CV and AI in Seaport Parking Space Allocation

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Urban expansion has ushered in a landscape of opportunities and challenges across housing, transportation, education, health, and the economy. In response to these evolving dynamics, the application of artificial intelligence (AI) and computer vision (CV) technologies has emerged as a transformative solution. While smart traffic monitoring and advanced parking distribution systems have eased urban pressures, optimizing mobility remains pivotal in the context of burgeoning smart cities.

port management computer vision deep learning machine learning artificial intelligence

1. Introduction

Urbanization has brought about numerous opportunities and challenges in various sectors, such as housing, transportation, education, health, and the economy, as highlighted by Ke et al. (2020) [1]. These opportunities and challenges have led to rapid changes in human behavior. To address the challenges, artificial intelligence (AI) and computer vision (CV) tools have been implemented in fields such as health, education, housing, and transportation. The Oxford Learner's Dictionary defines AI as "the study and development of computer systems that can copy intelligent human behavior" [2]. Hence, the need of the hour is a machine that can replicate human intelligence to solve various problems.

A review study on smart cities by Winkowska (2019) [3] suggests that the term smart city has been described as a digital city, information city, sensing city, and more. According to the review, a smart city comprises six main elements: smart economy, smart mobility, smart environment, smart people, smart living, and smart governance. Among all elements, smart mobility is a crucial component of a smart city. In designing sustainable and effective transportation systems in a smart city, the increasing number of automobiles poses a challenge. Traffic management and parking space allocation become problematic. Hence, smart traffic surveillance and parking space allotment systems have been introduced, as highlighted by Ke et al. (2020) [1]. A survey by Turjman et al. (2019) [4] on smart parking indicates that it takes approximately 107 h per year to find a parking spot in New York City. However, with technological advancements, on-road traffic can be managed, and space can be allocated in random parking areas.

For a city to be truly 'smart', all areas must be well-developed and equipped with technology. Thus, this study focuses on the need for AI and CV in seaports. The transportation of containers between storage spaces and cargo ships is a significant challenge in any seaport. The lanes between the stacks of containers are narrow, and heavy-duty trucks often cause traffic congestion. With globalization and the increasing import and export of goods, seaports have become busier day by day [4][5]. Therefore, optimizing the space allocation in seaports using AI and CV techniques can improve overall efficiency.

Smart cities have arisen as a solution to these difficulties, utilizing technologies such as AI and CV to improve people's quality of life. Despite substantial progress in smart city development, the primary focus has been on upgrading city transportation systems. Smart city technology, on the other hand, must be expanded to encompass seaports, which are key components of the global economy. Seaports play an important role in the transportation of products, and optimizing space allocation within them can have considerable efficiency and sustainability benefits [6]. As a result, the purpose of this research is to investigate the use of AI and CV techniques in seaport parking management and provide a thorough knowledge of their potential benefits.

2. Computer Vision and AI in Parking Space Allocation

Several studies have explored the use of computer vision (CV) and artificial intelligence (AI) to manage parking spaces. Chandrasekaran et al. (2022) [7] proposed a prototype model that uses CV built on the Django framework in Python 3.0. The authors discussed various studies and emphasized how the use of CV could be advantageous in identifying occupancy in parking slots. According to their prototype, users can be informed about the available slots in the parking area for a selected time duration through video capturing using CCTV cameras. It's worth noting that their prototype is based on school and university parking areas.

Another study by Ke et al. (2020) [1] explored the feasibility of using edge computing and AI to identify space in the parking area. The prototype used real-time video feeds from CCTV cameras in the Angle Lake Parking Garage to allocate space in the garage. The authors achieved an accuracy of 95% in real-time scenarios.

As previously mentioned, a driver in New York City spends approximately 107 h per year searching for a parking spot while driving, which becomes even worse during peak hours [8]. Finding a parking spot manually in a multilevel parking garage is tough and leads to air pollution. Therefore, using AI and CV for the same is advantageous.

The next question is which CV or AI technologies should be used for managing parking slots effectively. Researchers have suggested that technologies such as image processing and analysis, object detection and recognition, machine learning, deep learning algorithms, and real-time monitoring and control systems have been working effectively in space allotment in different parking areas.

