Video Analytics at the Edge
System Requirements Document (SRD)
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1. Executive Summary

1.1 Purpose

1.1.1 Video Analytics at the Edge

This design effort aims to demonstrate video analytics with edge computing techniques. "The Edge" defines effective video analytic methods, such as machine-learning based object detection, performed in the proximity of the optical instrument. Unlike the traditional approach, edge computing reduces the bandwidth requirement between the sensor and the central computer (known as the command center). The prototype developed in this design effort will optimize the cost, size, weight, and power envelopes (C-SWAP) of available off-the-shelf components. The prototype will generally operate autonomously to provide insights into anomalous objects or motions of interest. Instead of transporting raw or compressed data of the captured video signal, the prototype will compute and process these signals to then deliver a set of pre-defined parameters of interest to the command center, where the decision process will ultimately take place. A user interface will allow users to customize the system so that desired anomalous threshold will be detected as well as giving the users some control and monitoring of the data. This effort will benchmark the differences between video analytics at the edge compared to a traditional surveillance system.

1.2 Scope

1.2.1 In Scope

This document will define the following requirements:

- Objectives to be achieved in this design effort for a prototype unit.
- Expected standards to be met by porotype unit.
- Expected performance and design for the prototype unit.

1.2.2 Out of Scope

This document indicates the design effort will not achieve the following:

- Standards related to consumer electronic products.
- Standards related to professional and industrial products.
- Cost and lifespan standards

1.3 Table of Definitions, Acronyms, and Abbreviations

AI	Artificial Intelligence
CAT	Category
C-SWAP	Cost, Size, Weight, and Power
CSS	Cascading Style Sheets
DC	Direct Current
EE	Electrical Engineering
FPS	Frames Per Second
GPIO	General Purpose Input and Output
HDMI	High-Definition Media Input
IP	Internet Protocol
ME	Mechanical Engineering
MS	Motion Sensor
SOP	Standard Operational Procedures
UDP	User Datagram Protocol
NN	Neural Network
USB	Universal Serial Bus
UPS	Uninterruptible Power Supply
VBP	Virtual Buttons Panel

1.4 References

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2. Design Description

2.1 Design Context

2.1.1 Video Analytics

Video analytics is a branch in computational technology that focuses on the analysis of multiple graphical frames within a specificized time-period. Video analytics algorithms and techniques are at the cornerstones for infrastructure security, machine vision, and the multi-media industry.

2.1.2 Edge Computing

Traditional sensor-processor network architectures, especially video surveillance technologies, physically separate computational power from sensor networks. A traditional network often consists of a sensor that sends remotely captured raw or processed data to a computer through high-speed data mediums. In this paradigm, trouble often arises when unforeseen burst of inrush data creates a critical congestion to the network, impeding system stability. Edge computing is an architectural approach that brings computational resources closer to the source of information. Developers at Akamai Technologies, Inc., define edge-computing as “a system to serve requests from a variable number of surrogate origin servers at the network edge” (Akami 1).
In edge computing, transport related congestive issues are often mitigated, even during periods of intense activities.

2.1.3 Physical Prototype Design Overview

The prototype system shall consist of a high-resolution optical imager of sufficient sensor size capable of achieving adequate fidelity to realize the needs of a surveillance system. The optical imager shall be located behind a varifocal or infinite-focal lens to capture long distances sufficient for surveillance needs. Connecting the optical imager shall be the central processor, the Raspberry Pi.

An intermediate processor, the Nvidia Jetson TX1 or TX2, shall connect to the central processor. An over-encompassing physical enclosure protects the optical imager, the intermediate processor, and the central processor from the elements.

The general approach of the prototype system is to achieve the most optimal cost, size, weight, and power (C-SWAP) envelope as possible. The rational of such approach is to accommodate the possibility of the prototype being mounted on a mobile or a flying platform.

Figure 1 physical design of the prototype.

