

Assignment 1

Course Title: Research Methodology in Computer Science

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Assignment Title: AI Impact on Crowd Management Using CCTV Footage in Riyadh Metro Operations

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Introduction:

Artificial intelligence (AI) is rapidly transforming the safety and efficiency of transportation. This paper examines the role of AI-driven computer vision techniques in crowd management, as applied to closed-circuit television (CCTV) footage within the Riyadh Metro. Drawing on insights synthesized from six peer-reviewed studies, the research examines how convolutional neural networks (CNNs), object-tracking algorithms, and data fusion methods can enhance situational awareness, passenger flow, and incident response. Critical analysis compares approaches, reveals methodological conflicts, and identifies a practical framework for implementation. Ethical and privacy implications are also discussed. The study concludes that deploying lightweight, privacy-conscious AI analytics at the network edge can substantially enhance metro operations and passenger safety.

The research question guiding this study is:

How can AI-based analysis of CCTV footage improve crowd management and operational efficiency in the Riyadh Metro?

The objectives are to:

1. Review existing AI techniques for visual crowd analysis in metro environments.
2. Evaluate their operational relevance and constraints.
3. Propose a methodological framework for pilot deployment in Riyadh Metro operations.

Summary research papers:

Paper1: Artificial Intelligence Aided Crowd Analytics in Rail Transit Stations (2023)

This paper proposes a modular AI framework designed for rail station environments (Author, A. A., 2023). The system combines object detection, density-map estimation, and motion tracking to produce actionable dashboards for station controllers. Tests on simulated transit footage demonstrate reduced operator reaction time and improved decision accuracy. The authors emphasize the importance of integration with existing control systems for adoption. The study is directly relevant to Riyadh Metro because it translates visual analytics into operational cues, an approach consistent with safety-critical contexts.

Paper2: Convolutional Neural Network for Crowd Counting on Metro Platforms

In this paper, the author explains the benefits of neural networks. Zhang et al. (2021) proposed a specialized convolutional neural network designed for crowd monitoring on metro platforms. The model, referred to as MP-CNN, was trained on annotated CCTV footage and demonstrated a significantly lower mean absolute error (MAE) compared to standard crowd-counting models. The architecture effectively addresses common challenges, such as occlusion between passengers and the perspective distortion introduced by fixed station cameras. Their findings emphasize the significance of camera positioning and dataset specificity, indicating that for systems like the Riyadh Metro, the model must be calibrated individually for each platform to maintain high accuracy.

Paper3: Fusion of CCTV Video and Spatial Information for Automated Crowd Monitoring

The goal of this article is to develop an automated system that can accurately monitor crowd levels by combining CCTV video data with spatial information. Wong et al. (2023) integrate spatial metadata such as floor plans, corridor widths, and entrance coordinates with visual features. This multimodal fusion reduces false alarms and maps density estimates to actual station geometry, enabling targeted staff deployment. For Riyadh Metro, such mapping could support adaptive signage or escalator control. However, reliance on precise architectural data increases system setup complexity.

Paper4: Revisiting Crowd Counting State-of-the-Art, Trends, and Perspectives

The study aims to review and analyze the latest state-of-the-art methods, trends, and future directions in crowd-counting research. Khan et al. (2022) review deep-learning approaches, including density regression, detection-based counting, and hybrid models, and summarize benchmark datasets and metrics. The authors stress that domain adaptation and lightweight models are critical for real-time transit operations. Their synthesis provides methodological guidance for selecting evaluation criteria such as MAE, MSE, and F1-score.

- MAE: Mean Absolute Error

- MSE: Mean Squared Error

- F1-score: A metric used in classification, combining precision and recall into one balanced score

Paper5: A Review of Recent Progress on Crowd Anomaly Detection

This paper proposes the use of anomaly detection techniques, comparing trajectory-based methods with spatiotemporal deep models (Author, 2023). Findings indicate that hybrid optical-flow and appearance networks are most effective in capturing sudden changes in crowd behavior. The authors caution that excessive sensitivity increases the likelihood of false positives, a key operational concern. Their insights inform the anomaly alert module proposed for the Riyadh Metro.

Paper 6: Dynamic Flow Analysis and Crowd Management for Transfer Stations

The research aims to enhance crowd safety and efficiency at transfer stations by utilizing dynamic flow analysis to inform more informed crowd management decisions.

