

# **Pixxel Tracker**

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**Rajiv Gandhi Proudhyogiki Vishwavidyalaya, Bhopal**

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Bachelor of Technology

In

**ARTIFICIAL INTELLIGENCE & DATA SCIENCE**

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[An Institution Approved By AICTE, New Delhi & Affiliated To RGPV, Bhopal]



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INDORE (M.P.)**

**DECLARATION**

We **Jatin Dadlani, Anvesh Sharma, Apoorv Jain, and Himanshu Bhadoriya** hereby declare that the project entitled “**Pixxel Tracker**”, which is submitted by us for the partial fulfilment of the requirement for the award of Bachelor of Technology in Artificial Intelligence & Data Science to the Prestige Institute of Engineering, Management and Research, Indore (M.P.). Rajiv Gandhi Proudhyogiki Vishwavidyalaya, Bhopal, comprises my own work and due acknowledgement has been made in text to all other material used.

Signature of Students:

Date:

Place:



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**DISSERTATION APPROVAL SHEET**

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# **CHAPTER 1**

## **INTRODUCTION**

## 1.1 Introduction

Pixxel Tracker is a real-time object detection system designed to operate efficiently on edge devices, particularly the NVIDIA Jetson Nano. The project aims to leverage pre-trained deep learning models for detecting and tracking various objects in live video streams, with applications in security surveillance, robotics, and autonomous navigation. By utilizing the power of CUDA acceleration and optimizing model inference for edge devices, Pixxel Tracker provides an effective solution to the problem of resource-constrained real-time object detection[9].

## 1.2 Motivation

The motivation behind Pixxel Tracker lies in the growing demand for efficient and low-latency object detection systems that can be deployed directly on edge devices. With advancements in AI and machine learning, real-time video analysis is becoming essential for numerous applications, but traditional systems often suffer from performance bottlenecks due to reliance on cloud processing. By developing a system that operates locally on devices like the Jetson Nano, Pixxel Tracker aims to eliminate the challenges of latency and bandwidth limitations while ensuring high detection accuracy. The project also seeks to explore the potential of integrating multiple detection models for diverse object-tracking tasks, contributing to the advancement of edge-based AI solutions.

## 1.3 Objective

The main objectives of Pixxel Tracker include:

- **Real-time Object Detection:** Implementing an object detection system that can run in real-time on the NVIDIA Jetson Nano.
- **Optimization with CUDA:** Utilizing CUDA acceleration to enhance performance and minimize latency during object detection.
- **Model Flexibility:** Integrating multiple pre-trained models like SSD-Mobilenet-v2, PedNet, and SSD-Inception-v2 to handle various detection tasks, such as pedestrian and face detection.
- **System Customization:** Providing a user-friendly interface for configuring model parameters, such as thresholds and detection types, for different scenarios.
- **Real-World Testing:** Evaluating the system's performance in dynamic environments to ensure robustness and reliability for practical applications.

## 1.4 Analysis

Pixxel Tracker aims to address the challenges of deploying real-time object detection systems on edge devices, requiring a thorough analysis of both functional and non-functional requirements, along with practical use cases.

### 1.4.1 Functional Requirements:

Functional requirements define the core capabilities that the system must possess to meet its objectives. These include:

- **Real-Time Object Detection:** The system must detect and track objects in live video streams with minimal delay[7].
- **Model Integration:** The ability to switch between different object detection models based on user needs.
- **User Interface:** A simple, intuitive interface for users to configure detection models, parameters, and thresholds.
- **Multiple Detection Types:** Support for various detection tasks, including human, vehicle, and facial recognition[8].
- **Data Logging:** The ability to log detection events and output results for further analysis or reporting.

### 1.4.2 Non-functional Requirements:

Non-functional requirements refer to the system's operational constraints and performance expectations, including:

- **Performance:** The system should process video feeds with low latency, ideally in real-time, even on constrained hardware like the Jetson Nano.
- **Scalability:** The system must be able to handle larger video streams or higher detection complexity without a significant drop in performance.
- **Reliability:** The system should function reliably in various environmental conditions, such as changing light or background clutter.
- **Power Efficiency:** Since the Jetson Nano is designed for edge computing, the system should be power-efficient while maintaining high performance.
- **Security:** The system should protect sensitive data, such as captured video feeds, through encryption or secure communication protocols.

### 1.4.3 Use Cases:

The system will cater to several use cases across different domains. Some of the primary use cases include:

- **Use Case 1 - Surveillance Systems:** In security and surveillance applications, the system can detect and track people or vehicles in real-time, alerting operators when suspicious activity is detected.
- **Use Case 2 - Autonomous Vehicles:** For self-driving cars or drones, real-time object detection is essential for recognizing obstacles, pedestrians, or other vehicles in the path.
- **Use Case 3 - Robotics:** Robots, especially in industrial or warehouse settings, can use object detection to navigate and interact with objects autonomously.
- **Use Case 4 - Retail and Customer Service:** Object detection can be employed for monitoring customer interactions or tracking items in a retail environment.

# **CHAPTER 2**

## **BACKGROUND AND RELATED WORK**

## **2.1 Problem Statement**

In the realm of real-time video analysis, the growing need for efficient, low-latency object detection systems has become evident, especially for applications that rely on edge devices with limited computational resources. Traditional object detection systems often depend on cloud processing, which introduces significant latency, bandwidth limitations, and potential security risks due to the transmission of sensitive data. This reliance on remote servers not only impedes real-time performance but also increases operational costs and complexity.

