ANALYSIS OF THE EFFICIENCY OF COMPUTER VISION FOR THE DETECTION OF VEHICLES AND PEDESTRIANS IN TRAFFIC

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Abstract:

Within this research, the focus was on analyzing the effectiveness of Computer Vision (CV) in detecting vehicles and pedestrians in traffic. The YOLOv5 model was utilized for object detection, along with publicly available, unmodified libraries like OpenCV and TensorFlow. The approach involved a careful selection of three different traffic scenarios: a rainy day, daytime, and night-time, with the intention of creating realistic conditions for testing the performance of vehicle and pedestrian detection systems. An algorithm for detecting pedestrians and vehicles was implemented, contributing further to road safety. Through experiments, exploration was conducted into how various factors, such as weather conditions and lighting, influence the accuracy of the system. Following a meticulous analysis of the results, situations in which the system exhibits high detection accuracy, as well as those that pose a challenge to the system were identified, in order to provide a profound understanding of different aspects of pedestrian tracking and vehicle detection. Through the application of image analysis techniques, the focus was on identification of key features of pedestrian crossings, contributing to the recognition of potentially dangerous situations. The objective was to draw accurate conclusions regarding the system's performance under actual traffic conditions, thus enhancing the overall comprehension of how these technologies effectively contribute to improving road safety.

Keywords:

Computer vision, Pedestrian detection, Traffic safety, OpenCV, YOLO.

INTRODUCTION

With the continuous advancements in CV technology, pedestrian and vehicle detection has become a crucial component in enhancing traffic safety. One pedestrian loses their life every 1.6 hours due to a traffic accident [1], and pedestrians are 1.5 times more likely to face a fatal outcome in a traffic accident compared to vehicle passengers. The introduction of driving support systems, such as automatic braking, has contributed to a decrease in pedestrian fatalities.

The automated tracking of individuals in videos has consistently captivated researchers, given its interdisciplinary nature and limitless applications across various domains. For these reasons, in recent decades, the tracking and detection of pedestrians and vehicles in traffic have become significant research areas in the field of CV [2].

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This research aims to analyze the effectiveness of pedestrian and vehicle detection systems, utilizing advanced CV technologies, with a specific emphasis on the application of OpenCV and YOLOv5 models. These models, with their high efficiency and precision, have the potential to significantly enhance the performance of detection systems in real traffic situations. The focus will be on testing the systems in different conditions, such as rainy days, daytime, and night-time, to identify their performance in real-world situations.

2. RELATED WORK

In this chapter, a review is conducted on previous research and works addressing the theme of pedestrian and vehicle detection using CV in traffic. Surya and Fussy investigated [3] a pedestrian detection system utilizing YOLOv5 within the framework of an Advanced Driver Assistance System (ADAS). The pedestrian detection approach is based on deep learning, and the model is trained across various epochs. The system implementation on a Raspberry Pi 4 with a monocular camera enables object detection at a rate of 0.9 frames per second. However, achieving real-time pedestrian recognition requires upgrading the main processing unit to more advanced hardware, such as Jetson or other dedicated object detection mini-computers.

Messelodi et al. utilized monocular images from pole-mounted cameras, combining segmentation and motion information for vehicle detection, tracking, and classification. The system, adaptable to intersection geometry and camera positions, demonstrated robust, real-time performance in classifying vehicles across various lighting conditions in extended video sequences [4].

Suryakala et al. [5] addressed the challenges of vehicle and pedestrian detection in Intelligent Transportation Systems. They employed the Haar Cascade Classifier for efficient vehicle detection and the Background Separation method, utilizing the K-NN algorithm, for pedestrian identification. The goal was to develop an automated system capable of detecting vehicles and pedestrians in various conditions, considering challenges such as climate and lighting changes. The paper focuses on improving performance, particularly in scenarios with increased object occlusion.

Pardeep and Satish [6] addressed the crucial issue of recognizing pedestrian movement direction. This aspect is vital for enhancing pedestrian safety and enabling driver assistance in autonomous systems.