2.1.4 System Architecture Overview

From the captured light data of interest, the optical imager transmits the relevant light data to the central computer through the MIPI-CSI interface. The central computer then passes this data to the intermediate processor through the network interface, more specifically the IP/UDP protocol. The intermediate processor executes an optical flow algorithm to detect moving objects of interest. The intermediate processor then classifies the detected objects and transmits relevant telemetry data back to the central interface to the main computer. The central computer will execute the main logic from a pre-programmed application which determines the desired response upon detecting anomalies of interest. The central computer also publishes this data through a wireless network.

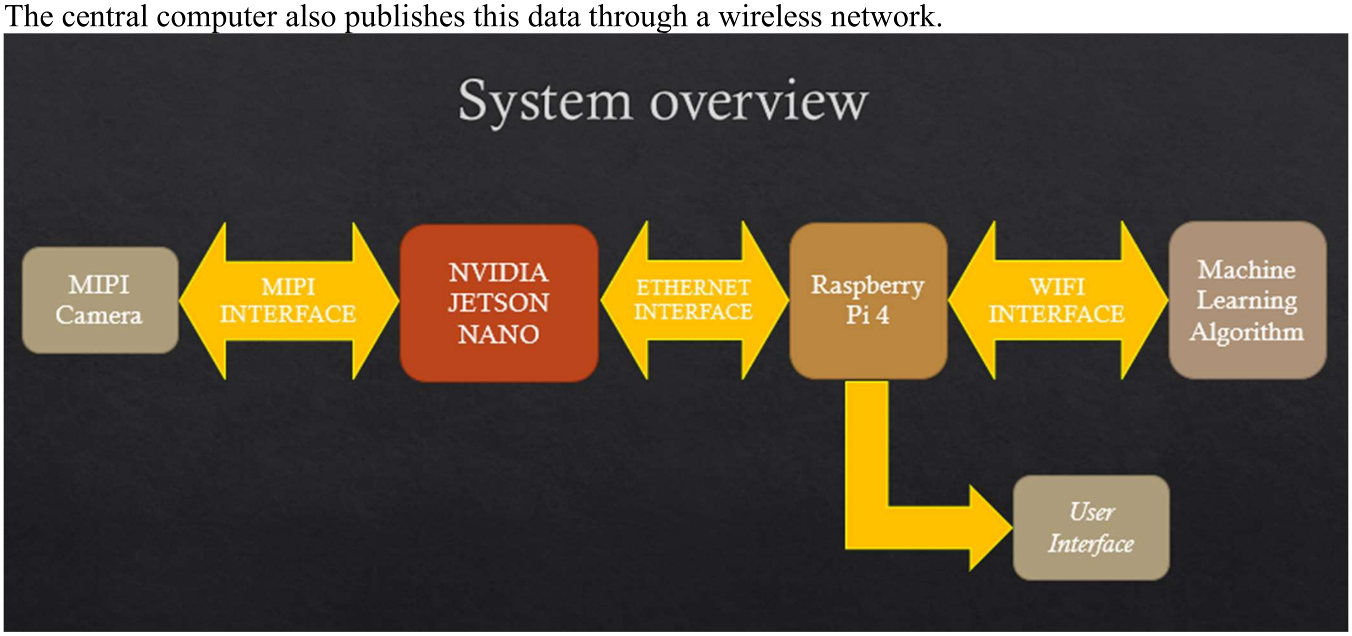


Figure 2 overview of the interconnect system

2.2 Assumptions

2.2.1 Operating Conditions

The prototype device shall be operated at a remote location away from the graphical user interface, to demonstrate remote edge computing. We assume that the prototype is operated much like an autonomous agent, where it can produce valid results without any extensive interaction with the operator.

2.2.2 Minimal Operator Competency

The operator is assumed to operate the graphical user interface on a web-based application on a personal computer. The operator is assumed to be familiar with the operation of a web browsing application and shall be capable of basic user commands such as accessing web pages. The internet browser should preferably support the latest version of CSS and JavaScript frameworks.

2.2.3 Mounting Assumptions

The prototype is to be mounted either on a stable surface or on a mobile platform with vibrational dampeners. The prototype is assumed not to be subjected to significant vibrations that can affect the optical imager's image capture quality.

