Ministry of Education and Science of Ukraine
Black Sea Universities Network

ODESA NATIONAL UNIVERSITY OF TECHNOLOGY

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2022

PROCEEDINGS

ODESA, ONUT 2022

Ministry of Education and Science of Ukraine

Black Sea Universities Network

Odesa National University of Technology

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2022

Proceedings

Odesa, ONUT 2022

UDC 001.8(063)

Black Sea Science 2022: Proceedings of the International Competition of Student Scientific Works / Odesa National University of Technology; B. Iegorov, M. Mardar (editors-in-chief) [*et al.*]. – Odesa: ONUT, 2022. – 749 p.

Proceedings of International Competition of Student Scientific Works «Black Sea Science 2022» contain the works of winners of the competition.

The author of the work is responsible for the accuracy of the information.

Odesa National University of Technology, 2022.

Organizing committee:

Prof. Bogdan Iegorov, D.Sc., Rector of Odesa National University of Technology, Head of the Committee

Prof. Maryna Mardar, D.Sc., Vice-Rector for Scientific and Pedagogical Work and International Relations of Odesa National University of Technology, Deputy Head of the Committee

Prof. Baurzhan Nurakhmetov, D.Sc., First Vice-Rector of Almaty Technological University (Kazakhstan)

Prof. Michael Zinigrad, D.Sc., Rector of Ariel University (Israel)

Prof. Plamen Kangalov, Ph.D., Vice-Rector for Academic Affairs of “Angel Kanchev” University of Ruse (Bulgaria)

Prof. Heinz Leuenberger, Ph.D., Professor of the Institute of Ecopreneurship of University of Applied Sciences and Arts (Switzerland)

Prof. Edward Pospiech, Dr. habil., Professor of the Institute of Meat Technology of Poznan University of Life Sciences (Poland)

Prof. Lali Elanidze, Ph.D., Professor of the Faculty of Agrarian Sciences of Iakob Gogebashvili Telavi State University (Georgia)

Dr. Dan-Marius Voicilas, Ph.D., Associate Professor of the Institute of Agrarian Economics of Romanian Academy (Romania)

Prof. Stefan Dragoev, D.Sc., Vice-Rector for Scientific Work and Business Partnerships of University of Food Technologies (Bulgaria)

Prof. Jacek Wrobel, Dr. habil., Rector of West Pomeranian University of Technology (Poland)

Dr. Mei Lehe, Ph.D., Vice-President of Ningbo Institute of Technology, Zhejiang University (China)

Dr. V. Kozhevnikova, Ph.D., Associate Professor of the Department of Hotel and Catering Business of Odesa National University of Technology, Secretary of the Committee

INTRODUCTION

International Competition of Student Scientific Works “Black Sea Science” has been held annually since 2018 at the initiative of Odesa National University of Technology (formerly Odesa National Academy of Food Technologies) with the support of the Ministry of Education and Science of Ukraine. It has been supported by Black Sea Universities Network (the Association of 110 higher education institutions from 12 countries of the Black Sea Region) since 2019, and by Iseki-FOOD Association (European Integrating Food Science and Engineering Knowledge into the Food Chain Association) since 2020.

The goal of the competition is to expand international relations and attract students to research activities. It is held in the following fields:

- Food science and technologies
- Economics and administration
- Information technologies, automation and robotics
- Power engineering and energy efficiency
- Ecology and environmental protection

The jury includes both Ukrainian and foreign scientists. In the 4 years that the competition has been held, the jury included scientists from universities of 24 countries: Angola, Azerbaijan, Benin, Bulgaria, China, Czech Republic, France, Georgia, Germany, Greece, Israel, Italy, Kazakhstan, Latvia, Lithuania, Moldova, Pakistan, Poland, Romania, Serbia, Slovakia, Switzerland, Turkey, USA.

At the same time, every year the geography has expanded and the number of foreign jury members has increased: from 46 jury members representing 25 universities from 12 countries in 2018, to 73 jury members of the 46 universities from 19 countries in 2022.

More than a thousand student research papers have been submitted to the competition from both Ukrainian and foreign institutions from 25 countries: China, Poland, Mexico, USA, France, Greece, Germany, Canada, Costa Rica, Brazil, India, Pakistan, Israel, Macedonia, Lithuania, Latvia, Slovakia, Romania, Kyrgyzstan, Kazakhstan, Bulgaria, Moldova, Georgia, Turkey, Serbia.

