Intel College Excellence Program
Project Synopsis

“ Edge-Based Real-Time YOLOv8 Face Detection with Multi-View Image Processing ”

“<u>EDGE COMPUTING</u>”

Team member’s detail			
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BACKGROUND

In recent years, advancements in computer vision and artificial intelligence (AI) have transformed how machines perceive and interact with their surroundings. Technologies like autonomous vehicles, security monitoring, industrial automation, and robotics heavily depend on the capability to detect, track, and analyze objects in real time.

Traditional methods typically involve transmitting video data to a central server or cloud for processing. Although cloud-based processing can manage complex algorithms, it introduces delays, consumes bandwidth, and raises privacy concerns. This is where edge computing plays a crucial role. By enabling processing directly on the device or near the data source, edge computing allows for immediate decision-making, reduces network traffic, and enhances privacy.

YOLO (You Only Look Once) is a state-of-the-art object detection algorithm known for its speed and accuracy. Its latest iteration, YOLOv8, supports real-time detection even on devices with limited resources, making it ideal for deployment at the edge.

In addition to object detection, various image processing techniques—such as grayscale conversion, binary and adaptive thresholding, edge detection (Canny and Sobel), color mapping, heatmaps, night vision, sepia filters, blurring, and RGB channel separation—provide improved visualization, feature extraction, and analysis of different scene elements. Combining these methods into a dynamic multi-view grid enables simultaneous viewing of multiple transformations, which is beneficial for education, monitoring, and decision-making.

This project integrates YOLOv8 object detection with multiple image processing transformations on a single live video stream, all processed locally on an edge device. The outcome is a comprehensive real-time video analysis system applicable to:

- Security surveillance (detecting intruders and monitoring environments under low light with night vision).
- Educational use (demonstrating image processing and object detection techniques in real time).
- Industrial monitoring (analyzing live machine operations or production lines).
- Creative video applications (applying various visual effects and filters in real time).

This system showcases the potential of combining edge computing with modern computer vision methods, delivering a scalable and efficient solution for real-time multi-view video analytics..

PROBLEM IDENTIFICATION

In the rapidly evolving landscape of smart devices, IoT, and AI-powered systems, real-time video analysis has emerged as an essential need for applications like security surveillance, autonomous vehicles, industrial monitoring, robotics, and smart home automation. Many traditional systems depend on transmitting video data to cloud servers for processing, leading to considerable latency, high network bandwidth usage, and increased privacy and security issues due to the transfer of sensitive information over networks. Additionally, current systems typically offer only one viewpoint, concentrating either on object detection or a specific image processing effect, restricting a thorough comprehension of the scene. This complicates real-time comparisons of various computer vision techniques for researchers, students, or professionals.

Integrating sophisticated object detection models like YOLOv8 with various image transformations including edge detection, heatmaps, night vision, and color filtering on one device poses significant computational challenges, particularly on devices with constrained processing capabilities. Numerous systems do not offer a dynamic, well-structured multi-view interface, which complicates users' ability to analyze, interpret, and swiftly decide from various perspectives at once. Moreover, the lack of local edge processing heightens dependence on cloud services, rendering systems susceptible to network disruptions or delays, potentially jeopardizing time-critical applications such as emergency response or traffic surveillance. Additionally, there is a shortage of tools that enable students and developers to visually grasp the impacts of various image processing methods in conjunction with object detection, restricting opportunities for learning and experimentation.

This establishes a distinct demand for an edge-based video analysis system that can effectively carry out local object detection, multi-angle image transformations, and real-time visualization, all while minimizing latency, reliance on networks, and privacy concerns, thus facilitating quicker decision-making, improved resource management, and superior monitoring capabilities in diverse fields.