2.3 Constraints

2.3.1 Power Constraints

The entire unit shall be powered by a DC voltage source between 11 and 14 volts. The DC voltage source shall be able to deliver a constant current of 3 amps with a peak current draw of 7 amps.

2.3.2 Environmental Constraints

The prototype shall be operated in non-condensing conditions between 20 and 80 percent relative humidity. The prototype shall be operated with ambient temperatures between 10 to 30 degrees Celsius. For the adequate airflow of exhausts that provides active cooling to the components, a 50mm radius of clearance must be provisioned for all exhaust locations to prevent the obstruction of air exchange.

2.4 Dependencies

The successful operation of the prototype device depends on the completion of the tooling, setup, test, and configuration checklists.

2.4.1 Tooling Checklist

The tooling checklist lists the required tools to set-up, test, and configure the prototype unit. All items listed in the tooling checklist as REQUIRED must be procured before the setup of the prototype unit. Items listed as OPTIONAL are not required to complete the setup, test, and configuration checklists. However, optional tools are recommended as they can significantly reduce the overall setup effort and the time needed to realize completion.

2.4.2 Setup Checklist

The setup checklist describes the general approach of configuring the device upon the procurement of all components listed REQUIRED from the bill of materials.

2.4.3 Test Checklist

The test checklist describes the testing procedures required to confirm the operational health of the prototype device.

2.4.4 Configuration Checklist

The configuration checklist describes the final configuration options available to the prototype device. Depending on the desired operating conditions, the configuration checklist lists all options available to the operator and shall be the primary operator's manual for field operations.

3. Requirements

3.1 Following areas should be considered for Functional Requirements

3.1.1 User Interface Requirements

There exist two interface paradigms between the user and the prototype unit.

3.1.1.1 Graphical User Interface

The graphical user interface is the predominant user interface during the operational stage of the prototype unit. The graphical user interface shall consist of a virtual button panel (VBP), a monitoring panel, and a dynamic input panel.

3.1.1.2 Physical User Interface

The physical user interface is the physical user interaction between the physical equipment and the operator. The physical user interface shall feature ethernet, digital, power, and physical inputs that are clearly labeled and directly accessible to the operator.

3.1.2 Performance

3.1.2.1 Image Fidelity

The prototype unit shall consist of an optical image sensor with a sensor size of no less than 7.9 millimeters measured diagonally. The optical image sensor shall have a native output resolution of 12.3 megapixels. An IR filter must be present on the image sensor.

3.1.3 Capacity

3.1.3.1 Maximum processing framerate

The prototype unit shall be able to process an image rate of no less than 5 frames per second.

3.1.3.2 Maximum number of detected targets

The prototype unit shall be able to process no less than three active targets within a given frame of interest.

3.1.3.3 Maximum speed of target

The prototype unit shall be able to detect and classify optical targets no slower than 100 pixels per second in absolute pixels referenced from the data collected by the optical imager.

3.1.3.4 Minimum brightness level

The prototype unit shall be able to identify targets with a relative contrast level of no less than 0.4 percent.

3.1.3.5 Maximum monitoring size

The prototype unit shall be able to monitor targets no less than 64 by 64 in absolute pixel size from the data collected by the optical imager.

3.1.4 Availability

3.1.4.1 Operational Availability

The prototype unit is expected to operate for a minimum of seven days without requiring maintenance.

3.1.5 Latency

3.1.5.1 Expected anomaly publication delay

The expected anomaly publication delay shall be no less than thirty seconds.

3.1.6 Monitoring

The prototype unit will generate an onboard log file that describes all events of interest based on the configuration level of the application.

3.1.7 Maintenance

The prototype unit shall be capable of being disassembled by the removal all external fasteners. No adhesive shall be used to enclose the prototype unit to enable service and accessibility.

3.1.8 Systems Interfaces

3.1.8.1 Optical image sensor

The image sensor shall process the captured image data in RAW12/10/8 or COMP8 format. The image sensor shall transmit the data via the physical CSI-MIPI interface.

3.1.8.2 Intermediate and command computer interface

The physical link between the intermediate and command computer shall be of a physical CAT version 5-E cable. The command and intermediate computers shall have a standard female RJ45 port.

