Chapter 9
Edge AI-Based Crowd Counting Application for Public Transport Stops

Hakki Soy
https://orcid.org/0000-0003-3938-0381
Necmettin Erbakan University, Turkey

ABSTRACT

Recently, the evolution of artificial intelligence has caused the emergence of smart systems exhibiting intelligent behavior like the human brain. Specifically, as a class of artificial intelligence methods, computer vision empowered with deep learning has tremendous promise for the accurate detection of crowds in real-time. In addition, the edge artificial intelligence approach allows for the development and deployment of artificial intelligence methods outside of the cloud. This study introduces the deep learning-based computer vision implementation to monitor public transport stops. The main aim is to determine the count of passengers through edge computing. The experimental study is realized with the popular YOLO object detector model on the Maixduino board developed for edge-based artificial intelligence (AI) applications with the internet of things (IoT). The experiments' results show that the obtained accuracy of crowd counting was found to be satisfactory.

INTRODUCTION

The United Nations (2018) reports that 68% of the world's population will live in urban areas by 2050. As a result of the urbanization trend that started with the industrial revolution and accelerated with the rise of citizens' living standards, the demand for natural resources is increasing day by day. The fascination with urban living is essentially due to better livelihood opportunities and easy access to cities' educational and medical services. At the point reached today, in the face of the uncontrolled increase in the population in cities, the only way to meet the needs in a sustainable way is to ensure the transition to smart cities with the help of information and communication technologies (ICTs). The ICT-enabled smart cities aim to create innovative services that help to make life better by rapidly responding to citi-

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zens' requests. The main targets can be summarized as follows: to improve safety, reduce congestion, and minimize excessive consumption of finite resources (Bawany & Shamsi, 2015; Lonavath et al., 2017).

A smart city addresses the challenges of different applications, i.e., transportation management, public safety, street lighting, and waste management (McKinsey, 2018; OECD, 2019; Ismagilova et al., 2022). Among them, transportation management has special importance in smart cities, since it plays an influential role in shaping decisions that affect public safety, traffic congestion, resource efficiency, energy conservation, and fewer emissions. In a typical smart city, one of the biggest infrastructures is usually used for transportation and it may consist of multi-modal components that facilitate different transport options, such as cars, trucks, public transport (bus, tram, metro, train, and ferry), cycling, and walking. Smart transportation applications integrate independent transportation networks by connecting them into a single management platform and give the opportunity to intelligently control the traffic flows while optimizing the traffic signals (Shukla & Champaneria, 2017; Jawhar et al., 2018; Hanani et al., 2019).

During the last decade, traffic congestion has significantly increased in parallel with the increase in the number of vehicles. Therefore, the management of transportation systems has become increasingly difficult (Nguyen *et al.*, 2018). One of the most effective solutions to reduce traffic congestion is to encourage people to use public transportation in dense urban areas. On the other hand, especially due to the rapid increase in oil prices, the demand for the use of public transportation services has naturally increased in recent days. Public transportation means shared passenger-transport services, i.e., bus, tram (light rail), trolleybus (electrically powered bus), train, ferry, and metro. When the demand for public transportation increases, it becomes even more important to determine the crowding of bus/tram stops, metro stations, and even in-vehicles (De Weert & Gkiotsalitis, 2021). Smart cities have the ability to use technology to remotely monitor the number of passengers traveling by public transport. Based on the collected real-time crowd information, the Quality of Service (QoS) can be significantly improved by optimizing the timetables, service frequencies, and routes of public transportation vehicles. Consequently, smart (dynamic) public transportation management is an important part of smart cities to minimize the waiting time at stops and traveling time spent in traffic. More importantly, crowd monitoring shortens the dwell time, which refers to the time duration wherein public transport vehicles spend at a scheduled stop without moving (Franke et al., 2015; Khan et al., 2020).

The smart city trend introduces a variety of intelligent platforms consisting of distributed smart devices and decentralized decision-making systems that process real-time data. The provision of advanced applications in accordance with the smart city concept mainly depends on the use of ICTs, which enable people to access public services. ICTs refer to a wide range of technological tools that enable gathering, storing, analyzing, and sharing information through communications. When considering the communication part, the Internet of Things (IoT) comes to the fore and it allows to exchange of data between everyday objects, which are equipped with embedded electronics, mechanics, sensors, and actuators. Simply, IoT is an extensive network of connected devices, called 'things', which can be sensed or controlled remotely through the Internet. In light of evolving mobile technologies, the utilization of IoT in smart city services has a huge potential to change people's daily living habits for all social activities. Thanks to digitalized support systems, local governments and municipality authorities can provide efficient and optimal services to citizens. But, in parallel to the growing number of connected 'things', the digitalization of smart city operations can only be achieved when a huge amount of raw data is processed and analyzed (Zanella et al., 2014; Serrano, 2018; Cecaj et al., 2021; Salih & Younis, 2021).

Complementary to IoT, artificial intelligence (AI) and big data analytics are the key technologies to overcome the challenges of storing and analyzing massive volumes of data quickly (Allam & Dhunny,

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