Testing and Data Analysis

This system could be used in places such as factories to perform data analysis using cameras on different types of items going through a production line and based on the speed and detail of the products, this would change what type of camera or quality of camera that we would use.

**Different Use Cases:**

* Canning Factories:
  + In canning factories, where there are a lot of items going through the production line at once, for example in one of Coca-Cola’s canning ‘plants’, 110,000 cans go through the production line every hour (<https://www.packagingnews.co.uk/news/materials/metal/coca-cola-sidcup-29-04-2015>).
  + To handle this sort of load we would have to use a camera that could take photos / stream very quickly, with a half-decent resolution and a high-speed object detection / computer vision API using Mechanical Turk to label the items.
  + I would use the PiCam for this as they’re cheap to install everywhere, have a good resolution and can capture images relatively quickly, I could also use the iPhone however it is much more expensive.
  + I would also have to do the processing on the device such as a 2020 iPad / iPhone to reduce the need to send the feed of the cameras between devices, reducing latency.
* Automotive Factory eg. Car Factory
  + In car factories, there is a much slower rate of items going through a production line since the items are much larger and have some manual parts to it
  + To handle this, we would use a camera that has a very high resolution such as the iPhone so that we can get the best detail possible. I could also use a library such as Apple’s ARKit to detect the objects for this as well as Mechanical Turk to label the objects.
  + The processing for this could be done on an external machine to help reduce the load on the iPhone so it wouldn’t have to process as much detail.
* C&C Metal Fabrication Factories
  + In Northern Ireland, there is a large number of metal C&C factories. Due to a large number of factories being manual, such as people having to manually operate C&C machines, or in places such as the Tesla factory where workers manually assemble the bodies of the cars.
  + Using the cameras, we could check that the workers are interacting with the C&C machine correctly while monitoring the machine and potentially do quality control at the end to check what comes out of the C&C machine is up to par and the correct quality.
  + We would use the iPhone with this to take photos as it can zoom in / out, take high quality pictures at a relatively fast rate. This would also allow us to use ARKit to show above the C&C machine in AR what the finished product should look like as well as the current % the product is at.
  + We could also track the workers to ensure they are using the machines safely using TensorFlow’s body scanner.
* Farming
  + This system could also be used outside of factories, and in the farming industry instead. We could look at both plants and animals.
  + **Plants**
    - For plants, we could use cameras such as the GoPro, which are already waterproof and more resistant than the iPhone and PiCam to monitor the growth of crops and analyse when they will be ready to harvest or if they are dehydrated, for example.
    - There would be a number of issues with this such as being able to power and easily transmit the data across a long distance.
  + **Animals**
    - In terms of animals, we could use the GoPro for inside use to monitor animals such as cows in a barn to ensure they are eating an adequate amount and they are growing correctly, for baby cows.
    - Once again, this would be quite difficult to power the cameras and to transmit the data across a network, with the cameras being in quite a faraway location, such as if you were trying to access the live feed from your house to the barn which may be a considerable distance away.
  + However, this shows that this system could be used in more than just factories, it can be utilised in many different industries, but I think it is best to focus on factories for now.
* Thermal Imaging
  + With the iPhone, there are a large range of third-party attachments to the iPhone to allow the iPhone to use a thermal cameral. This could have many different uses such as getting the temperature of workers to detect potential sickness in combination with the speed of their work to ensure that they aren’t just warmer because they’ve been working harder.
  + Some of these devices do cost a good bit, so we may have to find a more affordable solution if the client decides they would like this installed.

**Experiments**

I need to find a way to tell if a solution will actually be useful / helpful for the client and how to prove what I’m doing will be worth it to work on since I need to prioritise what to work on.

One way I could do this is by using a points-based system to produce a numerical value based on how useful each part of the product could be used. Each part of the product will have a certain number of points assigned to it.