Sudhakar et al. (2021) [9] developed a smart parking system integrating image processing with AI and machine learning. The researchers identified various problems in a smart parking system and resolved them using AI and ML. Their model detects a vehicle at the entrance and enters the details of available slots. If there are no slots available, it will say 'Parking Full'. If there are slots available, the model will capture the number plate and open the entrance gate. On reaching the parking spot, the system will update itself with the date and time, and once the vehicle leaves, it will capture the date and time. Using machine learning, the authors calculate the parking charges, and once a payment is made, the entrance gate opens for the vehicle to leave.

Similarly, Kaur J. (2019) [10] used automatic license plate identification (ALPI) using image processing technology while designing a smart parking system. With the help of imaging processing and machine learning techniques, the authors successfully demonstrated how the model works. However, it was a pilot study, and scaling this study needs more details.

Ruili et al. (2018) [11] built a smart parking system using image processing (reading number plates), AI, machine learning, big data, and neural networks. Ultrasonic sensors extract data on available parking spaces for parking a vehicle. Despite the advantages of using AI, CV, and machine learning in allocating space in parking areas, this system still has limitations. One limitation is the weather conditions when using sensors. The second is coverage. When using techniques such as AI and big data or machine learning, all data gets stored on the cloud, which must be strongly protected against hackers. A simple bug in the model could lead to complete model failure.

The use of CV and AI technology has shown to be advantageous in properly managing parking lots. Researchers have developed several models that include image processing, machine learning, and deep learning algorithms to identify car occupancy, distribute parking spaces, and compute parking rates. Nevertheless, these systems have limits, such as weather conditions and data security concerns, that must be addressed. Further research and development are required to scale up these models and make them more dependable and secure for use in real-world applications.

3. Parking Space Allocation in Sea Ports

With the rise of globalization and the smart city concept, seaport industries are expanding at an unprecedented rate. To increase efficiency and profitability, seaports are increasingly implementing digital technologies [12].

The application of the "simple shuttle problem" has been highlighted for distribution problems in seaports [13]. Seaports are more than just places for cargo import and export, they also involve loading and unloading goods, warehousing, storing, shipment, packing, and delivery. Due to the added value of seaports, any delay in the process could lead to significant losses and time consumption.

In a detailed study on how Malaysia's seaports developed and embraced IR 4.0, Othman (2021) [14] highlighted the adaptations made by Hamburg Port authorities to accept IR 4.0. The port authorities have coined the term "SmartPort" to refer to their adaptation to IR 4.0. The "SmartPort Logistics" feature manages internal truck parking areas in the port, and the "SmartPort Monitor" enables easy accessibility to all essential data necessary for port optimization.

However, the design of a seaport is very compact in nature, and the internal traffic and parking management of trucks remains a significant challenge. Long queues of trucks in seaports are a common problem [15]. The authors have proposed a lane allocation framework to manage truck allocation and traffic. By implementing a truck appointment system and lane allocation planning, the flow of trucks in the seaport could be optimized. The authors have identified four types of trucks in a seaport: those sending loaded containers, those sending empty containers, those taking loaded containers, and those taking empty containers. They have divided the lanes in the port accordingly. At the gate, there are four lanes, and during a given time duration, one lane opens for one type of truck while the other three lanes are open for the remaining type of truck.

Optimizing the truck parking system at a seaport could be improved if the storage of different containers is performed more effectively. Researchers have used various models for efficient container storage in seaports. Moreno et al. (2012) [16] highlighted the difficulties faced in a multiproduct manufacturing factory in labeling and storing products. The authors used a mixed-integer linear programming model to optimize tank allocation and storage. Similarly, there are several studies on how to solve the supply vessel scheduling problem, also known as the periodic supply vessel planning problem (PSVPP) [17]. Along with many other authors [18], Kisialiou (2018) [17] proposed the use of heuristic algorithms for optimizing container storage systems. All these studies had one thing in common: constraints. Space allocation of containers was based on size, weight, color, and destination. Positive results were seen in several studies, including a case study of the Port of Montreal in Canada [19]. Their objective was to optimize the container terminal, and they proposed a new layout by adding new pathways and some new handling equipment, such as an electric straddle carrier. Abu Aisha et al. (2020) [19] successfully achieved their objective by reducing transportation costs and CO_2 emissions.