The interest of foreign students in the competition grew every year. In 2018, the students representing 15 institutions from 7 countries have submitted 33 works. In 2021 the number of submitted works increased to 73, authored by the students of 40 institutions from 18 countries.

The competition is held in two stages. In the first stage, student research papers are reviewed by members of the jury who are experts in the relevant fields. In the second stage of the competition, the winners of the first stage have the opportunity to present their work to a wide audience in person or online.

All participants of the competition and their scientific supervisors are awarded appropriate certificates, and the scientific works of the winners are included in the electronic proceedings of the competition. Every year the competition receives a large number of positive responses from Ukrainian and foreign colleagues with the desire to participate in the coming years.

3. INFORMATION TECHNOLOGIES, AUTOMATION AND ROBOTICS

CYBER-PHYSICAL SYSTEM FOR SMART PARKING BASED ON COMPUTER VISION TECHNOLOGY

Authors: Volodymyr Avsiyevych
Volodymyr Kovalenko
Advisors: Olga Pavlova,
Pavlo Radiuk
Khmelnytskyi National University (Ukraine)

Abstract. *With the rapid growth of transport number on our streets, the need for finding a vacant parking spot today could most of the time be problematic, but even more in the coming future. Smart parking solutions have proved their usefulness for the localization of unoccupied parking spots. Nowadays, surveillance cameras can provide more advanced solutions for smart cities by finding vacant parking spots and providing cars' safety in the public parking area. Based on the analysis, Google Cloud Vision technology has been selected to develop a cyber-physical system for smart parking based on computer vision technology. Moreover, a new model based on the fine-tuned convolutional neural network has been developed to detect empty and occupied slots in the parking lot images collected from the KhNUParking dataset. Based on the achieved results, the performance of parking lots' detections can be simplified, and its accuracy improved. It was also concluded that the Google Cloud Vision technology as parking slots detector and a pre-trained convolutional neural network as a feature extractor and classification were decided to develop a cyber-physical system for smart parking.*

Keywords: *Video-image processing. Smart parking. Smart city. Deep learning. Convolutional neural network. OpenCV. Google Cloud Vision.*

I. INTRODUCTION

Nowadays, the issue of creating smart parking is crucial, especially in large cities. As the number of cars has rapidly increased for the last few years (Figure 1), so does the need for parking spaces and search facilities. Assuming that the average driver spends 20 minutes searching for such a place every day, about 120 hours a year could be spent on something more useful.

