Multiple Object Detection, Object Tracking, Lane Tracking, and Motion Detection Shadow Robotbased on Computer Vision

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Abstract—Multiple object detection, object tracking, lane tracking, and motion detection are the four crucial and difficult tasks in the Shadow robot. A dynamic background, clutter, occlusion, shadows, cluttering, noise, etc. make it difficult. The fundamental processes of a shadow robot's multi-camera video analytics include object detection, tracking, object matching across several cameras, and reidentification. Multiple object recognition and tracking of contents from resourceful city videos may be produced according to the suitability of society like Autonomous/Self-Driving vehicles, far-sighted clever inspection devices, traffic congestion administration devices, vehicle navigation, smart health management facilities, etc. Multiple object detection, object tracking, lane tracking and motion of moving objects are techniques used in computer vision and image processing. Several techniques are used to compare multiple consecutive frames from a movie to see whether any moving objects can be found. Results of the study show that the suggested technique may be used in areas such as object identification, motion detection, autonomous driving systems, and others.

IndexTerms—object detection, object tracking, lane tracking, motion detection, computer vision.

1. INTRODUCTION

Computer vision has emerged as an important technology in different applications such as autonomous driving, surveillance, robotics, and medical imaging. One of the most ambitiousquests in computer vision is multiple object detection, object tracking, lane tracking, and motion detection for moving objects. These tasks are crucial in many real-world scenarios, such as traffic surveillance systems, security surveillance equipment, and human-robot interaction.

Multiple object detection encompasses detecting and localizing multiple elements in a video or image stream. The approach of tracking an item’s movement over time in a video stream is termed object tracking. Lane tracking refers to the process of identifying and tracking the routes on a road, while motion detection for things moving is the method for detecting and tracking items that are in motion.

In recent years, considerable improvements have been achieved in computer vision, including the invention of deep learning-based techniques, which have attained progressive level performance in multiple object detection, object tracking, lane tracking, and motion detection for objects moving. These techniques have permitted real-time and exact tracking and identification of multiple objects in challenging conditions.

In this research study, we present a detailed overview of current developments in multiple object detection, object tracking, lane tracking, and motion detection for objects moving using computer vision. We study numerous deep learning-based tactics, like convolutional neural networks, recurrent neural networks, and object detection frameworks, and their usefulness in these tasks. We also analyze the challenges and limitations of these approaches and provide alternative avenues for future research.

2. Objectives

- To find and determine the location of one or more useful targets using still photos or video data.
- To create a robot that can autonomously follow and track a colored item under computer control.
- To determine if an item is moving.
- To design a robot that can follow a course and get where it is going.
- The ESP32 AI Camera on the Android phone will be used to control all of these tasks. e.g., line tracking, object tracking, and object identification.

3. Literature Review

Shijie Sun, Naveed Akhtar, HuanSheng Song, Ajmal Mian, andMubarak Shah, Fellow, IEEE, Deep Affinity Network for MultipleObject Tracking, IEEE TRANSACTIONS ON PATTERNANALYSIS AND MACHINE INTELLIGENCE, VOL. 43, NO. 1,JANUARY 2021.

The proposed Deep Affinity Network (DAN), a deep learning-based approach for posture estimation and tracking, trains compact, CNN for simultaneous detection and tracking inside the detection framework R-FCN.

Arindam Sengupta, Lei Cheng, and Siyang Cao, RobustMulti-object Tracking Using Mm wave Radar-Camera SensorFusion, IEEE Sensor council, VOL. 6, NO. 10, OCTOBER2022.

The radar, an electromagnetic device, andcamera readings in a particular frame are connected using the Hungarian method. A tri-Kalman filter-based architecture is employed as the tracking strategy. The suggested technique delivers promising MOTA and MOTP metrics embracing notably reduced missed detection rates that might enable vast and limited autonomous or robotic systems applications with the safe perceived notion. system resilient by constant object tracking even with single sensor malfunctions using a tri-Kalman filter arrangement.