The proposed framework, termed Origin-End-Point Incremental Clustering (OEIC), emphasizes the starting and ending points of pedestrian trajectories. The framework employs the YOLOv5 deep learning technique for pedestrian detection and a custom tracking algorithm for trajectory analysis. Despite challenges like partial occlusion and varying video conditions, the OEIC framework demonstrates efficient clustering compared to other models. The research includes testing on a publicly available dataset, with results indicating the effectiveness of the proposed framework.

Basheer Ahmed et al. [7] employed YOLOv3 to identify abnormal situations on roadways and effectively prevent secondary accidents. They developed a real-time notification application using AI CCTV. FFmpeg software was utilized to extract 700 frames of vehicle accidents from a series of collision videos to create the dataset. Additionally, they augmented the image dataset by rotating images 90 and 180 degrees, increasing its size to 2000 images. Consequently, the customized weights of the YOLOv3 model achieved a mean average precision of 82.36% and an intersection over union threshold of approximately 50%.

3. REAL-TIME OBJECT DETECTION (OPENCV, YOLO3)

The term "object detection" refers to a technology that enables humans to recognize specific types of entities in visual content [8]. Over the last two decades, there has been a rapid progression in technological advancements in object detection, significantly influencing the broader landscape of CV [9]. Object detection involves the process of identifying different objects within an image, which may belong to one or more defined classes [10]. There are many applications of object recognition, including optical character recognition, face recognition, or more recently, autonomous vehicles. Examples of objects belonging to multiple classes include trucks, bicycles, people, cars, dogs, and cats. This technology continues to evolve, with significant advancements. Object detection in a real traffic scenario using the YOLOv3 algorithm is illustrated in Figure 1.

Figure 1. Object detection in real-time traffic scenarios using the YOLOv3 algorithm.

4. THE USE OF CV AND DEEP LEARNING IN TRAFFIC

CV enables a computer to visually interpret the content within images or video footage, facilitating the development of innovative applications for everyday use [11]. The deep integration of deep learning and computer vision has given rise to a new breed of more intelligent computer vision systems. This synergy empowers machines to attain unprecedented levels of comprehension and analysis of image content [12]. Deep learning algorithms, drawing inspiration from the workings of the human brain, demonstrate remarkable proficiency in swiftly processing and scrutinizing extensive volumes of image and video data. This aptitude is pivotal in endeavors such as image recognition, object detection, and classification, facilitating machines to attain a level of visual comprehension reminiscent of human cognition [13].

Substantial progressions within this domain have bolstered applications like autonomous driving, wherein real-time algorithms scrutinize road conditions to ensure the safer navigation of self-driving vehicles [14]. Additionally, they enhance intelligent surveillance systems through rapid recognition of unusual behaviours or events. The effectiveness of these deep learning models hinges on vast training datasets, constantly refining accuracy and fueling the creation of novel models.

The fusion of deep learning and computer vision signifies a significant leap forward in the domain of Artificial Intelligence (AI), enhancing not only machine vision capabilities but also driving ongoing technological progress [15].

4.1. PEDESTRIAN AND VEHICLE DETECTION IN TRAFFIC

The application of computer technology in driving has been studied for many years. Most research has focused on autonomous driving in simplified environments, such as highways, or on systems that don't depend on real-time life data, such as GPS systems [16]. As one of the most promising applications of CV, vehicle detection based on visual perception to assist drivers has garnered significant attention over the last 15 years [17]. It serves as a vital and efficient component in the domain of traffic surveillance systems, where ensuring effective traffic management and safety remains of utmost importance [18].

However, creating a reliable and effective vehicle detection system through CV poses a challenging task due to phenomena such as shadows, variable lighting conditions, and unpredictable weather. For instance, on sunny days, shadows accompanying vehicle movement can easily be inaccurately identified as part of the vehicle, leading to inaccurate segmentation. In the evening, vehicle lights and poor illumination can complicate precise vehicle detection [19].