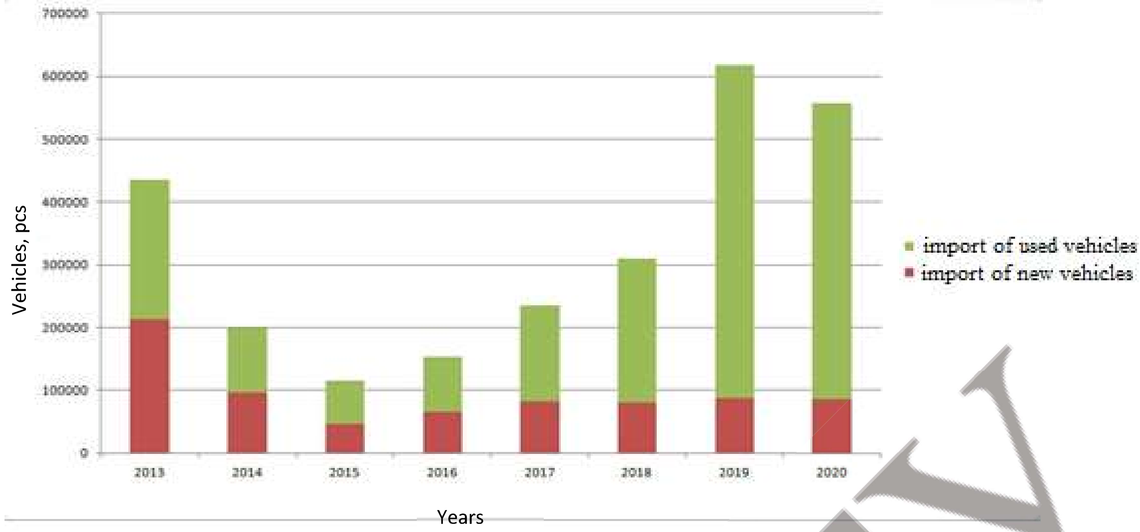


Fig. 1. Increase in vehicle numbers in Ukraine

As shown in Figure 1, the general increase in the number of vehicles includes imports of new cars (red part of the column) and used cars imported from abroad (green part of the column). At the same time, it is noticeable that from 2016 to 2020, the import of new vehicles remains at about the same level, but the share of imports of used cars is gradually increasing. Such an outcome was due to changes in the legislation on customs clearance of vehicles imported from abroad, namely on November 25, 2018; a law was passed to simplify the procedure for customs clearance of used cars imported from abroad [1].

Nowadays, there are many smart parking projects, but ready-for-use examples can be counted on the fingers of one hand, and information about the cost-effective aspect of their implementation is generally minimal. It should be noted that when designing such tools, the most significant financial part of the development is born by the software, not hardware. After considering and comparing different parking detection techniques [2], a conclusion has been made that the method of smart parking using a camera is much more effective than others, considering most of the factors considered. In addition, since most of the parking lots are usually located in public places, privacy and security factors also should be considered. Consequently, the aim of this work is:

1. To analyze modern technologies for image recognition based on artificial neural networks.
2. To select the most appropriate technology for creating a cyber-physical system for smart parking based on the outdoor surveillance camera of the university parking lot.
3. To develop an information model for parking slots detection and vehicle identification.
4. To evaluate the developed model on a testing dataset.

II. LITERATURE ANALYSIS

Multiple studies have been conducted over the past years to find the best approach for smart parking development in the past few years (Table 1).

Table 1 – Analysis of ready existing computer vision approaches for smart parking

Reference	Year	Algorithm / Model	Advantages	Disadvantages
[3]	2018	Deep convolutional neural network, OpenCV	Uses coordinate of each parking space, so less computation is needed.	The features obtained from the benchmark dataset may not be practical for recognizing real outdoor parking lot.
[4]	2019	Haar Cascade, AdaBoost	The car can be detected from any angle of view. The accuracy is 100% for single-car detection	In multiple-car detection, the accuracy is affected by the car and shadow, which results in detecting two cars as one object.
[5]	2020	Hough Transform, OpenCV	With a fixed camera placement and without changes in light intensity, a 100% correct result was obtained.	The light change and shadows negatively affect the classification Results.
[6]	2021	Long short-term memory	The prediction of empty parking spaces based on the computer vision system and the real-time car parking data.	If the car is not parked in the considered lot, it would not be correctly detected by the system.
[7]	2022	Mask R-Convolutional neural network, OpenCV	Based on video and image data, a scalable and relatively inexpensive system can detect empty parking spaces.	The method's accuracy can be improved using a better camera and a faster processing unit.

As can be seen from Table 1, a deep learning approach, particularly convolutional neural networks (CNNs), has been most frequently used over the past five years and has shown the most robust recognition of parking lots, among other approaches.

Thus, considering the abovementioned analysis, two computer vision technologies were chosen for further research – OpenCV library + artificial neural network and Google Cloud Vision API.

2.1. OpenCV Computer Vision Library + CNN

One of the popular technologies for image recognition is the OpenCV computer vision library [8]. This set of tools serves as a so-called infrastructure for applying computer vision techniques in information systems. OpenCV is used, among other things, to resize input images, convert them to vector form, and detect the features of target objects in the image. At the same time, one of the most popular approaches to detecting features in the image today is deep learning, in particular CNN [9–11]. The CNN model combines many functional operations that transmit the input image as feature vectors into the resulting data to estimate the belonging of the identified objects to predefined classes. The CNN architecture utilized in this study is from the authors' previous work [12] and is depicted in Figure 2.