*No Cameras / IoT Devices Currently Installed in Environment* – **2** points

*Resolution of Cameras Currently Installed in Environment Worse than Product’s Resolution* – **2** point

*Framerate of Cameras Currently Installed in Environment Worse than Product’s Resolution* – **2** point

*Current Camera Feed Cannot Be Remotely Accessed from Live Camera Feed* – **1** point

*Current Cameras Are Not Easily Maintainable / Sustainable / Easily Upgradable* – **1** point

*Design of Current Cameras Installation are Not Secure / Could be Easily Damaged or Stolen* – **1** point

*System in Place Does Not Use Object Detection* – **2** points

*System in Place Does Not Use Machine Learning to Automatically Detect Objects* – **2** points

*System in Place Does Not Use AR to Show Product Labels / Information* – **2** points

*System in Place Cannot Track People where the Client Wants This to be the Case* – **2** points

*Current System Does Not Have a Dashboard with Graphs to Display Information* – **1** point

*Current System Does Not Backup Data Off-Site* – **1** point

*Current System Does Not Use 3D Modelling of Factory to Display Data* – **1** point

This points system is out of **20** points.

A score over **15** could be called to be definitely useful for the client to invest in.

A score above **8** would show that the system would *probably* be useful for the client to invest in.

A score **below** that would show that the client may not need to invest in this product / system for their factory etc.

