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**Edge-Computing Video Analytics for Real-Time Traffic Monitoring in a Smart City: A Critical Analysis of the Liverpool Smart Pedestrians Project**

## **A. Introduction and Objectives**

The Liverpool Smart Pedestrians project aims to improve urban mobility and pedestrian safety through real-time traffic monitoring using edge-computing video analytics. The primary objective is to enhance urban planning by providing data-driven insights into pedestrian and vehicular movement patterns.

This project addresses several urban challenges, including congestion management, pedestrian safety, and efficient emergency response. Traditional centralized cloud-based analytics face latency and bandwidth limitations, making edge computing a viable alternative. By deploying smart sensors with real-time processing capabilities, the project seeks to optimize traffic flow, reduce accidents, and support smart city infrastructure.

## **B. Methodology**

The methodology of this project centers on the design and evaluation of an edge-computing device that processes video feeds locally before transmitting essential information to urban management systems.

### **Design and Evaluation**

* The system employs NVIDIA Jetson TX2, a high-performance edge AI computing device, for real-time video processing.
* The YOLO V3 (You Only Look Once) deep-learning algorithm is used for object detection, enabling accurate pedestrian and vehicle recognition.
* The Simple Online and Realtime Tracker (SORT) algorithm is implemented for tracking objects across frames efficiently.

### **Sensor Development Requirements and Constraints**

* Power Efficiency: The device must operate efficiently with limited power resources.
* Latency Reduction: Real-time processing is essential for immediate responses in traffic management.
* Environmental Adaptability: The system must function under varying weather and lighting conditions.

## **C. Technology and Implementation**

### **Hardware and Software Components**

* NVIDIA Jetson TX2 was chosen for its balance of computational power and energy efficiency.
* YOLO V3 was selected due to its fast inference speed and high detection accuracy, making it suitable for real-time pedestrian tracking.
* PyTorch framework was used to train and optimize the deep-learning models.

### **Edge-Computing Paradigm and Benefits**

Edge computing minimizes reliance on cloud services by processing data locally, reducing latency, improving response times, and lowering bandwidth costs. This aligns with smart city objectives by enabling immediate decision-making in urban environments.

## **D. Validation and Performance**

### **Validation Experiments**

To ensure effectiveness, the system underwent various performance evaluations:

* Accuracy Metrics: The YOLO V3 model achieved a high object detection accuracy, distinguishing between pedestrians, vehicles, and other objects.
* Speed Metrics: The system processed frames at a rate exceeding 30 FPS, meeting real-time processing standards.
* System Utilization: The Jetson TX2 efficiently managed computational loads, balancing performance with energy constraints.

## **E. Real-World Applications**

### **Indoor Deployment: Emergency Evacuation**

* The system was tested in an indoor environment to monitor pedestrian movement during an emergency evacuation.
* Results demonstrated the system’s capability to track pedestrian flow, facilitating efficient evacuation planning.

### **Outdoor Deployment: Liverpool Smart City**

* Deployed at key intersections, the sensor successfully identified congestion patterns and pedestrian density.
* This data was leveraged to improve traffic light control, optimize pedestrian crossings, and reduce accidents.

### **Impact on Urban Planning**

The project exemplifies how sensor technologies and edge gateways can enhance urban mobility by providing actionable insights into pedestrian behavior and traffic dynamics.

## **F. Challenges and Future Work**

### **Challenges Encountered**

* Environmental Variability: Adverse weather conditions affected detection accuracy.
* Computational Limitations: The edge device struggled with complex multi-object tracking in dense crowds.
* Scalability: Deployment in larger urban areas requires increased processing capabilities.

### **Proposed Solutions**

* Implementing adaptive image enhancement techniques to mitigate weather-related challenges.
* Exploring optimized neural network architectures to reduce computational overhead.
* Utilizing distributed edge-computing networks for scalability.

### **Future Developments and Technological Advancements Since 2019**

Recent advancements in edge computing, AI, and sensor technology could further improve the system’s performance:

* NVIDIA Jetson Orin Series provides superior computational power compared to Jetson TX2.
* YOLO V5 and YOLO V8 offer improved detection accuracy and efficiency.
* 5G and LoRaWAN enhance real-time data transmission and connectivity in smart city deployments.

## **G. Personal Evaluation**

The Liverpool Smart Pedestrians project demonstrates a successful integration of edge computing and AI in urban planning. The system effectively addresses real-time pedestrian tracking and traffic management needs. However, there is potential for improvement:

* Enhancing AI models for better detection in adverse conditions.
* Integrating LiDAR sensors to complement video analytics.
* Implementing federated learning to enable adaptive AI model training on edge devices.

Overall, this project serves as a pioneering example of smart city innovations, showcasing the potential of edge-computing video analytics in optimizing urban mobility and pedestrian safety.