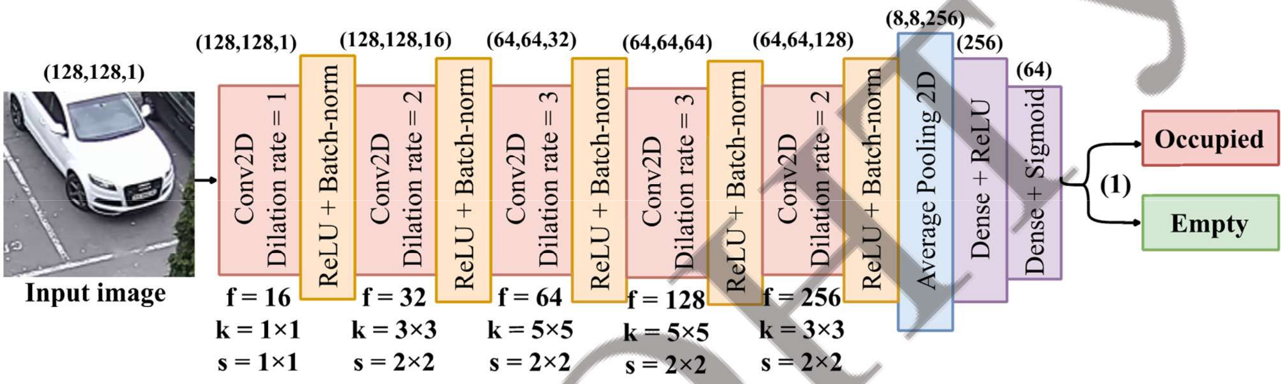


Fig. 2. The scheme of convolutional neural network used in this work

According to the classification results from our previous work [13], we conclude that combining the GCV API system and OpenCV + CNN tools may achieve more robust performance and higher classification accuracy.

2.2. Google Cloud Vision API (GCV API)

Another equally well-known image recognition technology is the Google Cloud Vision API (GCV API) [14]. The GCV API is a de facto set of prepared machine learning models and algorithms that service users can quickly implement to meet their business needs. The principle of the GCV API is to perform two steps: 1) assigning labels to the original image; 2) automatic recognition of objects in the image by predefined classes. The GCV API is a universal classifier that identifies various moving and still objects in an image.

In our previous work [13], we conducted a preliminary experiment: ten images were used from the video surveillance camera of one of the parking lots of Khmelnytskyi National University. The images were preliminarily prepared: the contours were cropped to bring the focus as close as possible to the location of the cars. In addition, the objects in the image were magnified to increase the likelihood of finding the object.

The experiment was to test the same image using two of the most popular image recognition technologies. The object identification results on the target image, performed using OpenCV + CNN and GCV API technologies, are shown in Figure 3.

a b

Fig. 3. Identified objects on the target image that correspond to the searched cars, found by:
a – OpenCV + CNN, b – GCV API [13]

Figure 2 shows that GCV API technology coped much better with the task of identifying cars on the image (Figure 3a) than OpenCV + CNN technology (Figure 3b). Hence, the GCV API system as parking slots detector and a pre-trained CNN as a feature extractor were decided to use to develop a cyber-physical system for smart parking.

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

Object of research: software and hardware of the cyber-physical system of smart parking.

Subject of research: image recognition technologies using artificial neural networks for smart parking.

Research methods: theoretical – methods of systematic and comparative analysis of scientific sources, scientific and technical, specialized literature for clarifying aspects of technological approaches and selection of the best technologies for solving scientific and applied problems; synthesis, generalization, and conceptualization to formulate the main provisions of the research; design and modeling for processing the results of the experiment; empirical methods – development and experimental verification of the method of image recognition from surveillance cameras based on artificial neural networks.

Expected scientific results: improvement of existing methods and algorithms for training convolutional neural networks for image recognition and implementation of these methods and algorithms in the smart parking system; the development of the parking slots recognition model.

Expected practical value: development of information system as a computer vision model for smart parking based on image recognition technology using artificial neural networks and its further implementation as a mobile application.

The authors compiled **Dataset (KhNUParking)** from the collected images extracted from an external closed-circuit television (CCTV). The CCTV was installed on Campus 3 of Khmelnytskyi National University, Khmelnytskyi, Ukraine. The images show parking spaces of the outdoor parking lot between campuses 3 and 4 of the university (Figure 4).

a b

Fig. 4. The samples of the KhNUParking dataset presenting targeted parking spaces:
a – almost all parking lots are empty, b – nearly all are fully occupied

The KhNUParking dataset contained 100 images, each of which is 853 × 480 pixels. The dataset was split into training (70%) and validation (30%) subsets. Also, a subset of 100 images was created to test the classification models. Finally, the authors provided the ground truth annotations of the parking slots delineations (33 slots) and the occupancy (3300) for evaluating the accuracy.

