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Edge-Computing Video Analytics for Real-Time Traffic Monitoring in a Smart City

Eduardo Cabrera-Lopez
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Professor Tawanda Chiyangwa
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A. Introduction and Objectives

Launched to solve urban planning issues related to fast population increase and redevelopment in Liverpool, a Sydney, Australia neighborhood, the Liverpool Smart Pedestrians project New infrastructure meant the city expected 30,000 additional daily pedestrians. Designing a privacy-compliant, real-time traffic monitoring system out of current CCTV infrastructure was the primary goal. By means of improved data on pedestrian, car, and bike flows, this system sought to enhance urban planning.

B. Methodology

The effort started with community seminars defining needs. This covered utilization of current CCTV infrastructure, scalability, privacy compliance, and multi-modal tracking. Using real-time video analytics, the sensor was built to identify and follow people, cars, and bicycles. Evaluation included real-world installations in addition to lab testing using an Oxford dataset.

C. Technology and Implementation

Selecting for its onboard GPU acceleration and economy, the edge device ran the NVIDIA Jetson TX2. Object detection using YOLO V3 was done in PyTorch using six classes—e.g., pedestrian, car. Combining Kalman filtering with the Hungarian method, the SORT algorithm was applied for tracking. The system sent just metadata via LoRaWAN or Ethernet while doing all analytics locally—edge computing. This limited bandwidth and safeguarded privacy fit ideas from Module 2 such as bandwidth efficiency and local processing.

D. Validation and Performance

Using the Oxford Town Center dataset (4500 frames), the system achieved:

- **General accuracy: 69%**
- **33% median relative error—mostly undervaluation of counts**

- **Speed: About twenty FPS (real-time capability).**

SORT is CPU-bound; hence performance dropped in busy scenes from occlusions. System metrics revealed consistent resource use with low bandwidth requirements, therefore supporting its fit for continuous deployment.

E. Useful Real-World Applications

1. **Indoor Emergency Deployment**:
   The sensor tracked 631 persons in an academic building for indoor emergency deployment. It identified evacuation routes and verified less return traffic following a fire alarm. This proved that it could pick out odd crowd behavior.

2. **Outdoor Liverpool Deployment**:
   Over one week, 20,399 items were found close to a busy junction outside Liverpool. Daily traffic rhythms were mirrored by patterns with peaks at lunchtime and during rush hours. The sensor also pointed up deviations like pedestrians outside crosswalks. These realizations help to guide better urban design.

Both applications demonstrated how edge gateways (as covered in Module 3) and sensor-based analytics might improve city-level decision-making.

F. Challenges and Future Work

Key challenges included:

- SORT creates a performance bottleneck by lacking GPU optimization.
- Underestimate in crowded densities resulting from YOLO's non-max suppression and occlusion.

Future improvements proposed:

- GPU-accelerated tracking techniques
- Next for improved performance: NVIDIA Xavier.
- migration from PyTorch to TensorFlow using TensorRT for best performance

Post-2019 tech that could improve this system:

- YOLOv7 and YOLO-NAS for faster, more accurate detection
- NVIDIA Jetson Orin for greater compute power
- 5G/6G and edge TPUs for lower latency and decentralized AI inference
- Federated learning and advanced privacy-preserving techniques

G. Personal Evaluation

This project offers a striking illustration of how edge artificial intelligence might improve smart city infrastructure. The solution was successful in including affordable deployment, privacy compliance, and real-time analytics. For cities trying to improve traffic planning without completely redoing infrastructure, this scalable approach fits. Future versions should concentrate on using more modern techniques like YOLOv7 and increasing capabilities by GPU optimization. I think sustainable urban design worldwide will revolve around such efforts.

References

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