PROPOSED SOLUTION

The proposed solution aims to develop a real-time, edge-based video analysis system that integrates YOLOv8 object detection with multiple image processing techniques. The system processes video locally on the device, eliminating the need for cloud processing and addressing issues like latency, bandwidth consumption, and privacy risks. The main features and components of the solution include:
Key Points:

1. **Edge-Based Processing**: All computations, including object detection and image transformations, are performed locally on the device, reducing latency and network dependency.
2. **Real-Time YOLOv8 Object Detection**: Detects and labels multiple objects in each video frame with high speed and accuracy.
3. **Multiple Image Processing Techniques**: Includes grayscale, binary and adaptive thresholding, edge detection (Canny and Sobel), heatmaps, color maps, night vision, sepia, blur, and RGB channel separation for enhanced visualization.
4. **Dynamic Multi-View Grid**: Displays all processed video outputs together in a grid layout, making it easy to compare multiple perspectives simultaneously.
5. **Interactive Controls**: Users can toggle object detection, adjust binary thresholds, and record video using simple keyboard commands.
6. **Performance Monitoring**: FPS (frames per second) and timestamps are displayed to monitor processing efficiency and ensure real-time performance.
7. **Versatile Applications**: Can be used for security surveillance, educational demonstrations, industrial monitoring, creative video content, and research experiments.
8. **Privacy and Security**: Sensitive data remains on the edge device, avoiding exposure to cloud servers and reducing security risks.
9. **Scalable and Extensible**: Additional image processing filters or AI models can be integrated into the system without major structural changes.
10. **User-Friendly Interface**: Provides an organized and visually intuitive way to analyze multiple video streams and processing results at once.

Setup Essentials

1. Hardware Needed:

- Computer/Laptop: At least Intel i5 or equivalent, 8GB RAM.
- Camera: USB webcam or built-in camera.
- GPU (Optional): NVIDIA GPU for faster YOLOv8 detection.
- Storage: Minimum 10GB free space.
- Display: Full HD (1920x1080) recommended for clear multi-view display.

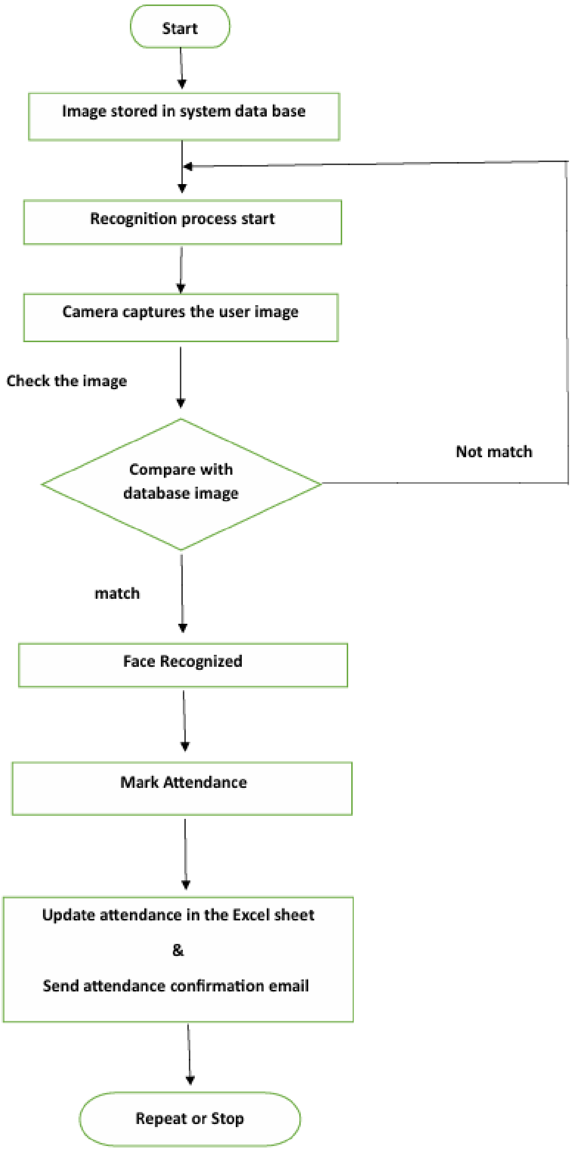
2. Software Needed:

- Python 3.9+
- Libraries: OpenCV, numpy, ultralytics
- YOLOv8 Model: yolov8n.pt
- Optional: Anaconda or virtual environment to manage Python packages

3. Setup Steps:

- Install Python and required libraries (pip install opencv-python numpy ultralytics).
- Download the YOLOv8 pre-trained model (yolov8n.pt).
- Connect the webcam and check it works.
- (Optional) Install GPU drivers if using GPU for faster processing.
- Run the Python script to start the real-time multi-view video system.