3.1.8.3 Power Rail

A standardized 12-volt regulated power rail shall be used to power the intermediate and command computer interface.

3.2 System Requirements Matrix

We define a software requirement that is solely restricted by software performance, hardware requirement that are restricted by hardware performance, and performance requirements that are restricted by both software and hardware performance.

Req. ID	Req. Reference	Req. Category	Requirement	Comments	Date Reviewed	Approval
1	3.1.1.1	Software	The GUI (1) Must be the predominate user interface (2) Must have VBP (3) Must have monitoring panel	The GUI must be designed to be interactable during moderate stress.		

			(4) Must have dynamic Input Panel			
2	3.1.1.2	Software	The device must contain physical inputs that operate the critical functions of the unit.	The user must be able to shut down, reset, and input data without having to rely on remote operation and/or manipulation of the main power supply rails.		
3	3.1.2.1	Hardware	Sensor size must be greater than 7.9mm. Image resolution must be greater than 12.3mp. Must have IR Filter	Required to obtain sufficient detail to capture anomaly features.		
4	3.1.3.1	Performance	Framerate speed must be greater than 5 frame per second	Sufficient frame rate needed to detect anomalies in time.		
5	3.1.3.2	Performance	Number of detected targets must be greater than 3	Must be able to discriminate multiple targets.		
6	3.1.3.3	Performance	Must be able to track targets faster than 100 pixels per second	Must be able to engage anomalies that have a velocity component.		
7	3.1.3.4	Performance	Sensor must have a dynamic range of 255 units.	Desirable for color and contrast information of targets		
8	3.1.3.5	Performance	Sensor must be able to distinguish targets greater that	Indiscriminate of target distance and size.		

			64 b 64 pixels large			
9	3.1.4.1	Performance	Must be able to operate without maintenance for 7 days.	Sufficient for surveillance purposes.		
10	3.1.5.1	Performance	Must push data within 30 seconds delay time	Sufficient target detection delay for surveillance purposes.		
11	3.1.6	Performance	Must be able to generate a log file containing error information and related data.	For debug purposes.		
12	3.1.7	Hardware	Device must be serviceable.	Machine fasteners preferred.		
13	3.1.8.1	Hardware	Device must communicate in RAW12/10/8 or COMP8. Must interface with CSI-MIPI	Common image sensor link to maximize compatibility and reduce cost.		
14	3.1.8.2	Hardware	Device must have a Rj45 communication port.	Preferred datalink to the Command Center.		
15	3.1.8.3	hardware	Device must be able to be powered by 12-volt input.	Common voltage for sensors to reduce cost.		

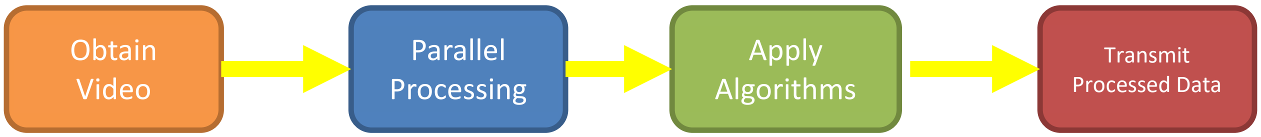
4. User Scenarios/Use Cases

The development of Artificial Intelligence algorithms to detect anomalies has multiple areas of application. There are multiple industries that could benefit from this technology, with minor changes in the algorithm to specifically hone the program for its intended purpose.