Container storage optimization is an important component of seaport optimization since it has a substantial influence on a port’s efficiency and productivity. Furthermore, the truck parking system at a seaport is a crucial aspect that might generate traffic congestion during peak hours.

The Port of Hamburg [12] has utilized digitalization to continuously monitor parking spot availability. While the port now employs radar technology to locate ship parking places, they are also attempting to optimize the intermodal traffic produced by trucks and other vehicles. The port employs a variety of sensors to monitor all of its assets, including cranes, trucks, and carriers, allowing it to apply AI and computer vision technology to enhance port operations and traffic management.

AI and computer vision technology [20] can help optimize seaport operations and traffic management by giving real-time information on traffic congestion and container storage capacity. Using this data, port managers may make informed decisions regarding truck routing and scheduling, reducing traffic congestion and increasing overall port efficiency. Furthermore, AI and computer vision technologies can improve port safety by detecting potential hazards, such as incorrect container stacking, and alerting operators to the need for corrective action. Furthermore, these technologies may help in the predictive maintenance of port equipment, ensuring that it is always functioning at optimal efficiency, reducing downtime, and increasing production. **Figure 1** displays a typical schematic diagram of the lane parking while loading and unloading the container from the truck to the container stacks. However, **Figure 2**a,b show the real photographs of Busan Seaport showing the real-time congestion created by the incoming container trucks, waiting for the loading and/or unloading of containers in the terminal.