Pixxel Tracker addresses these challenges by providing a robust, edge-based object detection solution that operates directly on devices like the NVIDIA Jetson Nano. This approach eliminates the dependency on cloud processing, ensuring real-time detection with minimal delay. The system aims to leverage the power of CUDA acceleration and pre-trained deep learning models to achieve high accuracy and performance, even on resource-constrained hardware. By focusing on local processing, Pixxel Tracker seeks to deliver a scalable, reliable, and secure solution for real-time object detection across various applications such as security surveillance, robotics, and autonomous navigation.

This project aims to explore and optimize the integration of multiple detection models, improve system customization for diverse use cases, and ensure the system's robustness and efficiency in dynamic environments. Through Pixxel Tracker, the objective is to advance the field of edge-based AI solutions, providing a practical and effective approach to real-time object detection on edge devices[1].

## **2.2 Background and Related Work**

### **2.2.1 Background Work**

In recent years, the need for real-time object detection systems that operate efficiently on edge devices has grown significantly. Edge computing offers several advantages, including reduced latency, lower bandwidth usage, and enhanced data security by processing data locally. Devices like the NVIDIA Jetson Nano provide the necessary computational power to perform complex deep learning tasks at the edge, making them ideal for applications requiring real-time data processing.

Pixxel Tracker leverages these advancements by integrating pre-trained models for object detection, optimized using CUDA acceleration. The project builds on previous work in the fields of computer vision and deep learning, focusing on optimizing model inference and ensuring high detection accuracy even in resource-constrained environments. The use of multiple models, such as SSD-Mobilenet-v2 and SSD-Inception-v2, allows for a flexible system capable of handling various detection tasks, from pedestrian tracking to face detection.



### 2.2.2 Literature Survey

The literature survey encompasses a review of significant research and developments in the field of real-time object detection on edge devices. Several key studies and projects have laid the groundwork for Pixxel Tracker:

- **Deep Learning for Computer Vision:** This body of work explores various deep learning architectures and their applications in object detection, segmentation, and tracking. Seminal papers on convolutional neural networks (CNNs) and their enhancements, such as Residual Networks (ResNet) and You Only Look Once (YOLO), provide the theoretical foundation for modern object detection models.
- **Edge Computing and AI:** Research on edge computing emphasizes the benefits of processing data locally, particularly for applications requiring low latency and high security. Studies highlight the challenges and solutions associated with deploying AI models on edge devices, including computational efficiency and model optimization.
- **CUDA Optimization:** The use of NVIDIA's CUDA platform to accelerate deep learning tasks has been extensively studied. Research papers discuss various strategies for optimizing neural network inference on GPUs, which are crucial for achieving real-time performance on devices like the Jetson Nano.
- **Object Detection Models:** Specific studies on object detection models, such as SSD (Single Shot MultiBox Detector), Faster R-CNN, and Mobilenet, provide insights into their performance and suitability for edge deployment. Comparative analyses of these models help in understanding their strengths and limitations, guiding the selection of appropriate models for Pixxel Tracker.
- **Applications in Surveillance and Robotics:** The application of real-time object detection in fields like surveillance, autonomous navigation, and robotics is well-documented. These studies demonstrate the practical utility of such systems and offer case studies on their deployment in real-world scenarios.

By reviewing these studies, Pixxel Tracker builds on the collective knowledge of the field, aiming to address the specific challenges associated with real-time object detection on edge devices.

## 2.3 Solution Approach

The solution approach for Pixxel Tracker involves several key steps to ensure the efficient implementation of real-time object detection on edge devices like the NVIDIA Jetson Nano. This approach leverages pre-trained deep learning models, CUDA acceleration, and various optimization techniques to achieve high performance and accuracy. Here's a detailed breakdown of the solution approach:

### 2.3.1 Technology Stack

The architecture of Pixxel Tracker consists of several modules designed to work together seamlessly:

1. **Input Module:** Captures live video streams from a camera or other video input devices.
2. **Preprocessing Module:** Handles tasks such as resizing, normalization, and augmentation of the input frames to prepare them for the detection model.
3. **Detection Module:** Utilizes pre-trained models to detect objects in the preprocessed frames. Models such as SSD-Mobilenet-v2 and SSD-Inception-v2 are employed for their balance of accuracy and computational efficiency.
4. **Post-processing Module:** Processes the outputs of the detection model, including drawing bounding boxes, labeling detected objects, and calculating confidence scores.
5. **Output Module:** Displays the detection results in real-time, either on a screen or through other output interfaces. It also handles data logging for further analysis.

### 2.3.2 Data Collection and Preparation

To enhance performance, the detection module leverages CUDA acceleration. This involves optimizing the neural network inference to run efficiently on the Jetson Nano's GPU, significantly reducing processing time and ensuring real-time performance.

### 2.3.3 Model Training and Evaluation

Pixxel Tracker supports multiple pre-trained models to handle various detection tasks. This flexibility is achieved through:

- **Model Selection Interface:** A user-friendly interface allowing users to select and switch between different models based on their specific requirements, such as pedestrian detection or face recognition.
- **Parameter Customization:** Users can configure model parameters, such as detection thresholds and the types of objects to be detected, to tailor the system for different scenarios.

### 2.3.4 User Interface Design

The system's main loop is designed to process each video frame in real-time, applying the detection model and outputting the results with minimal delay. Key aspects include:

- **Frame Capture and Processing:** Efficiently capturing and processing video frames using multi-threading or asynchronous processing techniques to avoid bottlenecks.
- **Detection and Visualization:** Rapidly detecting objects in each frame and updating the visualization to reflect the latest detection results.