- Item Processing – AI (Artificial Intelligence) can detect an anomalous item (e.g., spoiled fruit, defective electric components) and instruct a robotic mechanism to remove that item from an assembly line or functionally similar mechanical construction
- Surveillance Systems – The use of video analytics particularly lends itself to surveillance and security systems, where it may detect anomalous behavior in individuals. There are two areas that stand to benefit the most:
  - Public/Crime – the ability to detect behavior that coincides with the behavior patterns commonly observed in individuals who are planning the commission of a crime, or of those who have recently been engaged in criminal activity. The algorithm should then notify law enforcement officials or those responsible for security
  - Medical – This algorithm also has the potential to be used in the medical field, especially where there are not enough health care professionals to fill the demand. This technology could be deployed in psychiatric health units, senior care, palliative care, emergency clinics, and even the offices of general practitioners where atypical behavior could be an early indicator of an immediate health emergency
- Transport Monitoring – the detection of anomalous behavior has the potential to benefit transportation and road safety. By strategically locating cameras linked to computers running the developed algorithm, law enforcement and emergency medical services could be alerted to the positions of such road incidents like drivers under the influence, automobile collisions, and other road incidents.
- Wildlife Observation – a final potential application of this technology is in the observation of wildlife. The identification of animals displaying atypical behavior could alert authorities and help prevent the spread of diseases among animals or aid in the apprehension of poachers.

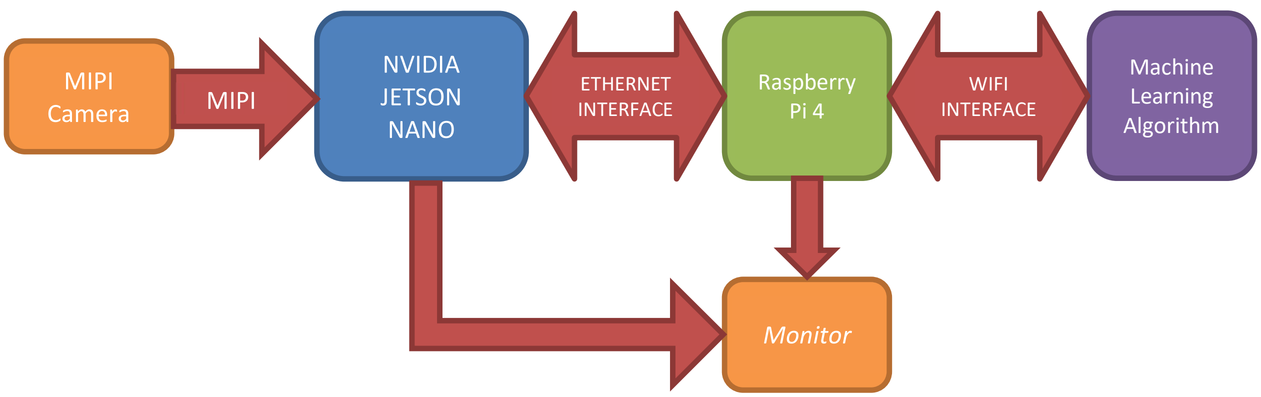
5. Analysis Models

5.1 Sequence Diagrams



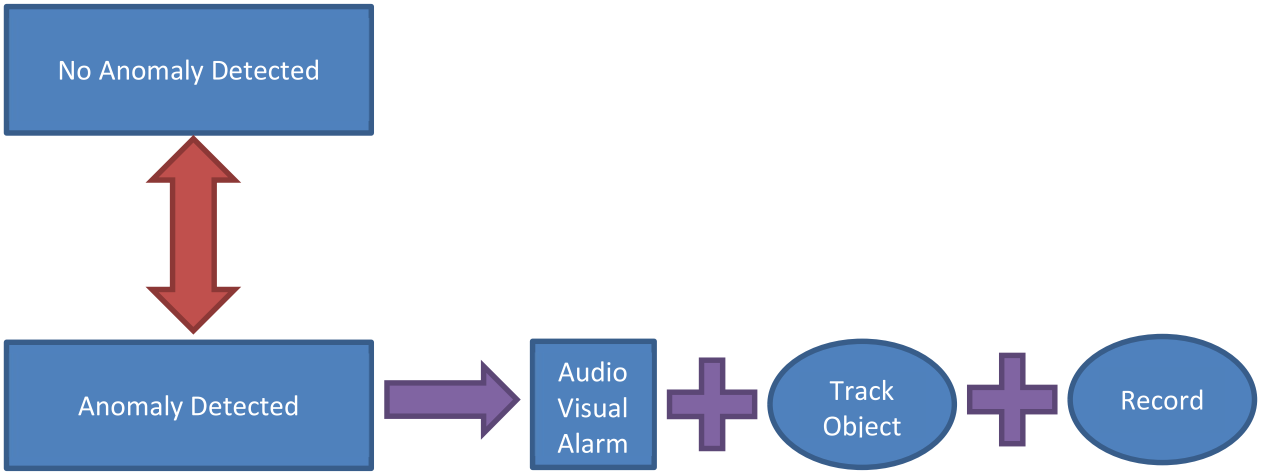
The Sequence that the system follows is simple. The system will perform all these sequences continuously. A live video feed is obtained with a low-resolution MIPI camera. The video feed is processed using many parallel processors. Using algorithms that are being created as a part of this project, objects of interest will be identify and anomalies (if any) will be highlighted. The processed video feed will then be shown on a HDMI monitor, where an operator may observe the feed.