Hui Zhang, Member, IEEE, Liuchen Wu, Yurong ChenMember, IEEE, Ruibo Chen, Senlin Kong, Attention-GuidedMultitask Convolutional Neural Network for Power Line PartsDetection, IEEE TRANSACTIONS ONINSTRUMENTATION AND MEASUREMENT, VOL. 71,2022.

This research attempts to increase the identification precision of the model and offer an attention-guided multi-task convolutional neural network (AGMNet). The refinable region proposal network (RPN) structure and dynamical training method to increase the resilience of the network, CNN algorithm utilized for Object identification

Xiangkai Xu, Zhejun Feng, Changqing Cao, Chaoran Yu,Mengyuan Li, Zengyan Wu, Shubing Ye, and Yajie Shang, STNTrack: Multiobject Tracking of Unmanned Aerial Vehicles bySwin Transformer Neck and New Data Association Method, IEEEJOURNAL OF SELECTED TOPIC IN APPLIED EARTHOBSERVATIONS AND REMOTE SENSING, VOL. 15, 2022,

Swin transformer neck-YOLOX (STN-YOLOX) object detection technique is employed as the detection module and the G-Byte data association method as the tracking module.

Azarakhsh Keipour, Graduate Student Member, IEEE, MaryamBandari, and Stefan Schaal, Fellow, IEEE Deformable One-dimensional Object Detection for Routing and Manipulation,IEEE, VOL. ROBOTICS AND AUTOMATION LETTERS 7, NO.2, APRIL 2022.

Deformable one-dimensional object detection techniques and Traversing contours for the DOO chain are used to identify the color-based segmentation of the DOO area.

4. Research Methodologies

Esp 32 cam typically uses pre-trained models.

There are just 2 pre-trained models available at present i.e., YOLO and COCO SSD models. From which YOLO pre-trained model is utilized for this project.

4.1 OpenCV

OpenCV is an open-sourced image processing toolkit that is frequently utilized not only in business but also in the area of research and development.

4.2 YOLO Model/Algorithm

YOLO (You Only Look Once) is a common object detection model/algorithm that can identify and categorize several things inside an image or video frame in real-time. YOLO has been trained on big datasets such as COCO (Common Objects in Context) dataset to understand how to distinguish distinct items.

Pretrained YOLO models are accessible to be downloaded, which may be utilized for numerous applications without the requirement for training from scratch. These models have been developed on big datasets and have learned to identify a broad variety of objects, making them appropriate for numerous applications.

For object detection, the cvlib library has been utilized. The package employs a pre-trained AI model using the COCO dataset to recognize objects. The nomenclature of the pre-trained model is YOLOv3.

In ESP 32 Cam AI thinker algorithm is applied for object detection and tracking. There is a particular "AI Thinker algorithm" in ESP32-CAM, which is a development kit made by AI Thinker that integrates the ESP32 microcontroller with a camera module. Nevertheless, the ESP32-CAM is meant to be utilized for multiple AI and computer application areas, which might include putting various AI algorithms on the boards.

To implement object detection, object tracking, lane tracking, and motion detection on ESP32-CAM, developers can use various software libraries and frameworks such as TensorFlow, OpenCV, and Arduino IDE. These libraries and frameworks provide pre-trained models and tools that can be used to implement various AI algorithms on the board.To perform object detection, object tracking, lane tracking, and motion detection using ESP32-CAM, developers may utilize several software libraries and frameworks like TensorFlow Lite, OpenCV, and Arduino IDE. These libraries and frameworks include pre-trained models and toolkits that may be used to create different AI algorithms on the board.

4.3CNNs(Convolutional Neural Networks)

Convolutional Neural Networks (CNNs) have been enormously employed in applications involving computer vision including object detection, object tracking, lane tracking, and motion detection. CNNs are a sort of neural network that are especially well-designed to suit image processing applications since they can learn to extract characteristics straight from raw picture data.