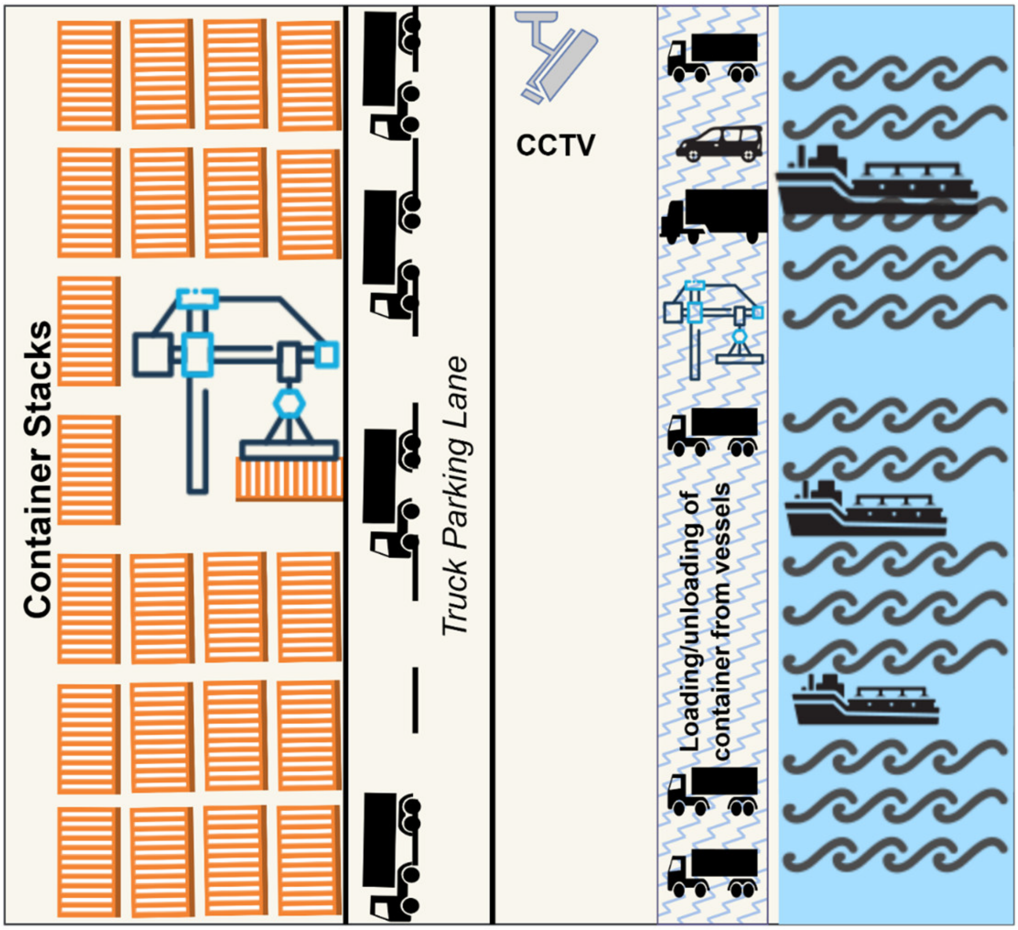
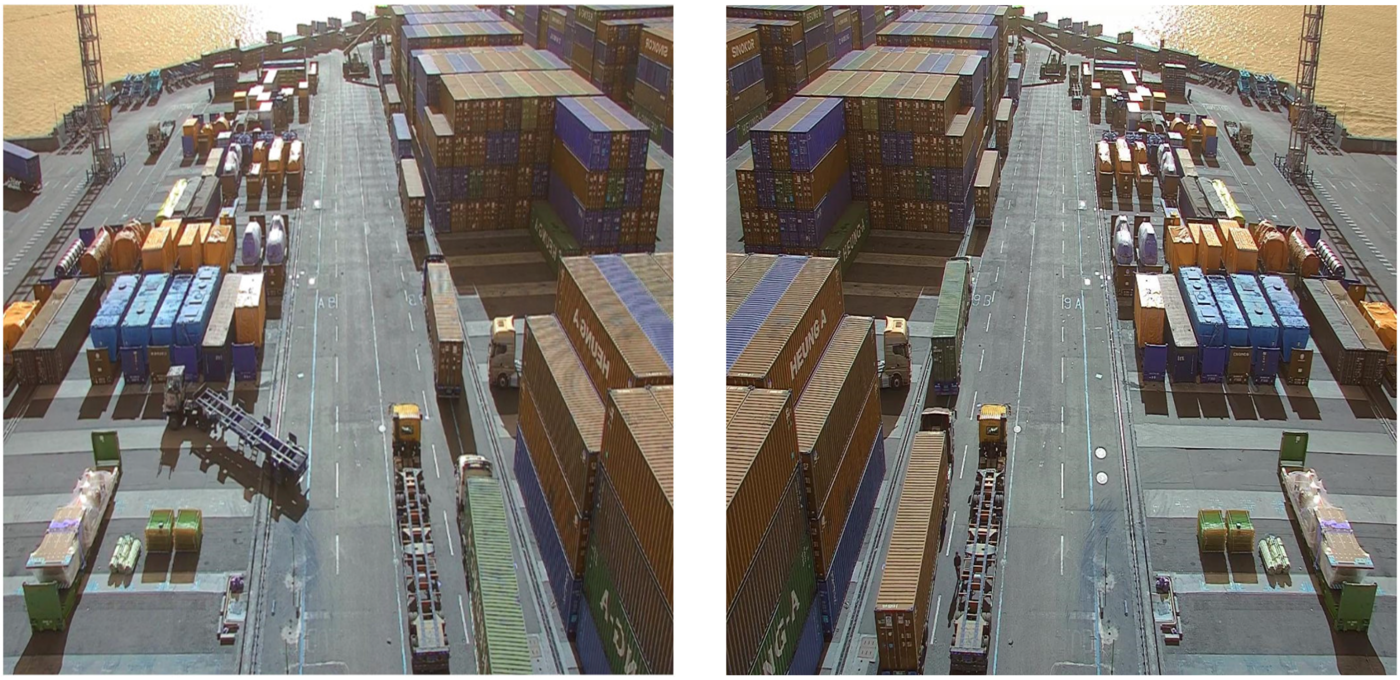


Figure 1. A parking space allocation scheme in a seaport.



(a) (b)

Figure 2. (**a**,**b**): Real photographs showing the congestion created by incoming container trucks for loading/unloading containers in the terminal. These pictures were taken by a CCTV camera located at a seaport in Busan, South Korea. Data Source: Total Soft Bank pvt ltd, South Korea.

Seaport optimization, in essence, demands an integrated strategy that considers all aspects of port operations, such as container storage, traffic control, and equipment maintenance. By using AI and computer vision technologies, port authorities may improve the efficiency, safety, and productivity of their operations, resulting in a better overall experience for all stakeholders involved in maritime activities.