5.2 Data Flow Diagrams



Due to the nature of this project, the data flow diagram is remarkably similar to the sequence diagram. In this system, visual data is obtained through an MIPI Camera. The visual data is transferred directly to the Jetson Nano. Due to the incredible power of the parallel processors of the Jetson Nano, all video processing is performed by the Jetson Nano. The processed video feed is then transferred to the Raspberry Pi 4B through a dedicated ethernet cable. The Raspberry Pi will perform the interaction with the machine learning algorithm and will perform the identification of objects and the identification of anomalous entities. The processed output from the Jetson Nano and the Raspberry Pi may be fed into a monitor, where an operator may observe the live video output and the processed video output.

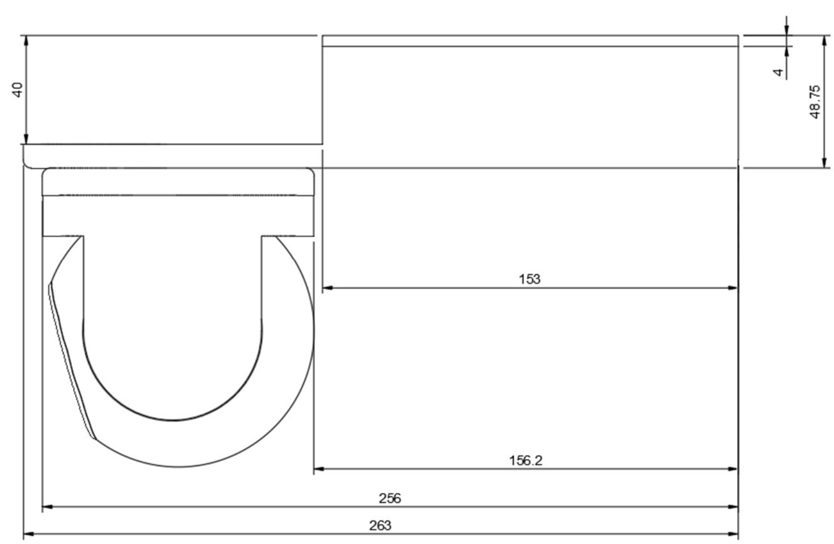
5.3 State-Transition Diagrams



The state-transition diagram shows the two states that the system may achieve, either it will detect an anomaly, or it will not. The camera will continuously monitor the pool of subjects from where it is meant to detect anomalies. If the system does not detect anomalies, there should be no activity and the camera system will continue monitoring (though objects of interest will be visually identified). If an anomaly is detected, multiple actions should be performed. Firstly, there should be an audio-visual alarm to notify an operator of the anomaly; secondly, the system should be able to track the object, possibly using a camera gimbal; and thirdly, the system should begin recording the anomaly.