Convolutional Neural Networks (CNNs) is a framework of artificial neural network that are meant to interpret and evaluate visual images. They are commonly utilized in computer vision applications like pictorial classification, object identification, and image segmentation They comprise layers of linked processing units that are trained to detect visual elements in pictures. The layers are often stacked hierarchically, with lower layers gaining knowledge of basic elements like edges/corners, and higher layers acquiring knowledge to recognize greater advanced structures and objects.

Convolutional Neural Networks (CNNs) are often employed for object recognition, tracking, lane tracking, and motion detection because they are capable of autonomously learning key characteristics straight from raw picture data.

CNNs may be utilized both for two-stage and one-stage object identification techniques. Two-stage techniques, such as Faster R-CNN, employ a region proposal network (RPN) to find areas of interest within a photograph, which are subsequently given to a hierarchical web for enabling object classification and localization. One-stage techniques, like YOLO (You Only Look Once), execute object detection straightly on the full picture in a single pass, which may be more rapid and effective than two-stage systems.

In summary, CNNs are often used for object recognition because they can learn key aspects out of unprocessed raw image data, can be trained using huge datasets of labeled pictures, and can be utilized for both two-stage and one-stage techniques

4.4 Object Detection

Object detection runs on computer vision methods that comprise of detecting notable things within an image or video stream and estimating their location and boundaries. Object identification techniques commonly apply a combination ofmachine learning and image processing methodologies, like convolutional neural networks (CNNs), to analyze the input data and identify the objects within it.

Figure 1. Object Detection

4.5Multiple Object Detection

Multiple object detection runs on computer vision that demands detecting and localizing many entities of different types within an image or video stream. Unlike mono object detection, which only detects one item, multiple object detection systems must be able to identify and find several things simultaneously.

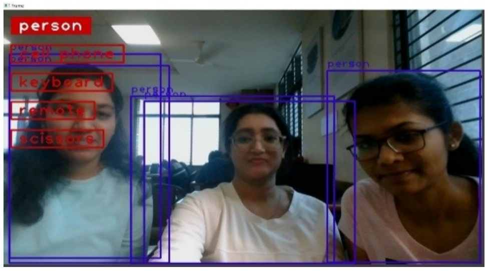

Figure 2. Multiple Object Detection

4.6Object Tracking

Object tracking is the process of locating and following an object of interest in a sequence of frames of a video stream. It involves identifying and tracking the object as it moves through the frames, even if the object changes in appearance or motion. Object tracking is a critical component of many computer vision applications, including surveillance, robotics, and autonomous driving.

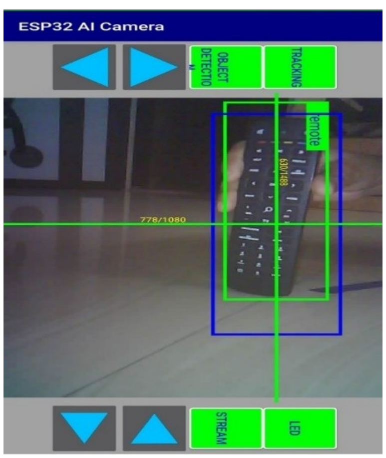

Figure 3. Object Tracking

4.7Lane Tracking

Lane tracking is the technique of distinguishing and tracking the routes on a highway using techniques of computer vision. Lane tracking is a critical aspect of various advanced driver assistance system(ADAS) technology and self-driving vehicle mechanizations because it enables the car to identify the road layout and keep within the allotted driving lanes. Lane tracking algorithms generally apply image processing techniques to distinguish the lane markers in a video stream recorded by a camera that is affixed to the vehicle. The algorithm then extracts the location and orientation of each lane marker and applies this information to estimate the position of the driving lanes on the road.