References

1. Ke, R.; Zhuang, Y.; Pu, Z.; Wang, Y. A smart, efficient, and reliable parking surveillance system with edge artificial intelligence on IoT devices. IEEE Trans. Intell. Transp. Syst. 2020, 22, 4962–4974.
2. Artificial Intelligence. Artificial Intelligence Noun—Definition, Pictures, Pronunciation, and Usage Notes|Oxford Advanced Learner’s Dictionary at OxfordLearnersDictionaries.com. Available online: https://www.oxfordlearnersdictionaries.com/definition/english/artificial-intelligence?q=artificial%2Bintelligence (accessed on 22 March 2023).
3. Winkowska, J.; Szpilko, D.; Pejić, S. Smart city concept in the light of the literature review. Eng. Manag. Prod. Serv. 2019, 11, 70–86.
4. Al-Turjman, F.; Malekloo, A. Smart parking in IoT-enabled cities: A survey. Sustain. Cities Soc. 2019, 49, 101608.
5. Mai, T.L.; Vo, A.K.; Jeon, M.; Yoon, H.K. Changes in the Hydrodynamic Characteristics of Ships During Port Maneuvers. J. Ocean Eng. Technol. 2022, 36, 143–152.
6. Chatterjee, I.; Cho, G. Development of a Machine Learning-Based Framework for Predicting Vessel Size Based on Container Capacity. Appl. Sci. 2022, 12, 9999.
7. Chandrasekaran, S.; Reginald, J.M.; Wang, W.; Zhu, T. Computer Vision-Based Parking Optimization System. arXiv 2022, arXiv:2201.00095.
8. Krieg, J.G.; Jakllari, G.; Toma, H.; Beylot, A.L. Unlocking the smartphone’s sensors for smart city parking. Pervasive Mob. Comput. 2018, 43, 78–95.
9. Sudhakar, M.V.; Reddy, A.A.; Mounika, K.; Kumar, M.S.; Bharani, T. Development of smart parking management system. Mater. Today Proc. 2021, 80, 2794–2798.
10. Kaur, J. Implementation of Smart Parking Using Artificial Intelligence. Int. J. Sci. Dev. Res. 2019, 4, 284–290.

11. Ruili, J.; Haocong, W.; Han, W.; O'Connell, E.; McGrath, S. Smart parking system using image processing and artificial intelligence. In Proceedings of the 2018, the 12th International Conference on Sensing Technology (ICST), Limerick, Ireland, 4–6 December 2018; IEEE: New York, NY, USA, 2018; pp. 232–235.
12. Agatić, A.; Kolanović, I. Improving the seaport service quality by implementing digital technologies. Pomorstvo 2020, 34, 93–101.
13. Stopka, O.; Gašparík, J.; Šimková, I. The methodology of the customers' operation in the seaport applies the "simple shuttle problem". NAŠE MORE Znan. Časopis Za I Pomor. 2015, 62, 283–286.
14. Othman, M.R. Malaysia Seaport Development towards Embracing Industrial Revolution 4.0: Enhancing the Quality and Competitiveness of Seaport Industry. Turk. J. Comput. Math. Educ. (TURCOMAT) 2021, 12, 1625–1635.
15. Jin, Z.; Lin, X.; Zang, L.; Liu, W.; Xiao, X. Lane Allocation Optimization in Container Seaport Gate System Considering Carbon Emissions. Sustainability 2021, 13, 3628.
16. Terrazas-Moreno, S.; Grossmann, I.E.; Wassick, J.M. A mixed-integer linear programming model for optimizing the scheduling and assignment of tank farm operations. Ind. Eng. Chem. Res. 2012, 51, 6441–6454.
17. Kisialiou, Y.; Gribkovskaia, I.; Laporte, G. Robust supply vessel routing and scheduling. Transp. Res. Part C Emerg. Technol. 2018, 90, 366–378.
18. Lin, D.Y.; Chiang, C.W. The storage space allocation problem at a container terminal. Marit. Policy Manag. 2017, 44, 685–704.
19. Abu Aisha, T.; Ouhimmou, M.; Paquet, M. Optimization of container terminal layout in the seaport—Case of Port of Montreal. Sustainability 2020, 12, 1165.
20. Chatterjee, I. Machine Learning and Its Application: A Quick Guide for Beginners; Bentham Science Publishers: Sharjah, United Arab Emirates, 2021.