Effectively and efficiently detecting pedestrians is also not a straightforward task due to the complexity of human body articulation [20]. Existing challenges include lighting variability, diverse background scenes, and varied pedestrian poses under different conditions. Therefore, efforts to enhance pedestrian detection methods contribute to the development of reliable traffic safety systems.

4.2. TRACKING AND DETECTION FROM VEHICLES

Advanced sensors and cameras in modern vehicles contribute to increased safety and efficiency during driving. Cameras can capture images, which can then be processed using CV techniques to detect objects. This methodology allows the computer to operate in a manner similar to human eyes, observing and recognizing objects in its environment [21]. In the context of vehicle detection systems, key factors include the space within the vehicle and the cost of hardware platforms [22]. For vehicle detection methods to be useful, they must be fast enough for real-time operation, resistant to changes in lighting and various weather conditions, and capable of accurately and efficiently extracting vehicles from image sequences [23]. These technological solutions not only enhance safety but also provide information to vehicles about their surroundings. Implementing a vehicle detection system is, therefore, a complex process that requires alignment with multiple factors to achieve high precision and reliability in various driving situations.

5. EXPERIMENT SETUP

The research aims to investigate how different lighting and weather conditions can significantly influence the performance of pedestrian and vehicle detection systems. As part of the experimental protocol, an algorithm for the detection of pedestrians and vehicles was implemented.

All video materials were captured from within a vehicle. The recordings were made on the streets of Ljubljana, Slovenia. We conducted 10 different recordings, during the day, in rainy conditions, and at night. In the analysis, the Python programming language and specific computer vision libraries were employed. The core of the system relies on YOLOv5, well-known for its efficiency in object detection.

Utilizing a pre-trained YOLOv5 model, a function for loading the model was implemented, enabling precise object detection. Each frame underwent preprocessing, including conversion to the Grayscale format and resizing for easier analysis. A specific function, named detect_collision, Fig. identifies contacts between pedestrians and vehicles in each frame, crucial for analyzing potential collisions. Visualization of results is facilitated through functions like draw_boxes and draw_collision_detection, providing a visual insight into the outcomes and facilitating an analytical review. Additionally, in Listing 1, a pseudo code used in the experiment is presented. Objectives were set for each of the chosen traffic scenarios:

- *Rainy Day*. Investigating challenges in detection due to reduced visibility and altered contrast during rainy days;
- *Day*. Monitoring system behaviour during daytime conditions, where lighting is optimal but with possible variations in object contrast;
- *Night*. Detection in low-light conditions during the night, presenting an additional challenge for accurate object identification.

These studies lay the groundwork for the development of advanced pedestrian and vehicle detection systems, opening possibilities for the implementation of more efficient solutions in the field of traffic safety. Their application has the potential to significantly reduce the number of traffic accidents and contribute to the overall improvement of road safety.

```
# Import necessary libraries
import cv2
import torch
import numpy as np
# Define the path to the video file for processing
video_path = 'video_recordings/day_1.mp4'
# Load YOLOv5 model
# Load YOLOv5 model
function load_yolov5_model()
try:
```

```
        return YOLOv5 model (loaded from 'ultralytics/yolov5', 'yolov5s', pretrained=True)
    except Exception as e:
        print(f"Error loading YOLOv5 model: {e}")
        return None
# Preprocess the frame for detection
function preprocess_frame(frame, size=(640, 640)):
    return resize_frame(convert_to_RGB(frame), size)
# Detect contact between pedestrians and cars
function detect_contact(frame1, frame2):
    # ... (as in the original code)
# Draw bounding boxes
function draw_boxes(frame, boxes):
    for box in boxes:
        draw_rectangle(frame, box, color=(0, 255, 0) if box[5] in (2, 3) else (255, 0, 0),
thickness=2)
# Draw collision detection
function draw_collision_detection(frame, collision_pairs, boxes):
    # ... (as in the original code)
# Main function for processing video footage
function main(video_path):
    model = load_yolov5_model()
    if model is None:
        return
    camera = open_video_capture(video_path)
    while True:
        success, frame = read_frame(camera)
        if not success:
            break
        frame = preprocess_frame(frame)
        results = perform_object_detection(model, frame, size=320)
        boxes = extract_boxes(results)
        car_boxes = filter_boxes(boxes, [2, 3])
        pedestrian_boxes = filter_boxes(boxes, [0])
        boxes = concatenate_and_sort_boxes(car_boxes, pedestrian_boxes)
        draw_boxes(frame, boxes)
        collision_pairs = detect_and_draw_collisions(frame, boxes)
        show_frame('Pedestrian and Car Contact Detection App', frame)
        if wait_key() == ord('q'):
            break
    release_video_capture(camera)
    close_all_windows()
# Run the main function with the specified video path
main(video_path)
        collision_pairs = detect_and_draw_collisions(frame, boxes)
        show_frame('Pedestrian and Car Contact Detection App', frame)
        if wait_key() == ord('q'):
            break
    release_video_capture(camera)
    close_all_windows()
# Run the main function with the specified video path
main(video_path)
```

