the "You Only Look Once , Unified, Real-Time Object Detection" (Redmon, et al., 2016) paper I read under Network Design this went onto describe how they use this type of machine learning to train there data sets , alongside this they also covered how "Google Net" model was used as an inspiration for there model and they followed this through by showing a detailed architecture diagram and explained further on how this architecture was constructed. As part of the process they also touched on how they could speed up the process by Training a machine learning called "Yolo" also know as you only look once they go onto to discuss in the paper how all this can be used to potentially detect people , moving objects and artillery they also discuss how "Fast Yolo" a neural network relies on less layers reducing from 24 to just 9 while also reducing the filters at the same time , this allows for a simpler network.

Supervised Learning Diagram
Here I created an example of what supervised learning may look like , I based this off my discovery and research into this topic. (Spotfire , 2025)
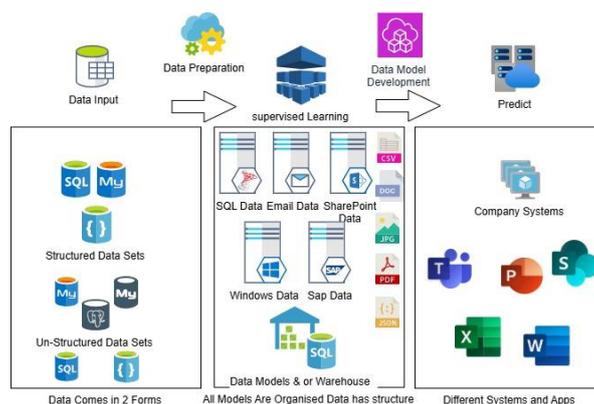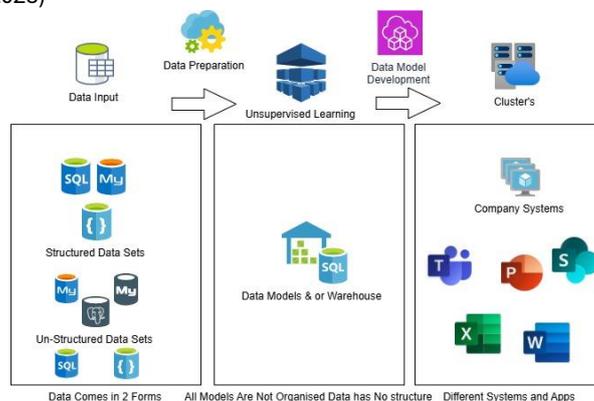
So, what is Un-Supervised Learning ?.

I continued my journey by trying to understand some of the key terminology these were words like Un-Supervised learning this focused on the idea of knowing that Un-Supervised learning can also be called "Cluster Analysis" (Gentleman & Carey, 2008) or "Class Discovery" it went into to explaining how both Un-Supervised Learning and Supervised Learning could not be cross compared as one would require a training set and the other would not meaning they could not be compared against one another , it continued on to explain the differences of the two of which were important where a dataset may have a clear and "optimal criteria" it essentially said that while they may poses this criteria you would not be able to say with 100% assurance that a solution could be obtained. For someone to be able to analyse this correctly its recommended that different "starting parameters" are used and event at this the desired result is not guaranteed this is because that even if an individual chose to use moderate or sample sizes of data, they still won't be using all portions of this. What clustering essentially allows an individual to do is to uniquely identify different pieces of data or in our case footage to be able to discover potentially a pattern within this data this could be useful in identifying a change in location of an object or following that object through camera footage an example of this could be following a criminal through metropolitan CCTV Camera footage from one city to another. Where clustering cuts down and saves time from a human effort point is it can and should be able to group similar footage together allowing an individual to build up a timeline of events which could be used in a criminal investigation.

Un- Supervised Learning Diagram

Here I created an example of what un-supervised learning may look like , I based this off my discovery and research into this topic. (Spotfire, 2025)


So, what is Natural Language Processing {NLP}?