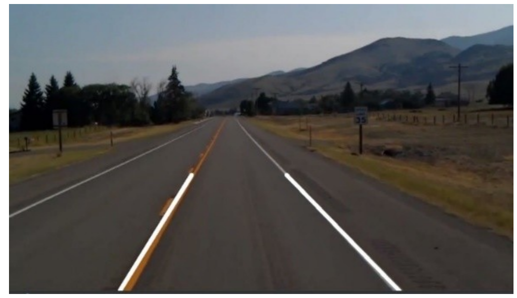

Figure 4. Lane Tracking

4.8Motion Detection

The technique of determining a shift in an object's location in relation to its environment across a period is referred to as motion detection. In this area of computer vision, motion detection is typically used to recognize and trace moving objects in a video stream. The method of motion detection generally includes comparing successive images of a video feed to find locations where there's a substantial shift in pixel values.

This shift may be caused due to the mobility of an item in the frame, changes in illumination, or camera movement.

4.9 PROPOESD SYSTEM

4.9.1. Block Diagram

This diagram is a graphical representation of our system process that shows the components used for our robot. In this block diagram, each block represents the components we have used. The selectivity of our components is as follows:

ESP32- ESP32 cam used for object detection, lane tracking, and object tracking.

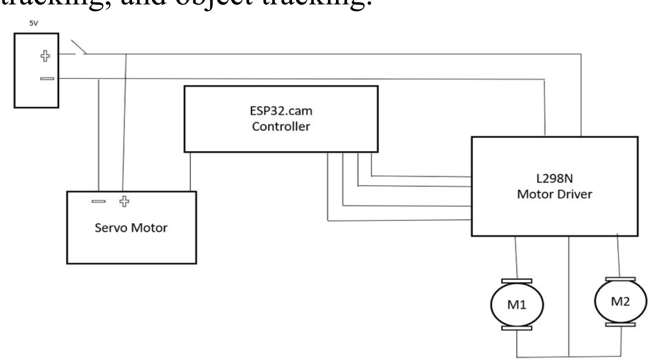

Figure 5. Block Diagram for our robot

Motor Driver i.e., L298N- it is a high-power

dynamic motor driver.
Use to administer the direction and acceleration of DC motors. Lithium Battery- A lithium battery is a type of rechargeable battery. Constant power is provided. It is temperature tolerant.
Servo Motor- It is an electrical device that can push and rotate objects with great precision.
DC Motors- Converts direct current into mechanical energy helping for rotation of the robot wheels. It operates using direct current.

4.9.2. Circuit Diagram

In this project ESP32 cam for multiple object detection, and tracking of objects and lanes. It is provided with a pocket size lowconsumption of energy, camera module based on ESP 32. It coexists with an OV2640 camera module. It has 10 general input and output pins which are used to interface peripheral devices. It has built-in Wi-Fi, and Bluetooth to develop a web-based user interface that will enable us to operate the robot and give video camera output.

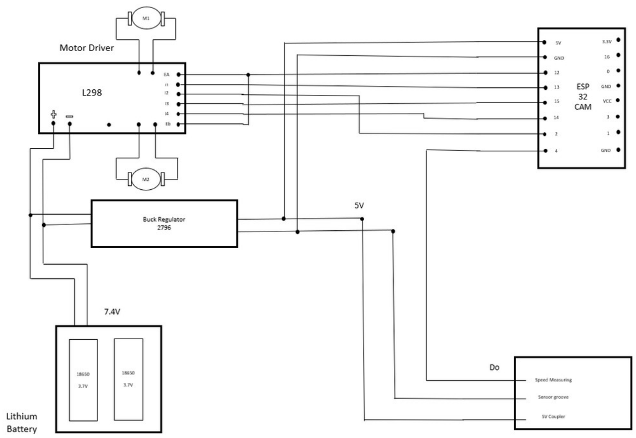

Figure 6. Circuit Diagram

For this project, L298N motor driver module is used. This driver module drives 2 DC motors with 7.4 V DC supplied from a Lithium battery. The direction and speed of the robot are controlled by this unit.
There is a need for 2 lithium batteries each of 3.7V connected in series to give 7.4 V. For ESP32 operating voltage is from the range of 3.3 V to max 5 V. So, for that a buck regulator is used to reduce the voltage from 7.4 V to 5V. A buck regulator i.e., LM2596 is a Step-Down voltage regulator. HC-SR04 module is an ultrasonic sensor module. It is used to measure the distance of the object in front of the robot. Therange of the Ultrasonic sensor is a max of 4m. For speed measurement speed measuring sensor groove couple is used. It counts how many pulses occur per second.