Listing1. Pedestrian and Vehicle Detection Pseudo Code Used in Experiment.

6. DATA ANALYSIS

In this chapter, a summary of data analysis is presented, which includes comparing results across different traffic scenarios to better understand the system's response in various conditions. This research focuses on assessing the effectiveness of vehicle and pedestrian detection in traffic, using the YOLOv5 model for object identification.

The results, shown in Table 1 and Table 2, demonstrate that the system achieves very high detection rates in various scenarios, but there are still limitations. Certain variations in performance were noticed depending on the conditions. During traffic congestion, the system often generates false detections and misses some vehicles, while during rainy conditions, there is a decrease in accuracy due to unclear and blurred images. Additionally, false detections are recorded in low-light conditions at night. Figure 2 displays examples of vehicle and pedestrian detection in real traffic conditions under different weather and lighting conditions on 3 different recordings. These results emphasize the need for further performance improvement and optimization considering various environmental conditions.

7. CONCLUSIONS

In conclusion, the emphasis is on potential future applications of the presented script, with mandatory use of commonly available open-source technologies only, to develop tools that could potentially evolve into a mobile application in the future. This application might play a role in providing contemporary driving assistance in older vehicles, which still make up the majority of the vehicle fleet in the countries of the Western Balkans. Given the statistics indicating that the average age of motor vehicles in Bosnia and Herzegovina is slightly over 16 years, with around 45% of vehicles being older than 21 years, and more than 87% older than 12 years [24], there is a recognized need for solutions that would enhance driving safety for older vehicles.

The analysis of the results reveals high detection rates. In the daytime scenario, the pedestrian detection rate was 92.8%, while for vehicles, it was 95.2%. However, during rainy conditions, the detection rates decreased, with pedestrian detection at 85.0% and vehicle detection at 91.8%.

Table 1. Pedestrian Detection Rate.

ITEM	DAY	RAIN	NIGHT
Number of samples	180	100	150
Accurately detected number	167	85	139
Detection rate/%	92.8%	85.0%	92.7%

Table 2. Vehicle Detection Rate.

ITEM	DAY	RAIN	NIGHT
Number of samples	270	220	155
Accurately detected number	257	202	143
Detection rate/%	95.2%	91.8%	92.3%