Continuing on from both supervised and unsupervised learning , my next attention was set to what is Natural Language Processing for machine learning for this I read an article which discussed some of the main points about what this is from reading the article I was able to articulate it as being a way for any type of computer operating system to be able to understand and communicate with the human language (Stryker & Holdsworth, 2024) , as we know the human language comes with many dialects and languages e.g. English , French , Irish , Spanish , German and so on , what natural language processing focuses on is how humans can interact with machine learning using their native language . Every day we use some form of natural language processing , this can be from contacting a mobile provider through their website using the chat function such as a chatbot , this could be powered by something like "Microsoft Co-Pilot" (Microsoft , 2025) "Chat GPT" (OpenAI, 2025) a good example of this of this would be when an individual goes to contact a specific department within an organisation through their website , we also use what's called voice and digital assistants these might be like "Apple's Siri" (Apple, 2023) , Amazon's "Alexa" (Amazon , 2025) or even automated answering systems by speaking to them and then they detect the issue while diverting you to the correct department example when you ring your tv provider as you ask to speak with the billing department. All these platform's constitute natural language processing allowing individuals to type in human readable format to get an output which is also human readable or spoken. NLP can also be used to automate specific boring or repetitive tasks , "documenting meetings" "conversations" "calls" or "transcripts" these are all integrated within application like Microsoft Teams , this messaging platform normally has this built into it or organisations can plug in "Microsoft Co-Pilot" where advanced functionality is required. Microsoft normally now has a suit of different "CoPilot" options available to both individuals and organisations.

Natural Language Processing Diagram

Here I created an example of how you could use Azure to analyse video files and pictures while using machine learning some of which includes a typical machine learning architecture for natural language processing. I based this off my discovery and research into this topic. (Microsoft Learn, 2022)
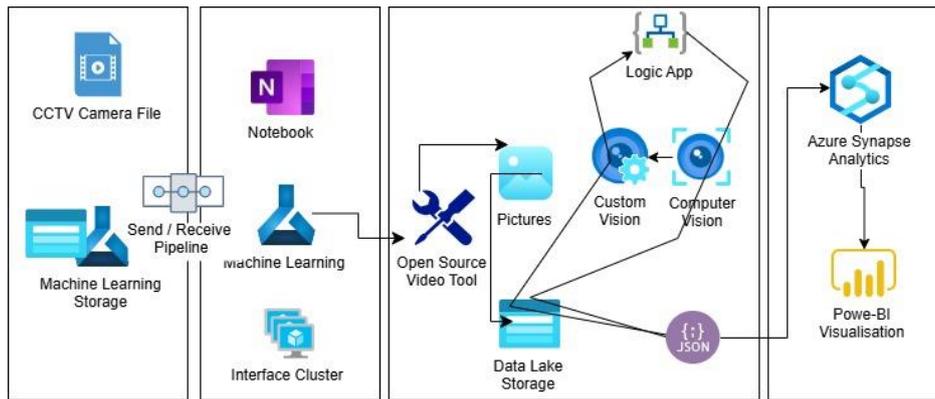
CCTV Footage and Picture Processing

Some of the key requirement of processing both picture and video footage require specialised techniques to be utilised to be able to accomplish the ability to track a foreign object or recognise a specific object or action taken within a video or image these techniques and technologies all form part of the combined effort for machine learning to automate this process.

Background Subtraction

(Berrios, 2023)

This was described as the ability an individual to use an existing good known background model take this from a current background frame and the result is your left with a foreground mask , what this essentially means is take a picture of a boat in a sea , behind this boat would normally be water so in our case the frame which would just be the sea is then subtracted from the frame which includes the boat what your left with is the foreground mask which is essential the outline of the boat without any background. The more images you feed into this model the better the accuracy for the result. Two of the keys are OpenCV KNN (OpenCV.org, 2025) and MOG2 (OpenCV, 2025) an example of where might this be required is it might be used in detecting foreign objects by the coast guard in international water such as the prevention of narcotics and smuggling.