PKLot: we gathered a subset of the original PKLot dataset [15] with 390 randomly sampled images of 1280 × 720 pixels. The vehicles in the PKLot dataset were parked only in up-down orientation.

Experimental setup: all computational experiments were performed on the Python v3.8 stack with Keras as the back end. The calculations were executed on 8-core Ryzen 2700 and a single GPU card GeForce GTX1080 with 8 GB of memory.

Methodology: the proposed approach for computer vision technology is depicted in Figure 5.

In this work, we utilized a neural network model based on pre-trained CNN as a feature extractor and a two-layer perceptron as a classification module. The pre-trained CNN contained 1000 classes (pre-trained with the ImageNet dataset). To prepare the model for detecting occupied and empty parking spaces, the last fully connected layers in the network were replaced with two classes that correspond to “Empty” or “Occupied.” In this work, the testing models were evaluated for binary classification accuracy and run-time – average time in seconds to read images from the hard disk and crop them. The binary classification accuracy was calculated by the formula below:

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{TN} + \text{FP} + \text{FN}},$$

where TP represents true positive cases in the testing dataset, TN stands for true negative cases, FN denotes false positive, and FN represents false negative cases.

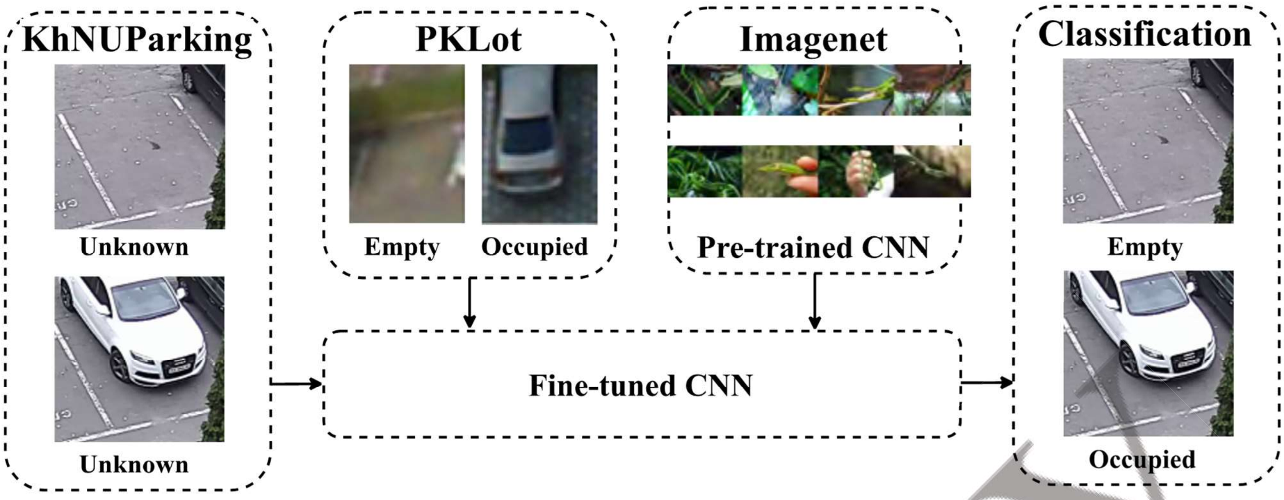
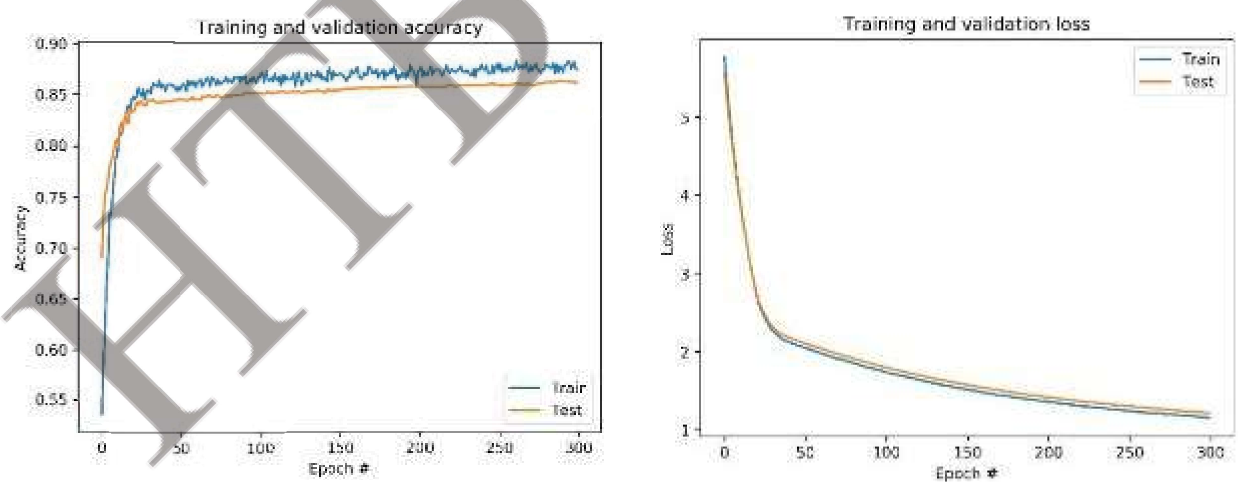