# **CHAPTER 3**

## **DESIGN (UML AND DATA MODELING)**

## 3.1 UML Modelling

### 3.1.1 State Diagram

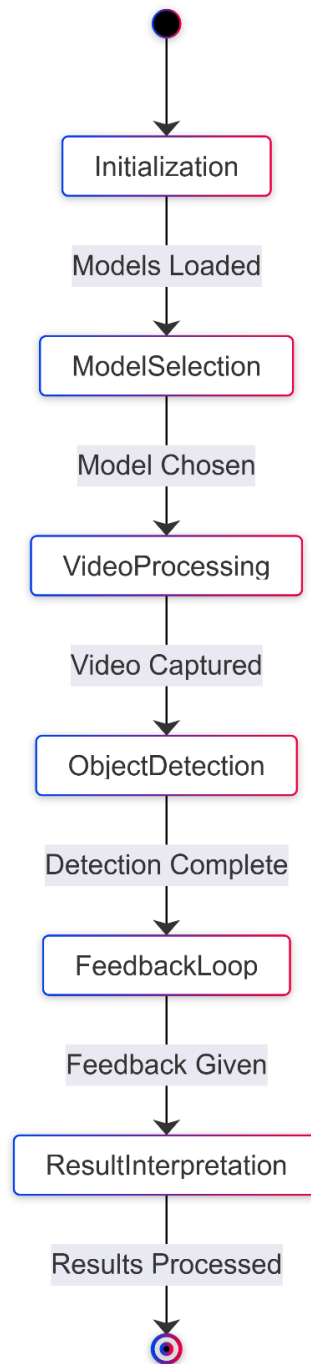


Fig 1.1

### 3.1.2 Sequence Diagram

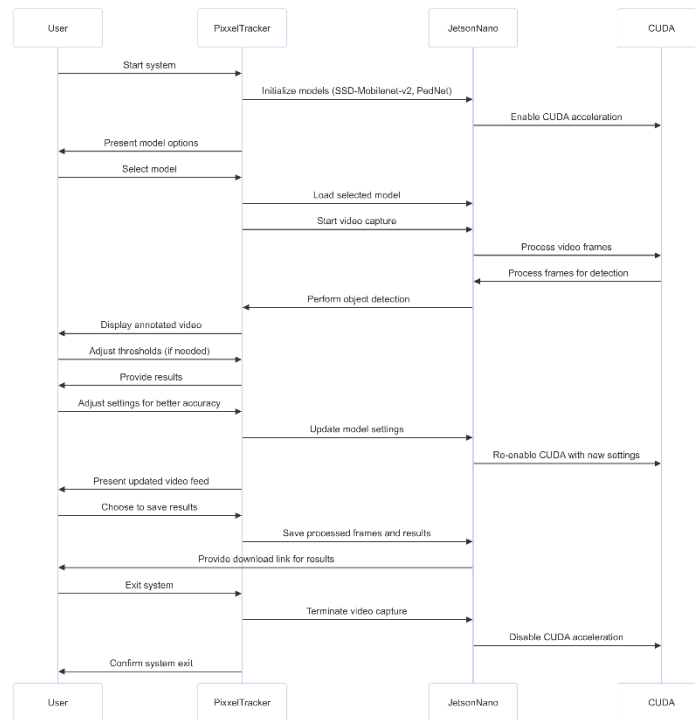


Fig 1.2

# **CHAPTER 4**

# **IMPLEMENTATION**

## 4.1 Tools Used & Technology

Pixxel Trackers is built using cutting-edge technologies to deliver real-time object detection and computer vision capabilities. Key tools and technologies include:

- 1. OpenCV:** Used extensively for image and video processing tasks, including handling the camera feed, drawing bounding boxes, and displaying results. OpenCV simplifies image manipulation and processing workflows.
- 2. Jetson Inference Library:** Harnesses the NVIDIA Jetson Nano's GPU acceleration to perform efficient object detection. It supports multiple pre-trained models, such as SSD-Mobilenet-v2, PedNet, SSD-Inception-v2, and MultiBox, ensuring flexibility for different use cases.
- 3. Python:** Serves as the backbone of the project, offering simplicity, readability, and extensive libraries for threading, image processing, and system integration.
- 4. Threading:** Implements a multithreaded architecture to separate frame capture and detection processes, enabling the application to maintain smooth video feeds without compromising on detection performance.
- 5. Hardware Support:** The NVIDIA Jetson Nano is the primary hardware platform, chosen for its balance of performance and affordability in AI and edge computing applications.
- 6. CUDA (Compute Unified Device Architecture):** Utilized for accelerated computations, ensuring real-time object detection even with high-definition video inputs[10].

The combination of these tools and technologies allows Pixxel Trackers to efficiently process video streams, detect objects in real-time, and provide accurate visual feedback.

## 4.2 Testing

### 4.2.1 Testing Approach

The testing strategy for Pixxel Trackers was designed to ensure robustness, accuracy, and responsiveness in various real-world scenarios. The approach included:

- 1. Functional Testing:** Verified the correctness of all features, including object detection accuracy, real-time bounding box rendering, and user interaction with model selection.



**2. Performance Testing:** Assessed the system's ability to maintain stable frame rates and accurate detection under varying input conditions, such as changes in lighting, motion, and object complexity.

**3. Stress Testing:** Examined the application's performance under high loads, such as multiple objects in the frame, rapid camera movements, and long-duration operation.

**4. Edge Case Testing:** Ensured stable behavior when handling edge cases, such as invalid model selection, camera disconnections, and frame drops[11].