5. Data Analysis and Interpretation

Data analysis and interpretation for object detection, object tracking, lane tracking, and motion detection of objects frequently comprise the following steps:
Data gathering: The first stage in data analysis and interpretation is data collecting. For object detection, object tracking, lane tracking, and motion detection, data is often acquired by different sensors, such as cameras, lidars, and radars.
Data pre-processing: After the data is acquired, it has to be pre-processed to eliminate noise, manage missing values, and normalize the data.
Object detection: Object detection is the act of recognizing items inside an image or video frame. This is often performed by utilizing deep learning-based methods such as YOLO, Faster R-CNN, and SSD.
Object tracking: Object tracking entails monitoring the movement of an item over time. This is commonly done by employing different tracking algorithms like the Kalman filter, Particle filter, as well as correlation filters.
Lane tracking: Lane tracking entails recognizing and monitoring the lanes on a road. This is often done using computer vision-based methods like Hough transforms, Canny edge detection, and Sobel edge detection.
Motion detection: Motion detection entails identifying any changes in the location of objects over time. This is commonly done using background subtraction methods, optical flow algorithms, and frame differencing algorithms.
Interpretation: After the data has been analyzed, object detection, object tracking, lane tracking, and motion detection techniques may be utilized to extract insights and create predictions about the behavior of objects in the environment. Thisinformation may be utilized for a multitude of

purposes, like automated driving, surveillance, and robots.

Altogether, data analysis and interpretation for object detection, object tracking, lane tracking, and motion detection entail gathering and processing data, using different algorithms to extract insights, and utilizing those insights to make predictions and judgments.

6. RESULTS

True Positive(TP)-the number of cases accurately labeled as the given class.

False Positive(FP)- the number of cases wrongly labeled as the given class.

True Negative(TN)-the number of cases appropriately labeled asthe given class.

False Negative(FN)-the number of cases falsely labeled as the given class.

Accuracy= TP+TN/TP+TN+FP+FN

Table I. Accuracy Result

Total	Identified (TP+TN)	Unidentified (FP+FN)	Accuracy in % TP+TN/ (TP+TN+ FP+FN)
50 people	45	5	90
75 books	69	6	92
150 Cell-phones	135	15	90

Calculating average accuracy from the above table

Average Accuracy = 90+92+90/3 = **90.6%**

6.1. Robot

This figure shows the actual hardware structure of the robot. It’s the view of the robot from the front side and upper side.

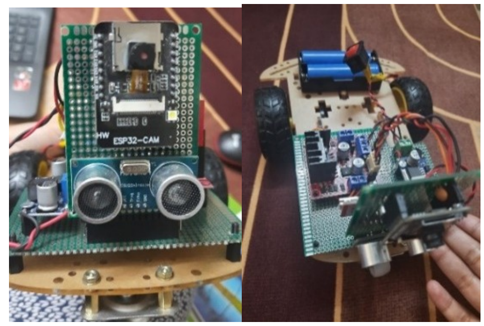

Figure 7. Robot Structure

6.2. Object Detection

The resulting figure of the object detection shows the performance of the model in identifying and localizing objects within an image. It may display the bounding boxes around the detected objects, and any relevant classification labels.