Fig. 5. The proposed approach for smart parking cyber-physical system

The data augmentation technique was also performed on the fine-tuning dataset to reduce over-fitting. Two transformations were applied: 1) reflection along X and Y axes and 2) change the X and Y scales of the images. Furthermore, the input images were resized according to the input size of the CNN, which was 128 × 128.

IV. RESULTS

The network was pre-trained with a stochastic gradient descent with a momentum of 0.8, an initial learning rate of 0.005, and a batch size of 64. The number of epochs was set to 20. Furthermore, the training data was shuffled at each epoch to remove any dataset bias due to image sequences. The pre-training process took roughly 50 minutes on a single GPU. The training and validation accuracy and loss curves are presented in Figure 6.



a b

Fig. 6. Training and validation curves of the pre-training procedure:
a – the fine-tuning and validation accuracy,
b – the fine-tuning and validation loss

The prepared model based on pre-trained CNN was tested with 100 KhNUParking images. It would crop out individual 33 parking slots of each image. After that, these cropped images were passed to the fine-tuned CNN for classification. The ground truth of the KhNUParking dataset contained the occupancy status (3300) and delineation of the parking slots (33). Here, we presented the delineations of parking lots as bounding boxes that are used to crop the individual parking slots. A bounding box is defined by [*x*, *y*, *w*, *h*], where [*x*, *y*] represents the middle of the box and *w* and *h* stand for the width and height of the boxes, respectively. Figure 7 presents the classification results obtained by the testing dataset.

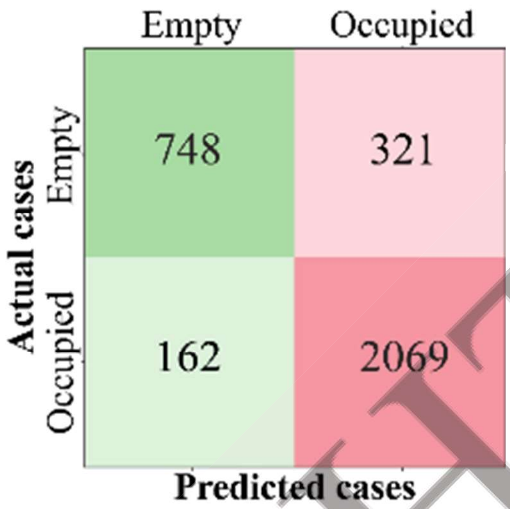


Fig. 7. The confusion matrix of the prediction results

As it is seen from Figure 7, 748 empty parking spaces and 2069 occupied parking lots were correctly identified; meanwhile, 321 vacant lots were classified wrongly, and 162 occupied spaces were recognized as open. So, the overall classification accuracy was 85.34%. From these results, we might assume that the proposed fine-tuned CNN is slightly less precise while identifying empty parking slots.

Upon visualizing a few of the wrongly identified parking spaces in Figure 8, it was observed that those parking lots mostly contained parts of vehicles, people, or other objects inside the image crop.