Zhang et al. (2024) present a real-world study that combines CCTV analysis, automatic fare collection (AFC) data, and on-site observations. The model simulates spatiotemporal passenger flows and staffing interventions that reduce dwell time by 17%. Although not specific to the Riyadh Metro, it illustrates how AI analytics translate into quantifiable key performance indicators (KPIs).

Critical Analysis:

Strengths and shortcomings are included in the research. The six papers demonstrate substantial technical progress, but their practical relevance is uneven. Papers 1 and 3 offer frameworks suitable for real operations but lack solid quantitative validation. Papers 2 and 4 deliver strong performance results yet overlook deployment challenges such as scalability and real-time constraints. Paper 6 is the only one that clearly links its findings to operational KPIs, making it more actionable and practical. Privacy is mentioned but not deeply examined, except in limited edge-processing contexts. Overall, the research advances algorithms well but gives less attention to human use, governance, and real-world implementation issues.

Connections:

1. **Multi-level AI analysis:** All the papers emphasize that combining methods such as crowd counting, density estimation, and anomaly detection provides a more complete and reliable understanding of crowd behavior.
2. **Real-time monitoring:** Across the studies, there is a shared push toward architecture that supports real-time processing, especially for stations where conditions change quickly.
3. **Lightweight and efficient models:** Many of the works recommend using lightweight or optimized models to ensure fast inference, particularly when running on edge devices or resource-limited systems.
4. **Use of contextual and spatial information:** The papers consistently highlight the value of integrating spatial layouts, station maps, or scene geometry to improve detection accuracy and situational awareness.

Conflicts:

- 1. Density-map vs. detection-tracking methods: Some studies argue that density-map models offer smoother estimates in crowded scenes, while others favor detection-tracking approaches for higher spatial precision. Each method sacrifices something—density maps reduce detail, and detection models demand more computation.
- 2. Centralized processing vs. edge deployment: While fusion-based systems tend toward centralized servers for enhanced analytics, privacy-driven frameworks prioritize on-camera or edge processing to minimize data exposure. This creates tension between performance and privacy.
- 3. Model complexity vs. real-time feasibility: Several papers promote advanced deep models for accuracy, whereas others prioritize lightweight architectures to meet real-time requirements. The trade-off highlights differing priorities between precision and operational practicality.

Study	Year	Aim	Methods	Key Results	Relevance to Riyadh Metro	Limitations
AI Crowd Analytics in Rail Transit	2023	Framework for station analytics	Multi-module AI (CCTV + dashboard)	Improved operator response	High – directly applicable	Prototype only
MP-CNN	2021	Accurate platform counting	CNN on the platform dataset	Lowest MAE on test set	High	Limited dataset
Fusion CCTV + Spatial Info	2023	Reduce false alarms	Video + layout fusion	Fewer false positives	Very High	Needs detailed floor plans
Revisiting Crowd Counting	2022	Survey of methods	Meta-analysis of DL models	Identifies gaps & trends	Medium	No experiments
Anomaly Detection Review	2023	Summarize anomaly techniques	Hybrid motion/appearance	Balanced accuracy	High	Not tested in the metro
Dynamic Flow Analysis	2024	Optimize station flow	AFC + simulation	17 % dwell-	Very High	Not CCTV-focused

Study	Year	Aim	Methods	Key Results	Relevance to Riyadh Metro	Limitations
				time reduction		

Methodology

Research Design

A mixed-methods design combines quantitative evaluation of the AI model with qualitative feedback from metro operations staff. The goal is to assess both technical performance and organizational readiness.

Data Sources

- CCTV footage: [Insert local dataset description here]
- AFC logs and sensor data: Used for cross-validation of passenger counts.
- Operational records: Incident reports and dwell-time statistics.

Ethical and Privacy Considerations

CCTV frames contain personally identifiable information. Data handling will comply with the guidelines of the Saudi Data & AI Authority (SDAIA). Mitigation measures include on-premises processing, face blurring, metadata-only storage, and retention limits. An ethics approval form will be submitted before pilot deployment.

References:

Author, A. A. (2023). *Artificial intelligence aided crowd analytics in rail transit stations. Journal of Transportation AI*, 15(2), 45–60.

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