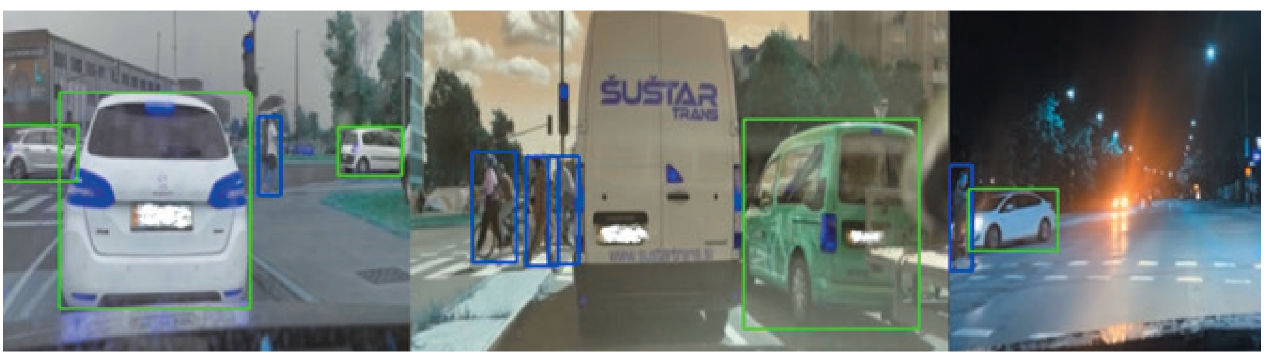

Figure 2. Display of Final Results for Car and Pedestrian Detection in Real Traffic Conditions under Various Weather and Lighting Conditions.

Similarly, during the night, pedestrian detection was at 92.7%, and vehicle detection was at 92.3%. These variations in performance underscore challenges the system faces in specific scenarios, indicating the necessity for further performance improvement in different conditions. Through the examination of the impact of various factors, such as weather conditions and lighting, a foundation is laid for the development of advanced detection systems. The utilization of tools such as OpenCV, TensorFlow, and YOLOv5 contributes to a deeper understanding of different aspects of pedestrian tracking and vehicle detection.

8. REFERENCES

[1] U. Chris and ". W. William, "Self-Driving Cars and the Urban Challenge," *IEEE Intelligent Systems*, vol. 23, no. 2, pp. 66-68 DOI: 10.1109/MIS.2008.34., 2008.

[2] B. Antonio, B. Domenico, F. Gianpaolo and B. Vitoantonio, "Computer vision and deep learning techniques for pedestrian detection and tracking: A survey," *Neurocomputing*, vol. 300, pp. 17-33 DOI: doi.org/10.1016/j.neucom.2018.01.092., 2018.

[3] M. N. Surya and M. D. Fussy, "Pedestrian Detection System using YOLOv5 for Advanced DriverAssistance System (ADAS)," *JURNAL RESTI (Rekayasa Sistem dan Teknologi Informasi),* vol. 7, no. 3, pp. 715 - 721, 2023.

[4] S. Messelodi, C. Modena and M. Zanin, "A computer vision system for the detection and classification of vehicles at urban road intersections," *Pattern Analysis and Applications,* vol. 8, pp. 17-31, 2005.

[5] S. Suryakala, K. Muthumeenakshi and S. J. Gladwin, "Vision based Vehicle/Pedestrian Detection in Traffic Surveillance System," in *International Conference on Communication and Signal Processing (ICCSP)*, Chennai, India, 2019.

[6] Monika, S. Pardeep and C. Satish, "Computer vision-based framework for pedestrian movement direction recognition," *Journal of Intelligent* & *Fuzzy Systems*, vol. 44, no. 5, pp. 8015-8027 DOI: 10.3233/JIFS-223283, 2023.

[7] L. Chaeyoung, K. Hyomin, O. Sejong and D. llchul, "A Study on Building a "Real-Time Vehicle Accident and Road Obstacle Notification Model" Using AI CCTV," *Applied Sciences,* vol. 11, no. 17, p. 8210, 2021.

[8] G. Swathi, V. Swathi, M. J. Narasimha and D. S. Kamesh, "Real-time object detection and localization for autonomous driving," in *Handbook of Artificial Intelligence,* Singapore, Bentham Science Publishers, 2023, pp. 112-127.

[9] K. C. Z. S. Y. G. a. J. Y. Z. Zou, "Object Detection in 20 Years: A Survey," *Proceedings of the IEEE*, vol. 111, pp. 257-276 DOI: 10.1109/JPROC.2023.3238524, 2023.

[10] Y. F. P. G. R. Amit, "Object Detection," *Computer Vision. Springer, Cham*, pp. 1-9 DOI: https://doi.org/10.1007/978-3-030-03243-2_660-1 , 2020.

[11] M. Hrga, "RAČUNALNI VID," *Collected papers of Šibenik College*, vol. 12, pp. 207-216, 2018.