Motion Detection & Frame Differencing

(Berrios, 2023) (Berrios, 2023)

Motion Detection the ability to be able to detect movement within a piece of footage by following the pixels across multiple frames something used when trying to detect movement in a secure area. Frame Differencing , this is described as using a piece of footage such as a car highway traffic this should always be the latest frames of the footage which would be 11:30 and then you would subtract this from the previous frame of footage at let's say 11:28 essentially you would be "Thresholding" the frame to get what's known as the motion mask one of the key requirements to this would be that the camera located on the highway must not be moving and should always be static , if this were to change additional controls would need to be in place to compensate for this. Essentially, you're comparing the frames with each other additional control's like "Blurring and Morphological op's" may be required. Another requirement would be to "compute the motion mask" this is the art of using the threshold to understand the differences within the frames and improve the overall quality of the motion mask , once you have this you can then see the background is removed , where your still left with the objects aka the cars on the highway from here you then need to begin the process of segregating and understanding the main objects from what is the movement this is known as "bounding box detection" the larger box usually indicates the original object while the smaller box dictates and shows the movement once you differentiate against the shadow and textures your normally able to get a better detection leaving you with a clear view on the movement.

Some of the issues with this can also be overlapping bounding box detections , this normally means that false detections can be evident in the results , to overcome this you would need to introduce an object detector a good example of this is "Yolo" using this allows you to input what's known as "non-maximal suppression" this will essentially allow you to understand and interoperate how much overlap one bounding box has with another. The formula for this is IoU= Area of overlap over Area of Union , using this an individual can implement a python algorithm to get a clean result which gives you a clean bounding box. Essentially this cleanup operation allows you to mitigate or remove inaccurate results and give you a pipeline for detecting the motion properly. By doing all of this you can perform motion detection from frame differencing. Where might this be required ? , it might be used in detecting again criminal negligence in road traffic incidents.

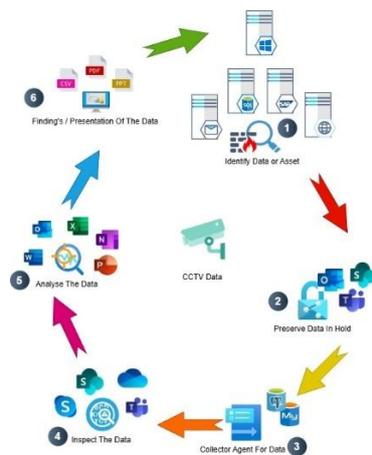### Digital Forensics Lifecycle and the part CCTV Take's in it.

(Servicenow , 2025)

So how does CCTV play a part in the Digital Forensics Lifecycle with respect of the Application of Data Analytics and Machine Learning in CCTV Footage Analysis for Criminal Investigations , this really delves into quiet allot of areas , to simplify this as part of the digital forensics lifecycle we focus on how data is , Acquired , Examined , Analysed and Reported on , some of example of how Machine learning has helped with this are ,

- Data, which is Acquired , the ability to use machine learning to ingest data which is fed in from multiple sources this can be camera feedback from any metropolitan city into police headquarters cloud systems for crime prevention or it could be speed camera zones for issuing fixed point penalty notices.

- Data, which is Examined , the ability to use machine learning to identify detection of motion in highly sensitive and secure areas or even the ability to detect an average speed zone for highway users who might be travelling beyond the recommended speed limits and issue direct automated process of issuing fines through a logic app trigger interconnected with key databases such as Road Safety Authority , An Garda Siochana and Interpol .

- Data, which is Analysed , the ability to use machine learning to recognize the identity of a Pearson travelling between countries an example would be the automated passport control systems for the governments within each EU country for citizens entering and existing countries.

- Data, which is Reported on , the ability to use machine learning to recognize generate notes from conference calls , transcribe video segments for those who are hard of hearing or even preparing evidence for court where executive summaries and legal speak may be required.