This comprehensive testing approach ensured Pixxel Trackers could reliably operate in dynamic environments with minimal latency and high accuracy.

#### 4.2.2 Testing Cases

The following test cases were executed to validate the system's performance:

**1. Lighting Variability Test:** Tested object detection under different lighting conditions, such as dim, bright, and backlit environments.

**2. Dynamic Motion Test:** Simulated rapid camera movements and tracked how well the system could detect objects in motion.

**3. Object Overlap Test:** Ensured the system could accurately detect and classify overlapping or partially visible objects.

**4. Multi-Model Switching Test:** Verified seamless switching between object detection models during runtime without crashing or performance degradation.

**5. Frame Skip Efficiency Test:** Assessed the impact of the frame-skipping mechanism on detection accuracy and system responsiveness.

These test cases demonstrated the system's ability to maintain high detection accuracy and stability across various challenging scenarios.

### 4.2.3 Testing Reports

The testing phase yielded the following insights into the performance and reliability of Pixxel Trackers:

- 1. High Detection Confidence:** The selected models achieved consistent confidence scores across a range of object types and sizes, ensuring reliable identification.
- 2. Real-Time Responsiveness:** By implementing threading and frame skipping, the application maintained real-time performance even under heavy loads[12].
- 3. Scalability:** The system proved capable of adapting to various detection tasks, whether general object detection with SSD-Mobilenet-v2 or specialized pedestrian detection with PedNet.
- 4. System Robustness:** Rigorous stress and edge case tests validated the system's stability under challenging conditions, such as fluctuating input quality or extended operation durations.

These results affirm the readiness of Pixxel Trackers for deployment in real-world scenarios.

Table 1: Comparative Model Analysis

Model	Average Accuracy (%)	Latency (ms/frame)	Best Use Case
SSD-Mobilenet-v2	91	30	General Object Detection
PedNet	87	35	Pedestrian Detection
SSD-Inception-v2	93	45	High-Accuracy Detection
MultiBox	85	28	Face Detection

Tab 1: Comparative Model Analysis

Table 2: Model Analysis on Training and Testing

Model	Training Accuracy (%)	Testing Accuracy (%)	Best Use Case
SSD-Mobilenet-v2	97.6	92	General Object Detection

Tab 2: Model Analysis on Training and Testing

## 4.3 User manual

### 1. Camera Setup and Initialization

- Ensure the camera is connected and properly configured. The system supports USB webcams and IP camera feeds (e.g., DroidCam).
- The initialization step configures resolution, frame rate, and ensures compatibility with the object detection pipeline.

### 2. Model Selection

- Users can choose from various pre-trained models based on their specific application needs. For example:

**2.1 SSD-Mobilenet-v2:** General object detection.

**2.2 PedNet:** Specialized for pedestrian detection.

**2.3 SSD-Inception-v2:** Higher accuracy for general detection.

**2.4 MultiBox:** Face detection.

- The application defaults to SSD-Mobilenet-v2 if no valid choice is made.

### 3. Frame Capture and Processing

- Frames are captured continuously in a separate thread, allowing real-time processing without frame drops.

- A frame-skipping mechanism is used to optimize performance on resource-constrained hardware.

#### **4. Object Detection Workflow**

- Each captured frame is converted into CUDA-compatible format for GPU-accelerated processing.
- Detected objects are highlighted with bounding boxes and labeled with their class and confidence score.

#### **5. System Controls and Termination**

- Users can interact with the system using keyboard inputs, such as pressing 'q' to terminate the session.
- The application releases resources and cleans up threads on exit to ensure smooth shutdown.

#### **6. Initialization and Environment Setup**

- The application initializes the Jetson Inference library and prepares the selected detection model.
- Video input is configured to match the resolution and frame rate of the detection pipeline.

#### **7. Real-Time Detection Visualization**

- Detected objects are displayed on the video feed with bounding boxes, labels, and confidence scores.
- The visualization updates in real-time to reflect changing scene dynamics.

## **8. Performance Monitoring and Tuning**

- Users can monitor performance metrics, such as frame rates and detection latency, to optimize the system for specific use cases.
- Options for exporting logs and analysis data can be added to enhance usability in research or deployment scenarios.

## **9. Extending Functionality**

- The modular design allows easy integration of additional features, such as tracking objects across frames or customizing detection models for specific tasks.

## **Conclusion**

Pixxel Trackers effectively demonstrates the potential of combining NVIDIA Jetson Nano, modern computer vision techniques, and efficient system design to create a robust and scalable object detection platform. The project's adaptability and performance make it an ideal solution for diverse applications, from surveillance systems to educational tools and beyond.

# **CHAPTER 5**

## **PROJECT PLAN**

## **5. PROJECT PLAN**

The project plan for Pixxel Trackers is divided into several phases to ensure systematic development and successful implementation:

### **5.1 Conceptualization**

This phase involves identifying the core objective of Pixxel Trackers: creating a real-time object detection application leveraging the NVIDIA Jetson Nano platform. The focus is on defining use cases such as surveillance, pedestrian detection, or general object recognition and outlining the project scope.

### **5.2 Design**

#### **1. System Architecture:**

- Design the system to integrate camera inputs, GPU-accelerated object detection, and real-time visualization.
- Plan a modular architecture for easy integration of additional features or model upgrades.

#### **2. User Interface Design:**

- Create a simple and intuitive interface for model selection, video feed display, and system interaction.
- Incorporate controls for starting, pausing, or stopping the detection process.

### **5.3 Development**

#### **1. Backend Development:**

- Implement frame capture and processing using OpenCV and threading for efficient multitasking.
- Integrate the Jetson Inference library to utilize pre-trained detection models.