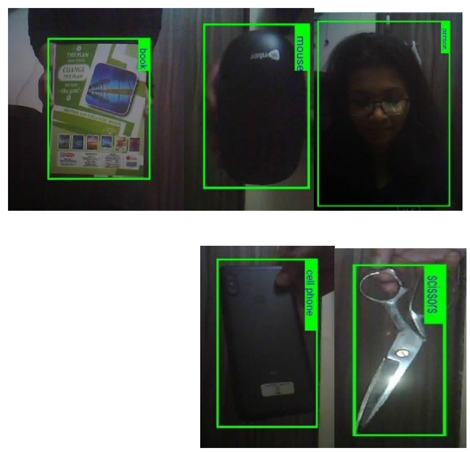

Figure 8. Detected objects such as book, mouse, person, cellphone, scissors respectively.

6.3. Object Tracking

Tracking of the book is done whenever it is moved i.e., it will track whenever the object is moving. In a similar manner, whenever the object is in motion it will track it.

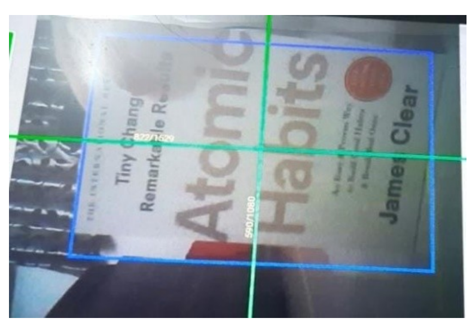

Figure 9. Tracking of the book

6.4. Lane Tracking

The robot is following the lane and accordingly will change its direction. The figure displays the detected lane markings, the predicted trajectory of the vehicle, and any relevant performance metrics such as lane deviation. It is also called a line follower robot.

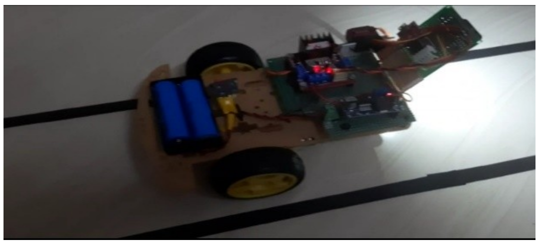

Figure 10. Tracking of lane/path

6.5. Motion Detection

This figure shows how motion detection will detect the change in the position of an object relative to its surroundings the position of the object during its motion will also be detected and from this figure, we can see the x-axis and y-axis values to determine that the object is in motion.

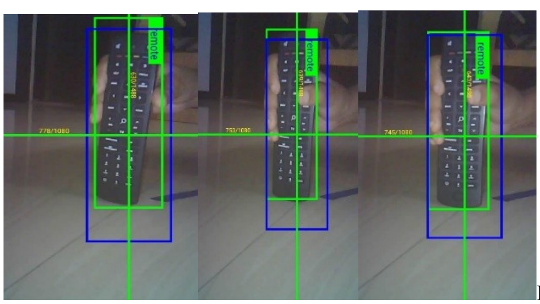

Figure 11. Motion Detection of Remote

7. APPLICATIONS AND LIMITATIONS

Object detection, object tracking, and lane tracking are crucial components of several computer vision applications, including autonomous cars, surveillance systems, and robots. Listed below are a few examples of how these strategies may be applied:

Automated cars: Item tracking and detection are needed for automated vehicles to move through their surroundings safely. By recognizing and monitoring items such as people, other cars, and signposts, an autonomous vehicle may make judgments on how to proceed safely through traffic. Lane tracking also is necessary for autonomous cars to remain inside their allotted lane.

Surveillance systems: Object tracking and detection may be used to monitor a certain region for any suspicious activities or items. For instance, if a surveillance system has been set up in a parking area, object detection may be used to identify and track any automobiles or persons moving in the vicinity. Lane tracking may also be beneficial for surveillance systems to monitor any cars that may be attempting to enter or exit the area.

Robotics: Item recognition and tracking are necessary for robots to recognize and operate things in their surroundings. For instance, a mechanical arm in a manufacturing plant may employ object detection and tracking to gather up and move products on a conveyor belt. Lane tracking may also be beneficial for robots to access a warehouse or industrial plant.

Overall, the applications of object recognition, object tracking, and lane tracking are numerous and have many potentials uses in many industries.