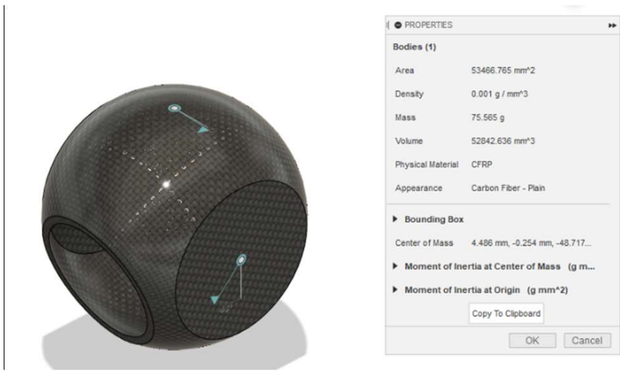
5.4 Size, Weight and Power

One of our main goals is the optimization of the size, weight, and power envelopes (C-SWAP) of available off-the-shelf components.



5.4.1 Size

First, we are planning on a simple but efficient design that shall have enough space for the Raspberry Pi and the Jetson, while also leaving enough room for air flow. Here are the initial designs that we came with:



The total estimated size when putting all the parts together would be 48.75mm tall, 110mm wide and 263mm long.

5.4.2 Weight

Another important aspect of our design is its low weight. Initially, we considered that we could produce an extremely light product, just over a kilogram. However, we decided to go with a more realistic approach at around 1.5kg considering both the Jetson and the Pi require extra heatsinks, wires, etc.

Here are some other physical dimensions of our product design:

Physical	
Mass	1448.584 g
Volume	7.401E+05 mm^3
Density	0.002 g / mm^3
Area	3.607E+05 mm^2

5.4.3 Power

While most CCTV Cameras require a 12V DC power supply, we estimate that our product will be more efficient in terms of power, and we decided to go with two separate batteries to power up our product. For instance, the Raspberry Pi would need a 5V/3A battery, while the Jetson will require a 5V/4A battery.

5.5 System Performance

The standard security cameras can operate at 30 FPS, but most CCTV cameras work just fine at just 10-15 FPS. We estimate that our product will easily achieve the 10 FPS mark. However, we are aiming at a 20 to 30 FPS, depending on the desired image quality, also, more testing is required since the velocity of both our product and the object being detected could interfere with the frames at which the product will work. On the other hand, latency will mostly depend on two things: First, the distance between our product and the video source, and secondly, on the internet speed at which our product will communicate with the server.

6. Requirements Test Matrix

Table 2 Test Requirements Matrix

Req#	**Function**	**Requirement**	**Test Method**	**Brief Test description**	**SME /Faculty Reviewed / Approved**
1	Software	The system must detect and differentiate objects from one another	Test	Compare real-time images with control images to recognize anomalies related to the figures shown (ex. strange objects)	
2	Software	The system must detect and compare motion by determining their speed	Test	Compare real-time images with the pre-recorded video and compare their velocities to detect anomalies (ex. objects moving at higher speeds than usual)	
3	Software	System must display the percentage in certainty when detecting an object / body	Inspection	We will be able to see how accurate the product is when detecting anomalies	
4	Software	When the product is plugged in, it must turn on the camera and the detection software	Test	The product must start working as soon as it gets plugged in (since it was previously trained, no internet connection is required)	

Req#	Function	Requirement	Test Method	Brief Test description	SME /Faculty Reviewed / Approved
5	ME	Raspberry pi board (with USB 3.0 port)	Inspection	We will look at the board and make sure it has at least one (1) USB 3.0 port to plug the camera in	
6	ME	Product must stay in place	Test	We will place the product on a steady surface to avoid distortion while analyzing the images	
7	ME	All connections must be wired	Inspection	We will visually identify all connections and make sure all wires are plugged correctly	
8	EE	Product must provide digital feedback when anomalies are detected	Demonstration	We will send a message with video-proof of the anomaly, including the exact time and date it happened	

7. Project Risk

Risk 1 – Camera Interface

One risk that the project may encounter is the interface between the camera and the computer system. The cameras used in video analytics typically rely upon Mobile Industry Processor Interface (MIPI). This interface may prove difficult to integrate into the script. If this proves to be the case, our team will substitute a high-resolution USB camera.

Risk 2 – Computer Processing Power

Another risk that this project could encounter is having a computer incapable of performing high speed video processing algorithms. A laptop computer will probably not have the ability to perform the number of computations without significant of overheating. A tower computer will be able to run the computations, however if the project is downsized, a tower computer will take up a large amount of space. Depending on the direction of the project, we may decide to utilize a Nvidia Jetson Nano, or a Nvidia Jetson Xavier.