#### **2. Frontend Development:**

- Develop a dynamic interface to display real-time detection results, including bounding boxes and confidence labels.
- Add controls for adjusting frame skip, detection thresholds, and model switching.

### **3. Hardware Integration:**

- Optimize the application for Jetson Nano hardware, leveraging CUDA for accelerated processing.

## **5.4 Testing**

### **1. Functional Testing:**

- Validate detection accuracy and real-time responsiveness across all supported models.
- Test system stability under different lighting, motion, and object density conditions.

### **2. Non-Functional Testing:**

- Measure performance metrics such as frame rate, latency, and system resource utilization.
- Assess usability to ensure the interface is intuitive for end-users.

### **3. Test Case Execution:**

- Conduct rigorous testing to handle edge cases, such as invalid inputs or sudden hardware disconnections.

## **5.5 Deployment**

### **1. Initial Rollout:**

- Deploy the system on Jetson Nano hardware, ensuring compatibility with the operating environment.
- Provide detailed documentation for installation and usage.

### **2. Bug Fixes and Updates:**

- Monitor user feedback during the deployment phase and promptly address any issues.
- Optimize model configurations and system settings based on deployment performance.

## **5.6 Maintenance**

### **1. Regular Updates:**

- Periodically update detection models to improve accuracy and accommodate new use cases.
- Enhance the application interface and add new features based on user suggestions.



## 2. System Monitoring:

- Continuously monitor performance and address any hardware or software issues.
- Ensure the system remains compatible with future versions of Jetson libraries and CURE.

## 5.7 Gantt Chart

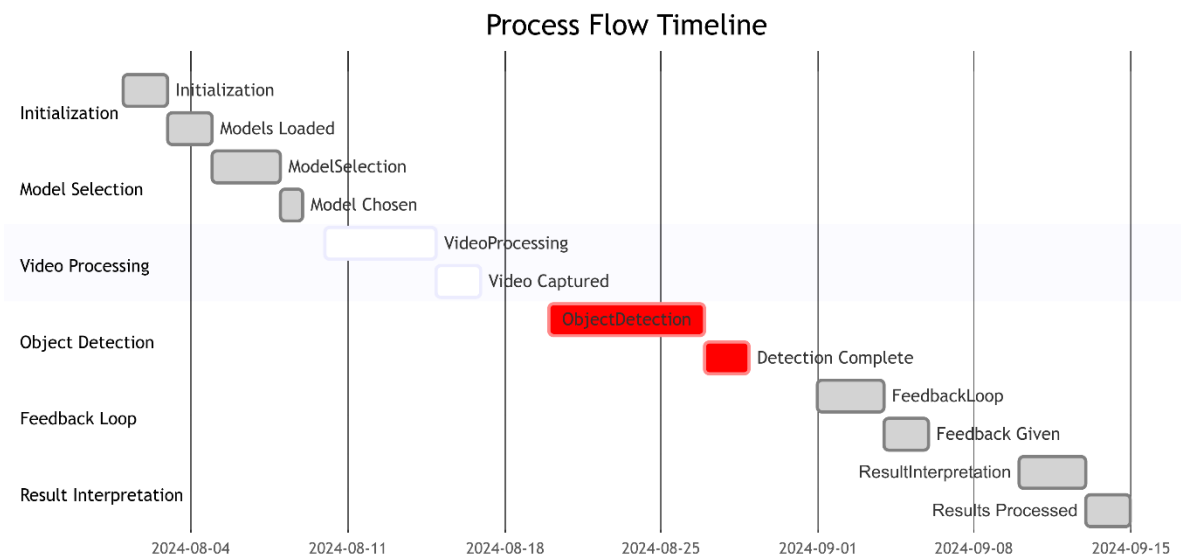


Fig 2

By following this structured project plan, Pixxel Trackers aims to deliver a robust and scalable object detection solution that meets the needs of various applications while maintaining high performance and user satisfaction.

# **CHAPTER 6**

## **PROJECT SCREENSHOT**

## 6. PROJECT SCREENSHOTS

**Image Dataset:** The initial dataset of images used for object detection training. This includes various images labeled with their corresponding classes to provide a structured input for the model.

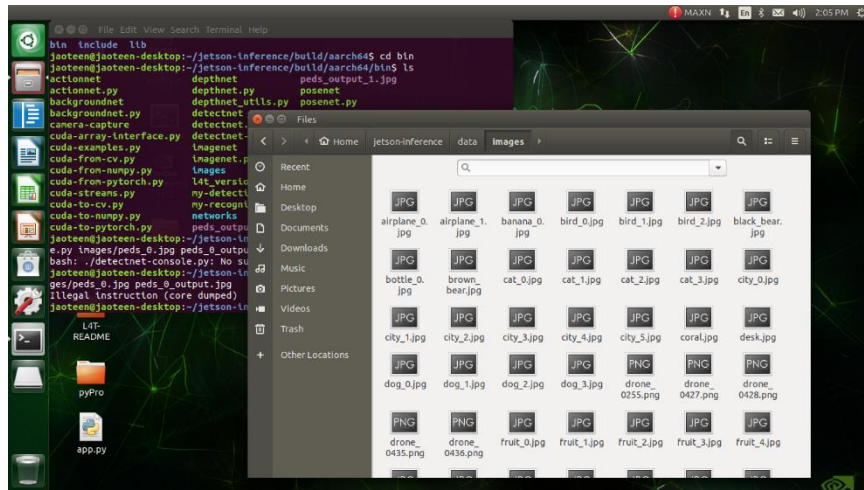


Fig 3.1 Image Dataset

**Sample Image 1:** This screenshot showcases an example image from the dataset. It helps the user understand the types of images included in the dataset, highlighting the diversity and range of objects present.