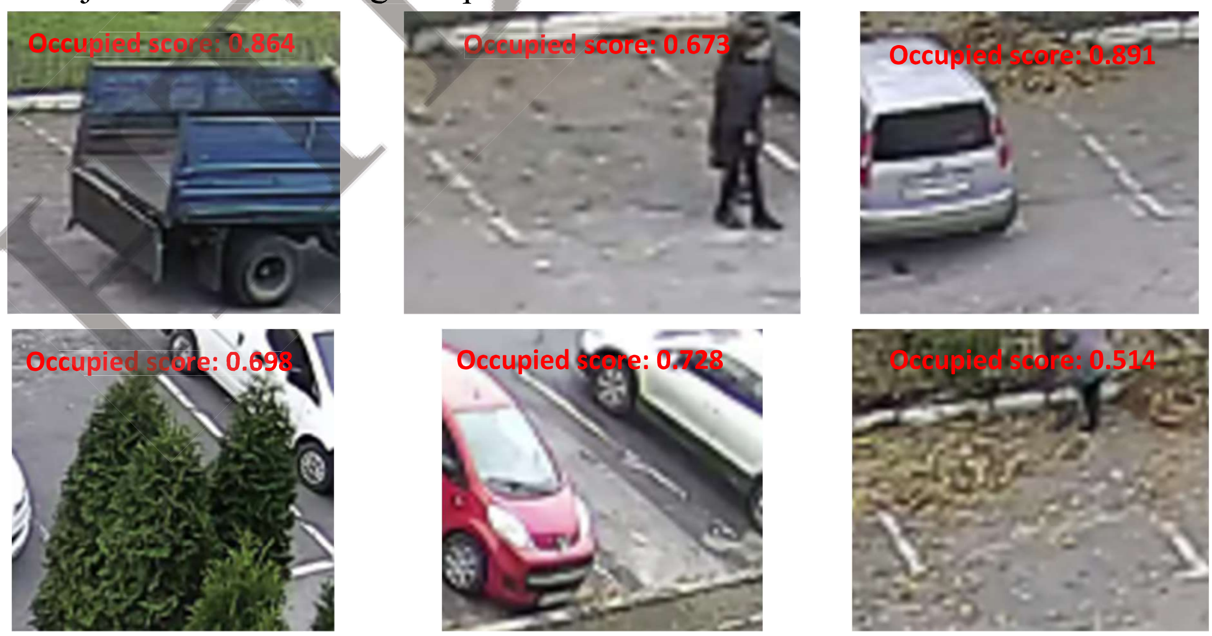


Fig. 8. A few falsely classified parking spaces with their respective classification scores

Finally, the occupancy of the parking slots is visualized in Figure 9.

Fig. 9. The visualization sample of the parking lot: red color represents the occupied slots, green color – empty slots

Several models, namely AlexNet [9], VGG-16 [10], and MobileNetV2 [11], were compared with the fined-tuned CNN in terms of their efficiency and accuracies. The classification results obtained from all models are shown in Table 2.

Table 2. The comparison of well-known neural network architectures with our proposed fine-tuned CNN based on the KhNUParking dataset

Approach	Run time on CPU, seconds	Accuracy, %
Google Cloud Vision API [4]	0.21	58.90
AlexNet [9]	0.54	77.31
VGG-16 [10]	0.62	84.10
MobileNetV2 [11]	0.96	89.26
Our fine-tuned CNN	0.15	85.34

Table 2 presents the run-time on CPU (efficiency) and accuracy achieved by comparing neural network models. The table shows that the generalizing ability of all models is high enough for this quality of parking spaces, yet MobileNetV2 achieved the highest accuracy. Concurrently, the proposed CNN scored a relatively good performance of 85.34%. As for run-time, our fine-tuned CNN showed the best efficiency, scoring only 0.15 seconds to read the images from the hard disk. Overall, our fine-tuned CNN can process approximately 66 parking lots in one second on a CPU with 85.34% accuracy.

V. CONCLUSIONS

Therefore, during the study, an analysis of information technologies for image recognition based on computer vision was conducted. A new model based on fine-tuned CNN has been developed to detect empty and occupied slots in the parking lot images collected from the KhNUParking dataset. Based on the achieved results, the performance of parking lots' detections can be simplified, and its accuracy improved.

Further investigation will be devoted to developing the server- and client-based parts in the form of a mobile app that tracks the availability of vacant places at the university's parking lot.