**Testing:**

* Will the cameras being installed be worth it in the long term?
  + I need to ensure that the cameras being installed into the client’s environments will actually be a useful investment for the client by improving their productivity and ensuring the camera system is better than any system they currently have in place.
  + In terms of knowing if the cameras will be better than any cameras they currently have in place, we can look at footage of some other factories to ensure that the resolution and framerate of the live feed of the cameras we are planning to use are better than the current cameras to ensure that we can beat competing products.   
    One of the largest camera solutions, [NEXCOM](http://www.nexcom.co.uk/Products/intelligent-digital-security/ip-camera) offer a range of IP Cameras for both outdoor and indoor use which can all only capture up to a maximum of 1080p, 30fps and only have a 3-10mm lens. However, with the cameras we are going to use, the iPhone and GoPro can both capture up to 4k and can both zoom in and out easily.
  + Another part of this is the security of the cameras. We need to ensure that the cameras are secure to ensure they can’t easily be removed from the mountings by employees or broken / damaged by employees with malicious intent. Once again, we can look at the designs of cameras by other companies to see what their security design is like to stop tampering of cameras and use this to iterate on our design for each device to help prevent this. Another solution with this is that some cameras such as the iPhone can use the built-in GPS to track where the iPhone is and use machine learning on the device to tell if the device is being tampered with.  
    Another big factor in terms of security is the cyber security aspect of this product. In an [article](https://www.wired.co.uk/article/internet-of-things-security-camera-search-location) by Wired from 2018, it shows that IoT cameras can be very easily hacked into since a lot of IP cameras are set up without cyber security in mind, or at least without it at the front of their priorities. This would be one of the top priorities of the product to ensure that clients would be happy to pick our solution over others due to cyber security being a top priority.
  + We also need to ensure that the technology that we’re incorporating into the cameras / system will actually meet the goal that the client wants. To do this we can research the technologies other cameras or IoT devices in the same industry are offering to see what we can improve or iterate on to ensure our product is better than theirs so that our solution will be helpful to the client. Some of the solutions we may use include Augmented Reality and Machine Learning as I’ve talked about in other points throughout this document.
* Data management
  + Storing Data
    - If the client wishes for the data to be stored and output in a certain format such as to a dashboard or in a CSV file, we would need to find a solution for that. The video footage of the cameras could easily be stored on a hard drive; however, we could run into some problems such as:
      * Security of the stored data
        + We need to ensure that the data is stored securely on the hard drive or other storage medium so that it cannot be accessed by a malicious user and all data is backed up using an off-site server to ensure if a physical attack is carried out and the on-site servers get damaged or destroyed, the data will still be in an off-site location.
      * What if the storage medium runs out of space?
        + We would need to have a system in place to notify the client and the product / business owner whenever the storage is nearly out of space so the client can choose whether to discard of the old data or increase the capacity of the storage medium.
      * Displaying the Data
        + There are different ways to display the data to the client; in raw format such as in CSV files or on a web interface such as a dashboard to show graphs etc. in an easy-to-read format that can be easily accessible through a logon portal. We could use a pre-existing graphing API to take the data and display it on interactive graphs such as [Google Charts](https://developers.google.com/chart).
* Factory Environments
  + For different types of factories, the cameras will need to be installed and set up in the factories in different ways.
  + If the cameras are being used for outdoor use, they would all need waterproof cases around all components to ensure they don’t get damaged by different weather conditions.
  + If the cameras are being used in factories where there may be dust or the cameras could get damaged, they would need to also be in protective cases that could either be designed by myself or be purchased from a third-party seller.
* Powering the Cameras
  + To power the cameras to ensure they don’t run out of battery we could use a variety of different techniques for each camera:
    - For the PiCam, we would need to ensure the Pi Zero is plugged into power at all times (for it to work), we could create a Python script to check that:
      * The Pi Zero is still getting power by attempting to SSH into it (already implemented into the system) and,
      * The PiCam is still connected to the Pi Zero successfully – this could however become a bit of a challenge because the cable between the PiCam and Pi Zero can easily come loose sometimes since it’s just a ribbon cable held down by a clamp, so I could design a part in Fusion 360 and 3D print it to help with this issue.
    - For the GoPro, we can constantly have the GoPro plugged in using it’s USB charging cable and still be able to take pictures. This would be the best method to ensure the GoPro doesn’t run out of battery. We could write a Python script that can try to SSH into the Pi Zero and create an instance of the GoProCamera using the GoProCam API which would let us know if the GoPro is successfully connected or not. We can also check the currently connected WiFi network of the Pi Zero to check if it’s connected to the GoPro’s WiFi (already implemented).
    - For the iPhone, when running the web server (without taking images constantly), I found that the iPhone X’s battery lasts c. 8-10 hours with the screen on. This figure would obviously be exponentially lowered whenever the iPhone is constantly taking pictures or streaming video. To charge the iPhone, we can just always have the lightning charging cable plugged into the iPhone, however this could cause some damage to the iPhone’s battery. To combat this, we could create a system to ensure the iPhone’s battery only charges after it gets to a certain %, such as 30%, and it stops charging once it gets to 90-95% charge. We can access all of this data currently through the iPhone’s JSON data retrieval system that I made which updates about every 0.4 seconds.
* What if the Cameras Die / Stop Working / Run out of Battery?
  + A logging system would be developed to log the state of each camera in the premises on the same system every specified amount of time so that if one of the cameras etc did stop working, we could more easily fix the issue and find out what the problem was.
  + Using the techniques described beforehand, we can constantly check if each camera is getting power, and for the iPhone / GoPro, constantly check the battery level to display a warning if it gets too low which would be an indicator that there is an issue present.
* Use for Safety in Factories
  + Using the cameras, we could track the workers in factories to ensure they are following correct safety procedures.
  + We could place GoPros or PiCams throughout the workspace and track the workers to check what equipment they are wearing such as if they’re wearing a hard hat and reflective jacket and notify the managers etc. if they are not following the correct procedures.
  + There could however be some ethical issues with this regarding constantly tracking employees, as discussed below.
* Ethical Issues
  + Constantly having cameras on and recording employees in a factory could cause some ethical issues with employees as they may not feel comfortable with this.
  + Many unions for workplaces such as factories have articles on this such as this one - <https://archive.acas.org.uk/index.aspx?articleid=5721> which states:
    - Employers should have written policies and procedures in place regarding monitoring at work.
    - Monitoring shouldn't be excessive and should be justified.
    - Staff should be told what information will be recorded and how long it will be kept.
    - If employers monitor workers by collecting or using information the Data Protection Act will apply.
    - Information collected through monitoring should be kept secure.
  + To keep with the final two of these points, we will need to ensure we comply with the Data Protection Act (DPA) and store any data collected through it securely.
  + It may be more difficult to implement this sort of system in some factories compared to others, as in some factory industries which are quite ‘old-fashioned’, workers can sometimes be quite *technophobic* and not feel comfortable with this and would rather stick with the traditional methods.
* Storing Data Securely / Complying with the DPA
  + If the client asks us to store the live feed to a disk or to another location, we will have to ensure we comply with GDPR and the Data Protection Act to ensure all employees data is safe and any images / video of them working are safe.
  + We will also have to ensure data collected by the monitoring using the cameras complies with the DPA in case the client wants us to link certain data to a certain employee etc.
* Securing the devices
  + We will have to ensure that the cameras are secure in the factory so that they can’t be tampered with or stolen. We could design a case for them which could be 3D printed and secured to a solid piece of infrastructure of the factory.
  + We could also find a more rigid, but more expensive case online, however we would choose which type of security to use based on the client’s preferences.
* How are we going to test the object detection?
  + There are a number of different options of how we could do this such as using factory footage or creating CAD models of common factory items:
  + Factory Footage
    - We could use footage of a factory that clients could potentially send in to test the object detection and to help train the machine learning algorithm. We would then be able to send the results of the footage back to them to make sure they’re happy with what’s going to be installed.
  + CAD Models of Factory Items
    - We could create models in Fusion360 or other CAD software of common factory items such as tins to ensure that the object detection algorithm correctly detects them.
* Quality Control
  + We can use cameras to ensure that the products going through a production line meet the correct quality such as ensuring that the labels or spray on tins / cans are adequate and readable.
  + This could be easily done using PiCams and a library such as ARKit or TensorFlow.
  + We could use TensorFlowJS and display the results on a web dashboard / interface such as a table showing the number of passed vs. failed quality tests in a day.