Risk 3 – Computer Memory

A final risk to consider is the possibility that a computer will not have the memory space required to perform video analytics. This problem can easily be overcome by incorporating extended memory into the computer, or even using external memory devices (such as an SD card or extremal hard drive).

8. Standards

ISO/IEC/IEEE International Standard - Systems and software engineering--Systems and software assurance --Part 1: Concepts and vocabulary

- https://standards.ieee.org/ieee/15026-1/7155/

Standard for a Basic Framework for Motion Training Systems

- https://standards.ieee.org/ieee/3079.2.1/10841/

Standard for Performance Evaluation of Biometric Information: Facial Recognition

- https://standards.ieee.org/ieee/2884/10304/

Standard for Arithmetic Formats for Machine Learning

- https://standards.ieee.org/ieee/3109/10698/

IEEE Standard for Telecommunications and Information Exchange Between Systems - LAN/MAN - Specific Requirements - Part 15: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Wireless Personal Area Networks (WPANs) [USB 3.0]

- https://standards.ieee.org/ieee/802.15.1/1180/

9. Engineering Ethical Responsibility

Environment

The Video Analytics at the Edge project is rooted more in software than the actual production of a hardware system. As such the environmental impacts of this project are synonymous with the environmental impacts of the production/disposal and the maintenance of computers.

As computers become increasingly advanced and the gratuitous desire to maintain Moore's Law continues, their production consumes an increasing number of resources. Due to the nature of these resources, they must be obtained through mining processes. Though some mining methods have lesser effects on the environment, it cannot be denied that, overall, mining can be incredibly destructive to the environment. Another concern that has been raised is the issue of resource depletion. "Resource depletion is another negative impact of technology on the environment. It refers to the consumption of a resource faster than it can be replenished [1]." Modern computers contain several exotic and rare elements and materials, some of which are becoming increasingly scarce.

Computer systems also have the misfortune of a short useful life. This gives rise to environmental concerns about their proper disposal. Electronic waste, colloquially known as e-waste, poses environmental concerns that are incredibly unique among waste disposal considerations. "The presence of hazardous materials such as lead, cadmium, mercury, nickel, hexavalent chromium, and brominated flame retardants increases the complexity of E-waste treatment. Thus, the disposal of hazardous waste is a major challenge in E-waste management [2]." Studies into e-waste management have found that "only 17.4% of E-wastes are formally collected and recycled, while the remaining 82.6% is traded through illegal markets and disposed in dumps and landfills [2]," usually in developing countries.

A final environmental consideration is the consumption of power. It has been estimated that information technology systems (including computers) consume 10% of all electricity produced. Additionally, video and image processing consume larger amounts of power than ordinary computers, due to the number of cores that are used and the cooling requirements. Some part of the environmental impact of this electricity consumption may be reduced with the introduction of renewable energy sources.

Society

Apart from environmental concerns, societal concerns should also be addressed. Though the detection of anomalous objects can be applied to many different areas and industries (for example fruit selection), it has the potential (and indeed, is likely to be used) to create surveillance systems. Surveillance systems can increase public safety and detect criminal elements within society, but it does come at the cost of reduced privacy for the individual citizen. "In the context of [a] connected society, conceptualization, definition, and establishment of both theoretical and legal parameters that would set ethical and efficient limits on the analysis, treatment, and use of citizens' data have become a challenge in scientific, legal, and professional settings [3]."

10. Change Management Process

The SRD is posted in Microsoft Teams in the file sharing section of a private team. All team members have access to this document, and all can edit and make any changes that are deemed necessary. Microsoft Teams displays each member's work simultaneously and changes made in the absence of members of the team are marked by the application. In this way, members can catch up on any changes made to the document (and particularly) their assigned portions. Additionally, the chat and live meeting features of Microsoft Teams allow the team to work in their own time or collaborate on the document. In the event that major changes need to be made a copy of the original will be made to prevent the loss of information and the loss of the required format.