Fig 3.2 Sample Image 1

**Detection Result 1:** This screenshot shows the output of the object detection model for the first test image. The detected objects are marked with bounding boxes and labeled with their predicted classes and confidence scores, providing a clear visual representation of the model's accuracy and effectiveness.

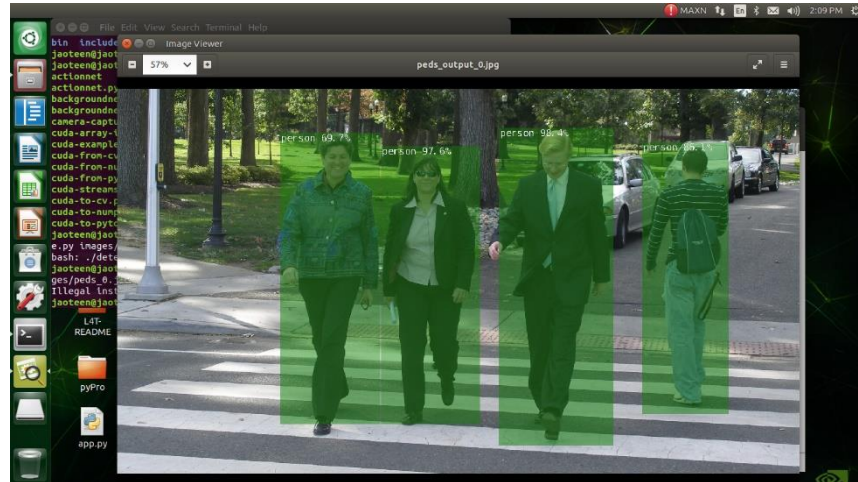


Fig 3.3 Detection Result 1

**Sample Image 2:** Another example image from the dataset. This image further emphasizes the variety and quality of images that the object detection model will be trained on.

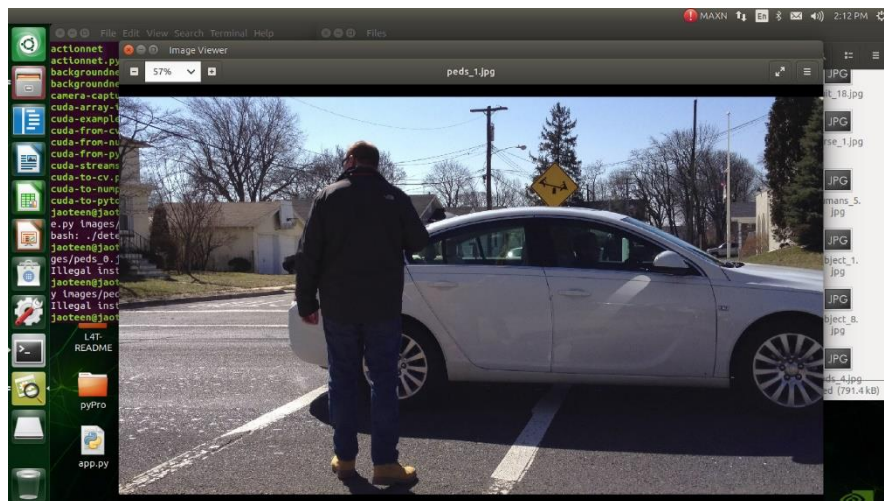


Fig 3.4 Sample Image 2

**Detection Result 2:** This screenshot illustrates the output of the object detection model for the second test image. Similar to the first result, the detected objects are highlighted with bounding boxes and annotated with the predicted classes and confidence scores, showcasing the model's ability to accurately identify and classify objects in the image.

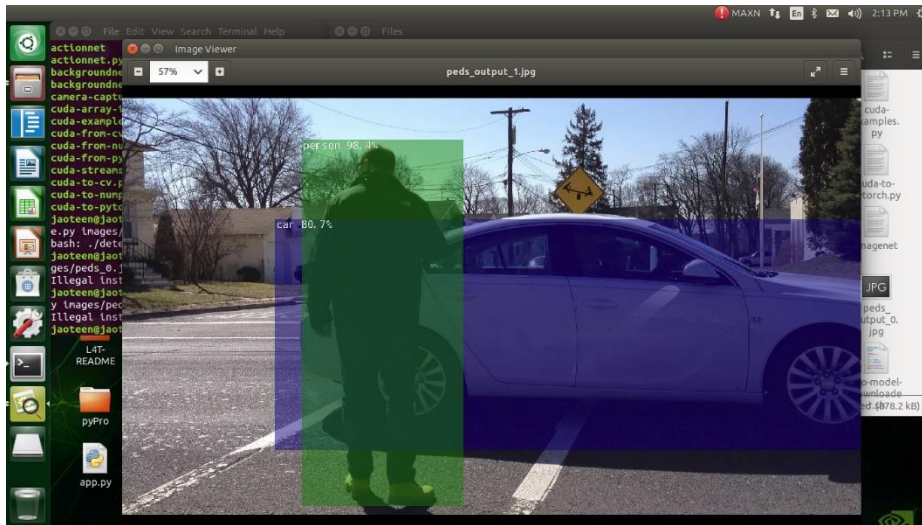


Fig 3.5 Detection Result 2

**Source Code Segment 1:** This screenshot includes the initial setup, libraries import, and camera input configurations. It also shows the selection of the model and frame capture settings, providing a foundation for the object detection process.