**Data Analysis**

Data Analysis will be what different things that the client requests based on their needs that change what we prioritise with the deployment of this system and cameras into the environment:

* Speed of Capture vs. Resolution of Cameras
  + We’ll be able to take and transmit photos faster, the lower resolution that we use for the photos as well as the capture speed of the cameras.
  + For items going through factories that don’t have a lot of detail and items are going through the production line quickly, we’d have to use a camera that prioritises the speed of capture over high resolution of the cameras.
  + Also, some cameras have a faster capture speed than others, such as the GoPro has a slower capture speed than the iPhone or PiCamera.
* Powering the Cameras: Portable Batteries vs. Wired Power
  + Based on the size and facilities in the factory, we may have to use portable batteries instead of using wired power to power the cameras.
  + If the factories / environments are bigger, with less facilities such as plugs around the walls, we may have to use portable batteries. However, this wouldn’t work too well since occasionally we would have to remove the batteries, charge them, and re-jigg the batteries, so this may be a problem I need to research into further.
  + If the factories are smaller and have a number of plugs or already installed power sources around the factory that we could plug the cameras into, we could just plug the cameras directly into these power sources.
* Number of Cameras Needed
  + Based on the size of the environment and the clients needs / requirements, we will need a different number of cameras for the factory. This will also increase the implementation time for the cameras.
  + If the factory is smaller with less products going through the production line, we would need less cameras, and the implementation time would be shorter.
  + If the factory is bigger with more products going through the production line, we would need more cameras, and the implementation time would be longer.
  + These may not always be true because in some factories they could be smaller with less products going through the production line, but the client may want a higher number of cameras for different reasons.
* Different tracking (People vs Objects)
  + In different cases, some clients might want to track people, some might want to track objects going through the production line and some might want to track both.
  + Factories that would want to track people would include ones that have safety concerns, a lot of not specialist employees and / or manual work. This could be implemented with TensorFlow’s built in body tracker.
  + Some factories may want to track objects, this would include factories that process most of their production automatically using methods such as robotics as an alternative to humans such as canning factories. This could easily be done with TensorFlow’s object detection or Apple’s ARKit in combination with labelling using Mechanical Turk.
  + Some factories may want to track both objects and people such as in metal fabrication factories which uses manual work to control the machines and also tracking that the end product is up to standard, which also could reduce the need for quality control / assurance, or at least not as much, saving the companies money. Once again, this would be best done with TensorFlow or ARKit. However, through testing out both, I’ve found that TensorFlow is a bit faster.
* The nature of pieces of information people want to gather
  + Different clients will want to gather different pieces of information. Some may want to gather precise details like the raw output from the object detection / machine learning algorithm, whereas others will want to gather processed data only such as the average number of failed products through a production line in a day.
  + Some clients with more of a technical expertise and maybe technical department with their own data analysists that analyse data may want more details from the object detection and machine learning algorithms such as the details of each product going through the production line, giving a score for how accurate the reading was and how good quality each product was, such as a percentage.
  + Other clients may want to get data that has already been processed by the machine itself such as the average number of products going through a production line, successful and failed along with the productivity rate of workers and speed of production (items going through a production line / hour), displayed as graphs, whereas the more detailed choice would be output in a CSV file.
* Real-Time Dashboard
  + A real-time dashboard could be created to display the information produced from the system. Some clients may want a dashboard, others may not.
  + Some clients may want a dashboard that can easily be accessed to display the live feed of cameras as well as the data in real-time such as the number of products going through a production line at once.
  + Some clients may not want or need this since it would cost more to create and be implemented into their system and some clients may just not find a need for it since the data being produced in a raw format could be enough for them.