[12] L. Bo, Y. Liqiang, C. Chang, L. Qunwei, H. Hao and Z. Xinyu, "Integration and Performance Analysis of Artificial Intelligence and Computer Vision Based on Deep Learning Algorithms," *Computer Vision and Pattern Recognition*, p. DOI: https://doi.org/10.48550/arXiv.2312.12872, 2023.

[13] S. Tianbo, H. Weijun, C. Jiangfeng, L. Weijia, Y. Quan and H. Kun, "Bio-inspired Swarm Intelligence: a Flocking Project With Group Object Recognition," in *3rd International Conference on Consumer Electronics and Computer Engineering (ICCECE)*, Guangzhou, China DOI: 10.1109/ICCECE58074.2023.10135464, 2023.

[14] M. Aditya, K. Marimuthu and K. Dietrich, "Trends in Integration of Vision and Language Research: A Survey of Tasks, Datasets, and Methods," *Journal of Artificial Intelligence Research (JAIR)*, vol. 71, p. DOI: https://doi.org/10.48550/arXiv.1907.09358, 2021.

[15] C. Chang, L. Bo, L. Shulin, H. Jiaxin and H. Hao, "Deep Learning for Precise Robot Position Prediction in Logistics," *Journal of Theory and Practice of Engineering Science*, pp. 36-41 DOI: 10.53469/jtpes.2023.03(10).05, 2023.

[16] F. Li-Chen and L. Cheng-Yi, "Computer vision based object detection and recognition for vehicle driving," in Proceedings 2001 ICRA. IEEE *International Conference on Robotics and Automation (Cat. No.01CH37164),* Seoul, Korea (South), 2001 2634-2641 vol.3, DOI: 10.1109/ROBOT.2001.933020..

[17] Z. Sun, G. Bebis and R. Miller, "On-road vehicle detection using optical sensors: a review," in *The 7th International IEEE Conference on Intelligent Transportation Systems (IEEE Cat. No.04TH8749)*, Washington, WA, USA, 2004 585-590, DOI: 10.1109/ITSC.2004.1398966..

[18] K. B. Prem and Y. Suet-Peng, "Image processing based vehicle detection and tracking method," in 2014 International Conference on Computer and Information Sciences (ICCOINS), Kuala Lumpur, Malaysia, 2014, pp. 1-5, DOI: 10.1109/ICCOINS.2014.6868357.

[19] Z. Shifu, L. Jianxiong, S. Zhenqia and Y. Liu, "A Night Time Application for a Real-Time Vehicle Detection Algorithm Based on Computer Vision," *Research Journal of Applied Sciences, Engineering and Technology*, pp. 3037-3043, 2013.

[20] P. Chia-Jung, T. Hsiao-Rong, L. Yu-Ming, M. L. Hong-Yuan and S.-W. C. , "Pedestrian detection and tracking at crossroads," *Pattern Recognition*, vol. 37, no. 5, pp. 1025-1034 DOI: https://doi.org/10.1016/j.patcog.2003.10.005, 2004.

[21] V. Wiley and T. Lucas, ""Computer Vision and ImageProcessing: A Paper Review," *International Journal ofÂ Artificial Intelligence Research*, vol. 2, p. DOI: https://doi.org/10.29099/ijair.v2i1.42 , 2018.

[22] K. Ying-Che, P. Neng-Sheng and L. Yen-Feng, "Vision-based vehicle detection for a driver assistance system," *Computers* & *Mathematics with Applications*, vol. 61, no. 8, pp. 2096-2100 DOI: https://doi.org/10.1016/j.camwa.2010.08.081, 2011.

[23] Y. Zi and S. P.-C. Lilian, "Vehicle detection in intelligent transportation systems and its applications under varying environments: A review," *Image and Vision Computing*, vol. 69, pp. 143-154 DOI: https://doi.org/10.1016/j.imavis.2017.09.008, 2018.

[24] Financa.ba, "Starost automobila u EU i BiH," https://financa.ba/starost-automobila-u-eu-i-bih/, 2022.