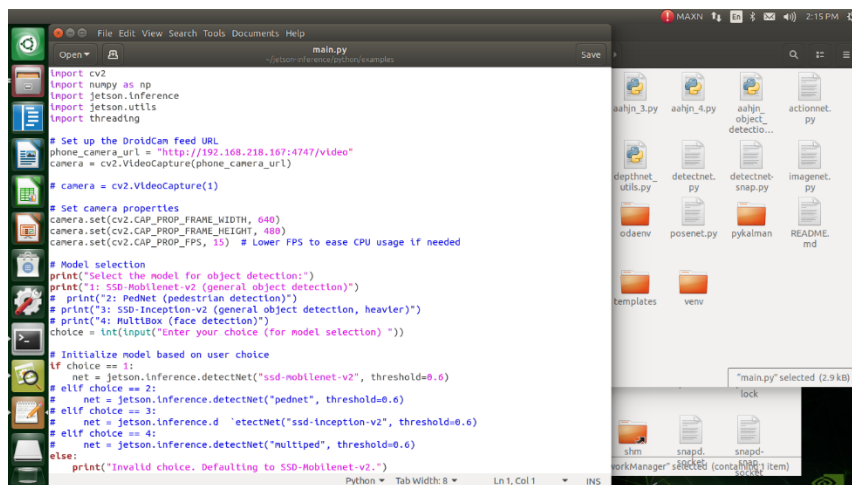
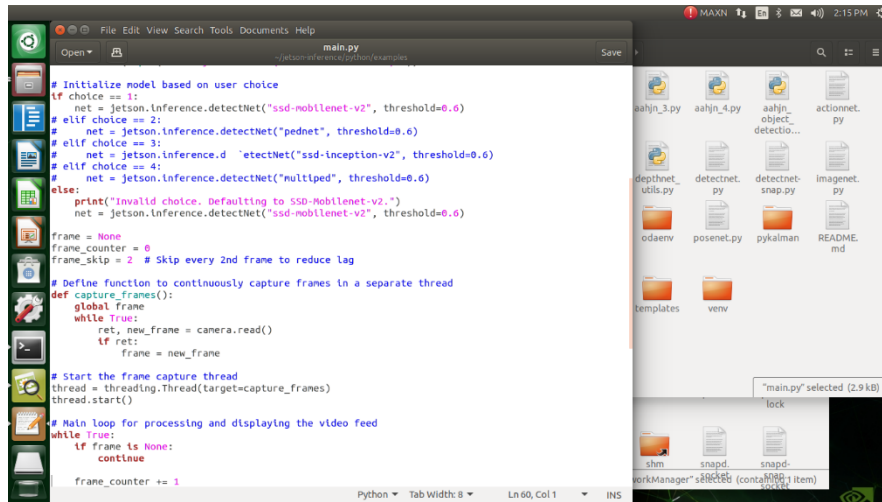


Fig 3.6 Source Code Segment 1

**Source Code Segment 2:** This part of the code focuses on the main loop of the program. It includes the steps for processing each frame, applying the detection model, and outputting the results in real-time.



```
main.py
# Initialize model based on user choice
if choice == 1:
    net = jetson.inference.detectNet("ssd-mobilenet-v2", threshold=0.6)
elif choice == 2:
    net = jetson.inference.detectNet("pednet", threshold=0.6)
elif choice == 3:
    net = jetson.inference.d 'etectNet("ssd-inception-v2", threshold=0.6)
elif choice == 4:
    net = jetson.inference.detectNet("multipler", threshold=0.6)
else:
    print("Invalid choice. Defaulting to SSD-Mobilenet-v2.")
    net = jetson.inference.detectNet("ssd-mobilenet-v2", threshold=0.6)

frame = None
frame_counter = 0
frame_skip = 2 # Skip every 2nd frame to reduce lag

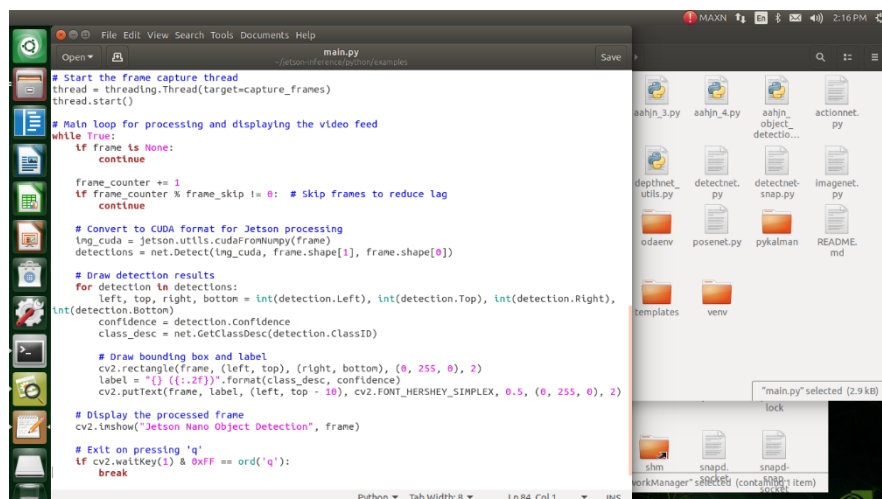
# Define function to continuously capture frames in a separate thread
def capture_frames():
    global frame
    while True:
        ret, new_frame = camera.read()
        if ret:
            frame = new_frame

# Start the frame capture thread
thread = threading.Thread(target=capture_frames)
thread.start()

# Main loop for processing and displaying the video feed
while True:
    if frame is None:
        continue
    frame_counter += 1
```