BLOCK DIAGRAM & DESCRIPTION



1. **Camera / Video Input**
   - The system begins with a live video stream captured from a webcam or camera module.
   - This serves as the raw input for both detection and image processing tasks.
2. **Pre-Processing Module**
   - Performs multiple transformations on the video frames:
     - Grayscale conversion
     - Binary thresholding
     - Adaptive thresholding
     - Edge detection (Canny, Sobel)
     - RGB channel separation
   - These help in highlighting different aspects of the image for analysis.
3. **YOLOv8 Object Detection**
   - Detects objects in the video stream in real-time.
   - Outputs bounding boxes, class labels, and confidence levels.
   - Provides annotated frames showing detected objects.
4. **Multi-View Grid & Visualization**

- Combines original video, YOLO detection, and pre-processed outputs into a single dynamic grid.
- Displays multiple views side by side for easy comparison.
- Adds overlays like FPS and timestamp for real-time monitoring.

5. **User Interaction & Recording**
   - Provides keyboard controls for easy operation:
     - SPACE → Toggle YOLO detection
     - v → Start/stop recording
     - +/- → Adjust binary threshold
     - q → Quit the program
   - Allows recording of the processed grid output for future review.

DESCRIPTION

This project is a real-time video processing system running on edge devices that integrates YOLOv8 object detection with various image processing methods. It captures live video from a webcam and processes each frame locally, avoiding cloud transmission to ensure low latency, reduced bandwidth, and enhanced privacy.

The process begins with capturing frames from the camera or video input in real time. These frames are then sent to a pre-processing module that applies multiple transformations, including grayscale conversion, binary and adaptive thresholding, edge detection (using Canny and Sobel methods), color mapping, night vision effect, sepia filter, blurring, and separation of RGB channels. These transformations provide diverse ways to analyze the video content.

At the same time, the frames are forwarded to the YOLOv8 object detection module, which identifies, labels, and highlights objects with bounding boxes and confidence scores, enabling real-time detection of multiple objects.

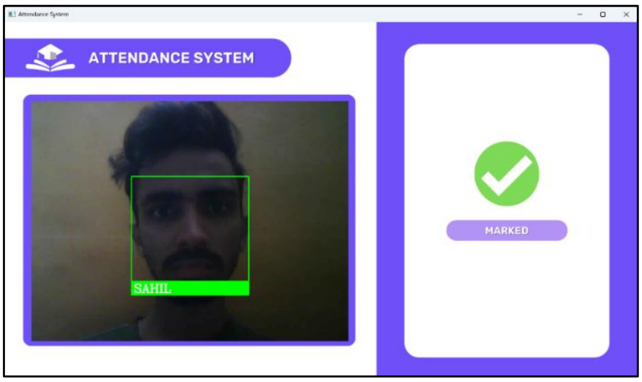
Subsequently, the system combines all processed frames—original, transformed, and YOLO-annotated—into a dynamic multi-view grid. This layout presents several visualizations simultaneously, facilitating easy comparison and analysis. Additionally, the system overlays key information such as frames per second (FPS) and timestamps to monitor performance

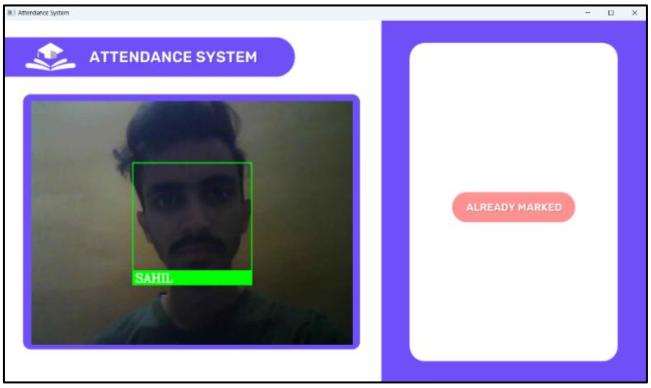
The user interaction and recording module allows control through simple keyboard commands, enabling toggling of YOLO detection, starting or stopping video recording, adjusting threshold values, and exiting the program. Recorded videos can be saved for later review or reporting.

In summary, this project showcases the capabilities of edge computing for complex tasks like real-time object detection and video processing without relying on cloud services. It is applicable in areas such as security surveillance, industrial monitoring, education, and creative video projects.