There are a number of different industries that could benefit from this technology;

* Electronics / Engineering
  + This product could be used in the making of electronics and also analysing assembled electronics (eg. Machines in factories). In terms of the making of electronics such as making phones in factories such as Apple or OnePlus. We would be able to track what the employees are doing in the manufacturing of the phones to help improve the quality of the phones and measure the speed in which the employees are moving.  
    We could also use it to track machines installed in factories such as to ensure that any machines aren’t overheating or not working properly by monitoring the movement of machines such as robotic arms. Through research, I have found that the costs to check that the components inside electrical boxes in factories which provide power costs quite a bit, has to be done on a regular basis and a specialist has to come in to check it. So, we could use cameras to ensure it isn’t overheating.  
    We could also track the temperature and activity of other machines in the factory such as robotic arms to ensure they’re not overheating and working properly. What we would track in this industry would depend on the clients’ requirements.
  + A study was conducted showing 92% of senior manufacturing executives polled for the Manufacturer’s Annual Manufacturing Report 2018 believe that digital technologies like AI will enable them to drive down production costs and empower staff to work smarter ([source](https://emsnow.com/the-role-of-ai-in-the-electronics-manufacturing-industry/)).
  + Also, according to a recent report, the AI in manufacturing market is expected to increase from $1 billion in 2018 to a staggering $17.2 billion by 2025 ([source](https://emsnow.com/the-role-of-ai-in-the-electronics-manufacturing-industry/)).
* Agriculture
  + This product could be used in the agriculture sector, both in farming of crops and animals. The UN projects that the world's population will reach 9.7 billion by 2050, causing global agricultural production to rise 69% between 2010 and 2050 ([source](https://www.businessinsider.com/smart-farming-iot-agriculture?r=US&IR=T)). To meet this demand, farmers need to start to turn to using IoT technology in their farming. By using the technology farmers could have cameras to monitor the growth of crops to predict when they’ll be ready, along with a variety of other sensors such as temperature sensors to monitor the temperature or moisture of the soil. This could help to know when to plant crops and when to harvest crops to find the most productive solution. This would also reduce the number of ‘manhours’ needed as farmers wouldn’t have to go and check on the crops manually every day, and rather just check a live camera feed.  
    In terms of livestock farming, farmers in the U.S. lose nearly $2.4 billion per year from animal illnesses that lead to death, according to the USDA ([source](https://www.precisionag.com/in-field-technologies/sensors/using-iot-to-increase-efficiency-productivity-for-livestock/)). We could use cameras to track the cows to see if they’re showing any physical signs on illness, we could also use devices to monitor the health of livestock to try to prevent death.  
    We could also use the cameras to monitor reproductive cycles / calving by using thermal cameras to monitor when a cow goes into heat and is ready for birth.  
    Finally, we could use IoT technology such as location trackers / GPS chips to track the cows positions and track where each of them are in combination with the cameras and AR to display which cow is which by displaying an AR info tag above each cow on the live camera feed. We could use TensorFlow to track the cows or ARKit as a more expensive solution.  
    However, this would depend on what the client wants, and we could implement these with relative ease into the environments.
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    However, this would depend on what the client wants, and we could implement these with relative ease into the environments.
* Housing
  + This technology could be implemented in housing such as with smart doorbells to detect whenever people come to the door. In this [article](https://www.technavio.com/report/smart-doorbell-market-industry-analysis), it showed how the smart doorbell market could increase by 1.19 billion USD between 2020 and 2024. This shows how large the IoT market is in not only the manufacturing industry, but also in people’s homes. With massive companies such as Google in the IoT market with their acquisition of Nest and their smart speakers, it shows how much potential this market really has.
* How to know what to focus to work on?
  + Due to the large number of industries and use cases of this technology, we need to find a way to learn from the clients to see what is most beneficial to work on.
  + One method of doing this is simply, by asking them. We could create surveys or even just email manufacturers in the UK to see what they’re most interested in in terms of Industry 4.0 / IoT technology.
  + We could also look at other products that are being advertised to the clients to see what they like, what they don’t like and research these other companies to see how we could get an advantage above them in terms of the technology they’re using.