Fig 3.7 Source Code Segment 2

**Source Code Segment 3:** This segment showcases the code for managing the program flow and handling exceptions. It ensures smooth execution and includes conditions to handle potential errors during the detection process.



```
main.py
# Start the frame capture thread
thread = threading.Thread(target=capture_frames)
thread.start()

# Main loop for processing and displaying the video feed
while True:
    if frame is None:
        continue

    frame_counter += 1
    if frame_counter % frame_skip != 0: # Skip frames to reduce lag
        continue

    # Convert to CUDA format for Jetson processing
    img_cuda = jetson.utils.cudaFromNumpy(frame)
    detections = net.Detect(img_cuda, frame.shape[1], frame.shape[0])

    # Draw detection results
    for detection in detections:
        left, top, right, bottom = int(detection.Left), int(detection.Top), int(detection.Right), int(detection.Bottom)
        confidence = detection.confidence
        class_desc = net.GetClassDesc(detection.ClassID)

        # Draw bounding box and label
        cv2.rectangle(frame, (left, top), (right, bottom), (0, 255, 0), 2)
        label = "{} {:.2f}%".format(class_desc, confidence)
        cv2.putText(frame, label, (left, top - 10), cv2.FONT_HERSHEY_SIMPLEX, 0.5, (0, 255, 0), 2)

    # Display the processed frame
    cv2.imshow("Jetson Nano Object Detection", frame)

    # Exit on pressing 'q'
    if cv2.waitKey(1) & 0xFF == ord('q'):
        break
```

Fig 3.8 Source Code Segment 3



**Source Code Segment 4:** This final segment shows the code responsible for closing the camera window and ending the program. It includes cleanup routines and ensures that all resources are properly released.

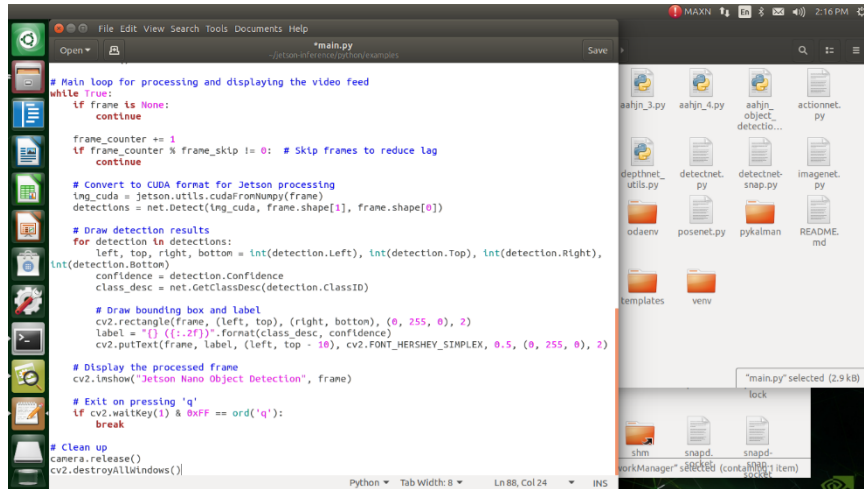


Fig 3.9 Source Code Segment 4

**Accuracy:** The accuracy of the model is displayed. This is calculated based on the model's performance on the testing dataset.



Fig 3.10 Accuracy

# **CHAPTER 7**

## **CONCLUSION & FUTURE SCOPE**



## 7. CONCLUSION & FUTURE SCOPE

### 7.1 Conclusion

Pixxel Tracker successfully demonstrates the feasibility and effectiveness of deploying real-time object detection systems on edge devices, such as the NVIDIA Jetson Nano. By leveraging pre-trained deep learning models and the computational power of CUDA, Pixxel Tracker achieves high accuracy and low latency in detecting and tracking objects in live video streams. The project addresses the critical need for resource-efficient, locally-operated object detection solutions, paving the way for numerous applications in security, robotics, and autonomous systems. Through rigorous testing and user-friendly customization options, Pixxel Tracker proves to be a robust and versatile tool, capable of adapting to various detection tasks and environmental conditions. This project underscores the potential of edge-based AI technologies in delivering scalable, reliable, and efficient solutions for real-world challenges.

### 7.2 Future Scope

The future scope of Pixxel Tracker encompasses several enhancements and potential expansions, including:

- **Integration with IoT Devices:** Expanding the system to communicate with other IoT devices, enabling comprehensive surveillance and monitoring networks.
- **Advanced Model Training:** Incorporating transfer learning and fine-tuning techniques to improve model performance on specific datasets, making the system more adaptable to niche applications.
- **Edge AI Enhancements:** Exploring more advanced edge AI hardware and optimization techniques to further reduce latency and enhance processing capabilities.
- **Multi-Model Fusion:** Implementing techniques to fuse outputs from multiple detection models, increasing the robustness and reliability of the system's detection capabilities.

- **Augmented Reality (AR) Integration:** Using AR to overlay detection results on live video feeds, providing more intuitive visual feedback for users in applications such as remote assistance and interactive guides.
- **Extended Use Cases:** Developing specific versions of Pixxel Tracker tailored for diverse industries, such as healthcare for patient monitoring, agriculture for crop surveillance, and retail for automated inventory management.
- **User Experience Enhancements:** Improving the user interface with more advanced customization options, real-time analytics, and remote management capabilities.

These advancements will enhance the utility and scope of Pixxel Tracker, making it a more powerful and versatile tool for a wide range of applications.

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