Motion detection seems to have a range of uses, including:

Surveillance cameras: Motion detection is also utilized in video surveillance systems to initiate recording when movement is detected. This may assist reduce storage capacity and make it simpler to discover certain moments in the recorded film.

Home automation: Motion detection is widely used in home automation systems to initiate particular activities, such as switching on lights whenever anyone enters a room or shutting off appliances when a room is vacant.

Games: Motion detection is utilized in gaming systems to monitor player movements and enables even more realistic gameplay experiences.

Health monitoring: Motion detection may be used in health monitoring devices to measure movement and identify changes in levels of activity, which can be beneficial for persons with chronic diseases or for older folks who might need further support.

Industrial automation: Motion detection is often utilized in industrial automation systems to identify whether the equipment is working outside of typical parameters or when there is an unexpected item or person in an unauthorized area.

The issues thataffect object recognition, object tracking, lane tracking, and motion detection are as specified:

Luminescence variation: Surface light variation carried on by daylight variations, weather, obstructions to light sources, etc.

Noise in images: Noise is the component that most impacts the visual attribute of the video frame. A poor-resolution video might make moving object detection and tracking might be challenging. In real-time, the topic might be obscured by other objects totally or partly. Yet, the approach is prone to complete occlusion.

Existence of shadow: Shadows arise whenever the source of light is obscured. monitor both extremely slow as well as very fast-moving objects.

Clutter: It suggests a complex backdrop that renders detection and tracking harder.

Complicated object motion: It could be challenging to track both extremely slow and rapidly moving objects.

8. CONCLUSION

In conclusion, object detection, object tracking, lane tracking, and motion detection are significant computer vision methods that are extensively employed in diverse applications such as autonomous cars, surveillance, and robots.

Object detection is the act of recognizing and localizing objects in an image or video, whereas object tracking is the process of tracing an item's movement through time. Lane tracking includes identifying and pursuing the lanes on a road, which is helpful for autonomous vehicle systems. Motion detection is the technique of recognizing changes in the location of items in a scene over time.Each of these strategies has its benefits and disadvantages, and the option of which one to utilize relies on the unique application needs. Item recognition and tracking are especially valuable for security and surveillance purposes, while lane tracking is vital for self-driving automobiles. Motion detection is a pivotal building element for several computer vision approaches and may be utilized in a broad variety of applications.

Overall, these strategies have transformed the way machines see and comprehend the world around usallowing the creation of breakthrough innovative technologies that havethe possibility of enhancing our lives in countless ways.

9. REFERENCES

- Fancy Joy, V. Vijaya Kumar, A Review on Multiple ObjectDetection and Tracking in Smart CityVideo Analytics,International Journal of Innovative Technology and Exploring Engineering(IJITEE) ISSN: 2278-3075, volume-8 Issue-2S2 December- 2018.
- Azarakhsh Keipour, Graduate Student Member, IEEE, Maryam Bandari, and Stefan Schaal,Fellow, IEEE Deformable One-Dimensional Object Detection for Routing and Manipulation,IEEE, VOL. ROBOTICS AND AUTOMATION LETTERS 7, NO. 2, APRIL 2022.
- Xiangkai Xu, Zhejun Feng, Changqing Cao, Chaoran Yu, Mengyuan Li, Zengyan Wu, ShubingYe, and Yajie Shang, STN-Track: Multiobject Tracking of Unmanned Aerial Vehicles by SwinTransformer Neck and New Data Association Method, IEEE JOURNAL OF SELECTED TOPICIN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING, VOL. 15, 2022.
- Zahra Soleimanitaleb, Mohammad Ali Keyvanrad, Ali Jafari, Object Tracking Methods: AReview, 9th International Conference on Computer and Knowledge Engineering (ICCKE 2019), Ferdowsi

University of Mashhad, October 24-25 2019.