Digital Forensics Lifecycle for CCTV Diagram

How EDRM Plays a role in Digital Forensics Lifecycle for CCTV

"EDRM" for short is also known as the Electronic Discovery Reference Model for short this is a standardised format that security professional's follow when identifying assets , preserving assets , collecting assets , inspecting assets , analysing assets and presenting back their findings about the assets. It covers nine core stages of which the digital forensics lifecycle does as well in short, the forensics lifecycle cuts these down into six stages in the context of CCTV and machine learning we as security professionals are still required to identify the types of data whether they be pdf, excel files , pictures videos and so on in our case majority of the time they will be pictures and videos as part of "EDRM" were also required to preserve this data example it might include timestamps , applying locks to files or even finding the Hex value of each digital file for comparison and integrity requirements , once each byte of data is preserved we may collect additional data through various tools and techniques just like we mentioned earlier such as "Background Subtraction" and "Frame Differencing" all of which would require various tools and specialised techniques.

Part of our requirement would be to preserve and audit this data where changes are found in videos and pictures. Processing the data is a key requirements and this is done in the form of inspecting and analysing the data , this can be for many reason such as confidentially , integrity and availability of the data alongside checking the image and video hashes , understanding how the data is broken up into smaller parts is important and using "EDRM" to process the data , review the data and its contents and analyse the data all form as part of a normal investigation. Producing the finalised report of findings is part of this process as it is for the digital forensics lifecycle all of which is completed in the production stage of providing the report to the relevant parties and presenting it in a readable format such as a report , chart , timeline and more tools like Autopsy would form part of this process. One of the key elements to presenting the findings is also by streamlining what's in the report taking into account the relevant parties and audiences such as managers , law officials , or lawyers. (Bougnague, 2023)

Findings
{30 Marks}

{Detailed description, interpretation, and critical analysis of the findings broken down into multiple subsections with meaningful headings for each aspect considered}

People Recognition and Identification

As part of Machine learning models which is used to be able to identify facial recognition of an individual for key systems like passport control or even highway traffic and cars for key systems like speed zone control's   toolkits like "NVIDIA Deep Stream" (NVIDIA, 2016) allow you to integrate neural networks to view and track key components involved in processing these tasks , all of

the rendering required is done through toolkits like these , some of the frameworks which may use them are "Deep Face and Face net" (Taigman, et al., 2014) , (Wikipedia, 2024)

Object Model's

Machine learning models like "Yolo" and Faster R Cnn" (Rishabh, 2024) allow for individuals to identify any given object and draw boundary boxes around them , this also allows them to classify what the object may be earlier I used the analogy of a high way where vehicles were travelling and how to determine the movements of the vehicles , this would be particularly useful should the Road Safety Authority wish to automate the process of fines in an average speed zone. Using these machine learning Modules will allow one to detect a licence registration on the front or back of a car on a highway.

Behaviour Pattern's

Machine Learning allow' s Individuals and organisations to incorporate its abilities into more mundane tasks which take up valuable time an example of this is the ability for cameras to detection bodies in restricted area's this is often used in secure building or at the reception of a building or data centre server room. By using Motion Detection & Frame Differencing an organisation can analyse video fragments in mili seconds and the Machine Learning will provide a frame-by-frame change of the chosen area example this might be used in a Bank building , a Treasury Department or a Department of Defense secure facility , the advances to this are machine learning can also go beyond just detecting behaviour it can begin to pattern match this , this may be most useful in a setting where an office is closed outside of business hours or maybe a house setting where a customer has sensors , camera's and alarms all of which the behaviour monitoring feeds back to a central mobile or server app for analysis and potentially undergoes further SIEM scrutiny and screening processes allowing for real time intervention and efficiency.