VI. REFERENCES

1. Automotive market research institute. (2021, December 30). *Analytical study of the secondary car market of Ukraine*. Eauto.org.ua. https://eauto.org.ua/news/13-analitichne-doslidzhennya-vtorinnogo-avtorinku-ukrajini
2. Pavlova, O., Kovalenko, V., Hovorushchenko, T., & Avsiyevych, V. (2021). Neural network based image recognition method for smart parking. *Computer Systems and Information Technologies*, *3*(1), 49–55. https://doi.org/10.31891/CSIT-2021-3-7
3. Zhang, L., Huang, J., Li, X., & Xiong, L. (2018). Vision-based parking-slot detection: A DCNN-based approach and a large-scale benchmark dataset. *IEEE Transactions on Image Processing, 27*(11), 5350–5364. https://doi.org/10.1109/TIP.2018.2857407
4. Hakim, I. M., Christover, D., & Jaya Marindra, A. M. (2019). Implementation of an image processing based smart parking system using Haar-Cascade method. *2019 IEEE 9th Symposium on Computer Applications Industrial Electronics (ISCAIE-2019)*, 222–227. https://doi.org/10.1109/ISCAIE.2019.8743906
5. Trivedi, J. D., Sarada Devi, M., & Dave, D. H. (2020). Different modules for car parking system demonstrated using Hough transform for smart city development. In A. N. R. Reddy, D. Marla, M. Simic, M. N. Favorskaya, & S. C. Satapathy (Eds.), *Intelligent Manufacturing and Energy Sustainability* (Vol. 169, pp. 109–121). Springer Singapore. https://doi.org/10.1007/978-981-15-1616-0_11
6. Canli, H., & Toklu, S. (2021). Deep learning-based mobile application design for smart parking. *IEEE Access*, *9*, 61171–61183. https://doi.org/10.1109/ACCESS.2021.3074887
7. Manjula, G., Govinda Rajulu, G., Anand, R., & Thirukrishna, J. T. (2022). Implementation of smart parking application using IoT and machine learning algorithms. In S. Smys, R. Bestak, R. Palanisamy, & I. Kotuliak (Eds.), *Computer Networks and Inventive Communication Technologies* (pp. 247–257). Springer Singapore. https://link.springer.com/chapter/10.1007/978-981-16-3728-5_18
8. Gollapudi, S. (2019). OpenCV with Python. In: *Learn Computer Vision Using OpenCV*. Apress, Berkeley, CA, 31–50. https://doi.org/10.1007/978-1-4842-4261-2_2
9. Krizhevsky, A., Sutskever, I., & Hinton, E. G. (2017). ImageNet classification with deep convolutional neural networks. *Communications of the ACM*, *60*(6), 84–90. https://doi.org/10.1145/3065386
10. Simonyan, K., & Zisserman, A. (2015). Very deep convolutional networks for large-scale image recognition. *3rd International Conference on Learning Representations (ICLR-2015)*, 1–14.
11. Sandler, M., Howard, A., Zhu, M., Zhmoginov, A., & Chen, L. (2018). MobileNetV2: Inverted residuals and linear bottlenecks. *2018 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR-2018)*, 4510–4520. https://doi.org/10.1109/CVPR.2018.00474
12. Barmak, O., & Radiuk, P. (2021). Web-based information technology for classifying and interpreting early pneumonia based on fine-tuned convolutional neural network. *Computer Systems and Information Technologies*, *3*(1), 12–18. https://doi.org/10.31891/CSIT-2021-3-2
13. Авсієвич, В., & Коваленко, В. (2021). Аналіз інформаційних технологій для розумної

паркoвки на основі штучних нейронних мереж. *Актуальні Проблеми Комп'ютерних Наук (АПКН-2021)*, Хмельницький, Україна, 15-16 жовтня 2021. Хмельницький : ХНУ, 2021. 12–14.

14.Google, Inc. (2021, October 10). *Vision AI Google Cloud.* Cloud.google.com https://cloud.google.com/vision

15.De Almeida, P. R. L., Oliveira, L. S., Britto, A. S., Silva, E. J., & Koerich, A. L. (2015). PKLot - A robust dataset for parking lot classification. *Expert Systems with Applications*, *42*(11), 4937–4949. https://doi.org/10.1016/J.ESWA.2015.02.009