- Yanhao Ren, Yi Wang, Qi Tang, Haijun Jiang, and Wenlian Lu, on a videoing control systemBased on object detection and tracking, 2020 IEEE/RSJ International Conference on IntelligentRobots and Systems (IROS), Las Vegas, NV, USA (Virtual), October 25-29, 2020.
- Hojoon Lee, Jeongsik Yoon, Yonghwan Jeong, and Kyongsu Yi, Member, IEEE, Moving ObjectDetection and Tracking Based on Interaction of Static Obstacle Map and Geometric Model-FreeApproach for Urban Autonomous Driving, IEEE TRANSACTIONS ON INTELLIGENTTRANSPORTATION SYSTEMS, VOL. 22, NO. 6, JUNE 2021.
- Kaige Wang, Tianming Wang, Jianchuang Qu, Huatao Jiang, Qing Li, and Lin Chang, An End-toEnd Cascaded Image Deraining and Object Detection Neural Network, IEEE ROBOTICS ANDAUTOMATION LETTERS, VOL. 7, NO. 4, OCTOBER 2022.
- Jie Bao, Xin Wang, Yihui Zheng, Feng Zhang, Member, IEEE, Xuyong Huang, and PengSun, Lightning Performance Evaluation of Transmission Line Based on Data-Driven LightningIdentification, Tracking, and Analysis, IEEE TRANSACTIONS ON ELECTROMAGNETICCOMPATIBILITY, VOL. 63, NO. 1, FEBRUARY 2021.
- Shijie Sun, Naveed Akhtar, HuanSheng Song, Ajmal Mian, and Mubarak Shah, Fellow, IEEE,Deep Affinity Network for Multiple Object Tracking, IEEE TRANSACTIONS ON PATTERNANALYSIS AND MACHINE INTELLIGENCE, VOL. 43, NO. 1, JANUARY 2021.
- Yeqiang Qian, John M. Dolan, and Ming Yang, DLT-Net: Joint Detection of Drivable Areas,LaneLines, and Traffic Objects, IEEE TRANSACTIONS ON INTELLIGENTTRANSPORTATION SYSTEMS, VOL. 21, NO. 11, NOVEMBER 2020.
- Shujian Wang, Rendong Pi, Jian Li, Xinming Guo, Youfu Lu, Tao Li, and Yuan Tian, ObjectTracking Based on the Fusion of Roadside LiDAR and Camera Data, IEEE TRANSACTIONSON INSTRUMENTATION AND MEASUREMENT, VOL. 71, 2022.
- YONG LV 1, YUEMEI FANG 2, WENZHENG CHI 2, GUODONG CHEN 2, AND LININGSUN2, Object Detection for Sweeping Robots in Home Scenes (ODSR-IHS): A Novel BenchmarkDataset, Digital Object-Identifier10.1109/ACCESS.2021.3053 54.
- Hui Zhang, Member, IEEE, Liuchen Wu, Yurong ChenMember, IEEE, Ruibo Chen, SenlinKong, Attention-Guided Multitask Convolutional Neural Network for Power Line Parts Detection,IEEE TRANSACTIONS ON INSTRUMENTATIONAND MEASUREMENT, VOL. 71, 2022.
- Ching yee young, Rubita Sudirman, Kim Mey Chew, Motion detection and analysis with Four different detectors Faculty of Electrical Engineering Universiti Teknologi Malaysia, 2011 Third International Conference on Computational Intelligence, Modelling&Simulation, September 2011.
- Arindam Sengupta, Lei Cheng, and Siyang Cao, Robust Multiobject Tracking Using Mmwave Radar-Camera Sensor Fusion, IEEE Sensor council, VOL. 6, NO. 10, OCTOBER 2022.
- KAIYUAN LI1, YUNSHENG ZHANG 2,5, YIQIONG ZHANG 3, YITING CHEN4, AND CHIHANG ZHAO, Infrared Detection of Small-Moving Targets Using Spatial Local Vector Difference and Temporal Sample Consensus Measures, Digital Object Identifier 10.1109/ACCESS.2022.3217656.