Activity Summary

Two of the key activities and or techniques you can learn from the ability of machine learning the ability to be able to both extract information from a call , meeting or presentation and present this a both a technical and not technical manor , an example of a tool that allows this is "Microsoft CoPilot" , this plugin and or companion will allow anyone to generate or spruce up any type of documentation , presentation , meeting transcript and more the technique behind this is "Keyframe extraction" (Kaur, et al., 2024) this allows an analyst or IT Professional to extract key information from a peace of video file and present this in a chronological easy to digest format for the viewer , this is particularly useful where your trying to analyse in a shop if something was stolen , it essentially parses through hours of footage and stops the individual from having to highlight key events manually all of this is done with the machine learning algorithm , removing the mundane task.

Comparative Technology Analysis (Proctored Exam Example)

If we look at three of the technologies, I spoke about in relation to Machine learning for Application of Data Analytics and Machine Learning in CCTV Footage Analysis for Criminal Investigations we can see for facial identification , object identification and behavioural anomaly all three have one thing common they all support machine learning , but if we look at the opposite side each one has clear distinction's ,

Facial identification Vs Object Identification Vs behavioural anomaly

Facial identifications work where an individual is singled out example at the automated passport control office both where you insert your passport and smile it takes your picture and your allowed entry back into the country , where if you tried to do this without the expected conditions the results would be more challenging and subject to errors and mistakes.

Object identification works well when signalizing or identifying a specific object where an individual might be on a proctored exam the webcam identified the individual holding up there id card and this is recorded where this suffers is for real time processing of this data if it was to identify lets say a group of people holding up there id's on a webcam it may suffer to record each id and essentially becomes application intensive.

While Facial identification is useful for identifying an individual and object identification can identifying something an individual may be holding all having the right condition's , what happens where an individual is in an proctored exam how does behavioural anomaly detection work for machine learning in this instance ? a good example of this is when an individual and or candidate may move their eyes , machine learning for exam proctoring focuses on four models' , "object , head lip and eye " (Yamuna, et al., 2023) as a Cybersecurity Professional who has taken over 250+ Proctored exam's I can attest to this , from here this is where the real attestation for the three are compared (M.M, et al., 2022)the overall result is if the conditions are rights for each of the technologies and techniques selected you will mostly likely get the desired results but should something such as light , sound , voice all cause an unknown or variable classifiers machine learning may not have a data set available and ultimately that is where you then may need to train up your own one which could be costly and time consuming (Hossain, et al., 2021) , this is evident in some of the studies I read about and wrote about as part of other engagements with Microsoft , Accenture , and Avanade.

Conclusions
{20 Marks}

{Include an overall discussion of the findings}
{Discuss the findings and limitations}
{Next steps what would you do if you had more time}

Based on the research I did for this paper the overall discussion and findings would be that Machine learning has become a monster of a game changer for the world , it has made an impact to so many of our lives , weather its in Road Safety , Exam Fraud Prevention , Passport control Policing , Criminal Investigation and forensic analysis and more. Closed circuit television has also become a security necessity for many organisations and individual's the ability to plug in machine learning , artificial intelligence and training data sets has significantly enhanced and enriched our lives , the ability to cut out the mundane tasks in cctv analysis has afforded many of us more time to focus on what's important in our workplace and it has also helped significantly with criminal investigation's the ability to supercharge our existing technology stacks like cctv , identification , analysis , investigation chatbots , customer service , pattern matching and more have allowed slow tasks to become more rapid in the face of danger's , uncertainty and reliability.

However the use and ethical responsibility of machine learning also presents some limitations around how we as organisations and individuals use it , its resulted in outright fraud against high stakes exams and standards , privacy concerns are at the heart of how and where machine learning stores our data and sends it the ability for the machine learning to apply its own bias based on the very fact its learning or can learn from poisoned data sets also showcases a worrying and disturbing trend , it really showcases that it has allot of vulnerabilities and nuances in which we must as a civilisation correct before it damages our people , minds , values and integrity with that being said I do feel the advantages out weigh the disadvantages and the list would be very long for a proper comparison.

If I had some more time, I would have loved to research further into the classification of machine learning into proctoring alongside the idea around training the data sets and how bias could be segregated and worked on the understanding behind the processing and where the machine learning and algorithms using python is another one, I would have liked to further explore as well.

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