Overall, this real-time visual analytics system combines object detection and image processing on an edge device, offering local data processing for low latency, privacy, and efficiency. It features a multi-view display presenting various processed frames—grayscale, adaptive binary, edge maps, heatmaps, and YOLO detection results. The system is highly interactive, with options for threshold adjustment, recording, and toggling detection. Such a solution is well-suited for smart surveillance, industrial monitoring, research, and educational demonstrations where multiple video perspectives are beneficial.

RESULT & ANALYSIS





The student is detected by the camera module for the first time and the attendance is marked.

The student is detected by the camera module for the Second time and as the attendance is already marked it is showing Already marked.

FUTURE SCOPE

- **Advanced Object Detection Models**: The system can be upgraded to use more powerful versions of YOLO, such as YOLOv8-large, or even custom-trained models to detect specific objects like vehicles, industrial machinery, or wildlife. This will improve detection accuracy and allow application in specialized industries and research domains.
- **AI-Based Activity and Behavior Recognition**: Beyond detecting objects, future versions can include action recognition, such as identifying human gestures, abnormal behaviors, or machine malfunctions. This is particularly useful for security surveillance, industrial safety, and smart monitoring systems.
- **Edge-IoT Integration and Multi-Camera Networks**: The project can be extended to work with multiple edge devices and IoT sensors, creating a distributed network for large-area monitoring. Real-time alerts and decision-making can be implemented without relying on cloud servers, increasing efficiency and reliability.
- **Mobile and Embedded Device Deployment**: The system can be ported to portable devices like Raspberry Pi, NVIDIA Jetson, or smartphones, allowing on-site monitoring in remote areas or field operations where traditional computing resources are not available.
- **Enhanced Visualization, Analytics, and Cloud Integration**: Future enhancements can include 3D heatmaps, augmented reality overlays, interactive dashboards, and integration with cloud storage for historical analysis, predictive monitoring, and trend reporting. This makes the system more interactive, intelligent, and scalable for education, industrial monitoring, and research applications.
- The Edge-Based Real-Time YOLOv8 Object Detection with Multi-View Image Processing project has a wide scope for future development and real-world applications. In the future, the system can be enhanced to use more powerful and specialized detection models, which will improve accuracy for applications such as traffic management, industrial inspection, healthcare monitoring, and smart surveillance.
- It can also be extended to include AI-based activity recognition, allowing not only object detection but also the recognition of human actions, behaviors, and abnormal events in real-time. This would be highly useful in areas like public safety, crime prevention, and workplace safety monitoring.
- By integrating with IoT devices and edge sensors, the system can be scaled into a distributed monitoring network, covering larger areas with multiple cameras and providing instant alerts

without relying on cloud servers. This makes the system more efficient, reliable, and cost-effective.

CONCLUSION

The Edge-Based Real-Time YOLOv8 Object Detection with Multi-View Image Processing project has been successfully developed, merging the capabilities of computer vision, deep learning, and edge computing. Using a webcam as the main input, the system captures live video and applies various image processing techniques including grayscale, binary thresholding, adaptive thresholding, edge detection, heatmaps, sepia, blur, and night vision effects, alongside YOLOv8-based object detection.

A dynamic multi-view grid offers a unified interface where users can simultaneously view the results of different processing methods. This setup facilitates understanding the impact of each transformation and allows real-time comparison. The addition of FPS and timestamp overlays improves system monitoring, while features like output recording and interactive threshold adjustment enhance the system's flexibility.

From a technical standpoint, this project showcases the benefits of edge computing compared to cloud-based solutions, such as lower latency, reduced bandwidth usage, improved privacy, and quicker response times. By performing all computations locally, the system guarantees real-time performance, making it suitable for applications that require immediate processing.

The system's practical uses are extensive, including smart surveillance, traffic monitoring, industrial inspection, as well as educational and research demonstrations. It lays a solid groundwork for developing intelligent monitoring systems that can be expanded with IoT and AI-driven analytics.

In summary, this project not only proves the feasibility of combining object detection with advanced image processing on an edge platform but also demonstrates its scalability, adaptability, and practical value in real-world contexts. With future enhancements like multi-camera support, mobile deployment, and AI-based activity recognition, the system has the potential to become a comprehensive and intelligent edge-based monitoring solution.

REFERENCES

Github link: https://github.com/Kshatri-Sahil/edgeComputing