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Vehicle Detection and Speed Tracking

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Abstract: This review surveys recent methods for vehicle detection, tracking, and speed estimation using monocular video, stereo vision, aerial imagery, LiDAR, and hardware-assisted optical sensing.Detection backbones such as YOLO, SSD, and Faster R-CNN areexaminedalongsidetrackingalgorithmsincludingSORT,DeepSORT,andByteTrack.Monocularhomography,stereodepth estimation,LiDAR-basedtracking,andopticalmodulationapproachesareanalyzedintermsofaccuracy,robustness,anddeploy-ment feasibility. Thepapersummarizesdatasets,evaluationmetrics,andresearchtrends,whileidentifyingkeychallengessuchas weather robustness, lackofstandardizedspeedgroundtruth,andreal-timesensorfusion. Recommendationsforfutureintelligent transportation systems are also discussed.

Keywords: VehicleDetection,SpeedEstimation,IntelligentTransportationSystems,LiDAR,ComputerVision

I. INTRODUCTION

Accurate vehicle detection and speed estimation are essential components of intelligent transportation systems (ITS). These sys-temsenabletrafficmonitoring,congestionanalysis,accidentprevention,andsmartcityinfrastructuredevelopment. Vision-based approaches usingsurveillancecamerasandaerialplatformshavegainedprominenceduetotheirscalabilityandcost-effectiveness when compared with traditional radar or loop-based systems.

Recent advancements in deep learning have significantly improved detection accuracy using models such as YOLOv8, SSD, and Faster R-CNN. Tracking algorithms including SORT, DeepSORT, and ByteTrack enhance temporal consistency, enabling reliablespeedestimationfromvideostreams.However,challengessuchasperspectivedistortion,illuminationchanges,occlusion, and adverse weather conditions remain critical concerns.

II. LITERATURE SURVEY

A. Monocular and Video-Based Methods

Monocular approaches rely on object detection and tracking combined with camera calibration or homography.Deep image homographytechniquestransformcameraviewsintobird’s-eyeperspectives,improvingdistanceandspeedestimationaccuracy. These methods are computationally efficient but sensitive to calibration errors.

B. StereoVisionSystems

Stereovisionsystemsestimatedepthusingdisparitybetweenpairedcameras. Suchsystemsprovidehigheraccuracythanmonoc- ular methods and are less affected by perspective distortion. However, precise camera alignment and calibration are mandatory.

C. LiDAR-BasedSpeedEstimation

LiDAR sensors enable precise three-dimensional vehicle tracking using point cloud clustering and Kalman filtering.These systems achieve very low speed estimation error and are robust to lighting conditions, though high cost limits large-scale deployment.

D. OpticalandHardware-AssistedTechniques

ModulatedMotionBlurandfrequency-modulatedopticalsensingencodevelocityinformationdirectlyintoimagepatterns. These approaches improve robustness in low-feature environments but require specialized hardware.

E. Aerial and UAV-Based Systems

UAV-basedmonitoringprovideswide-areatrafficanalysisusingdetectionandtrackingpipelinescombinedwithscalecalibration. These methods are effective for urban planning but are sensitive to altitude variation and motion blur.

III. ANALYSIS AND DISCUSSION

ComparativeanalysisindicatesthatLiDAR-basedsystemsofferthehighestaccuracy,followedbystereovisionapproaches. Monocular and aerial methods provide acceptable performance for large-scale monitoring with lower infrastructure costs.Hardware- assisted methods demonstrate promising robustness but lack widespread adoption.

IV. CONCLUSION

This review highlights the evolution of vehicle detection and speed estimation from traditional vision-based pipelines to modern deeplearningandmultimodalsystems. WhileLiDARandstereovisiondeliversuperioraccuracy,monocularandaerialmethods remain attractive for scalable deployment. Futureresearchshouldfocusonunifieddetection–tracking–speedestimationpipelines, weather-adaptive models, and real-time multimodal sensor fusion for smart transportation systems.

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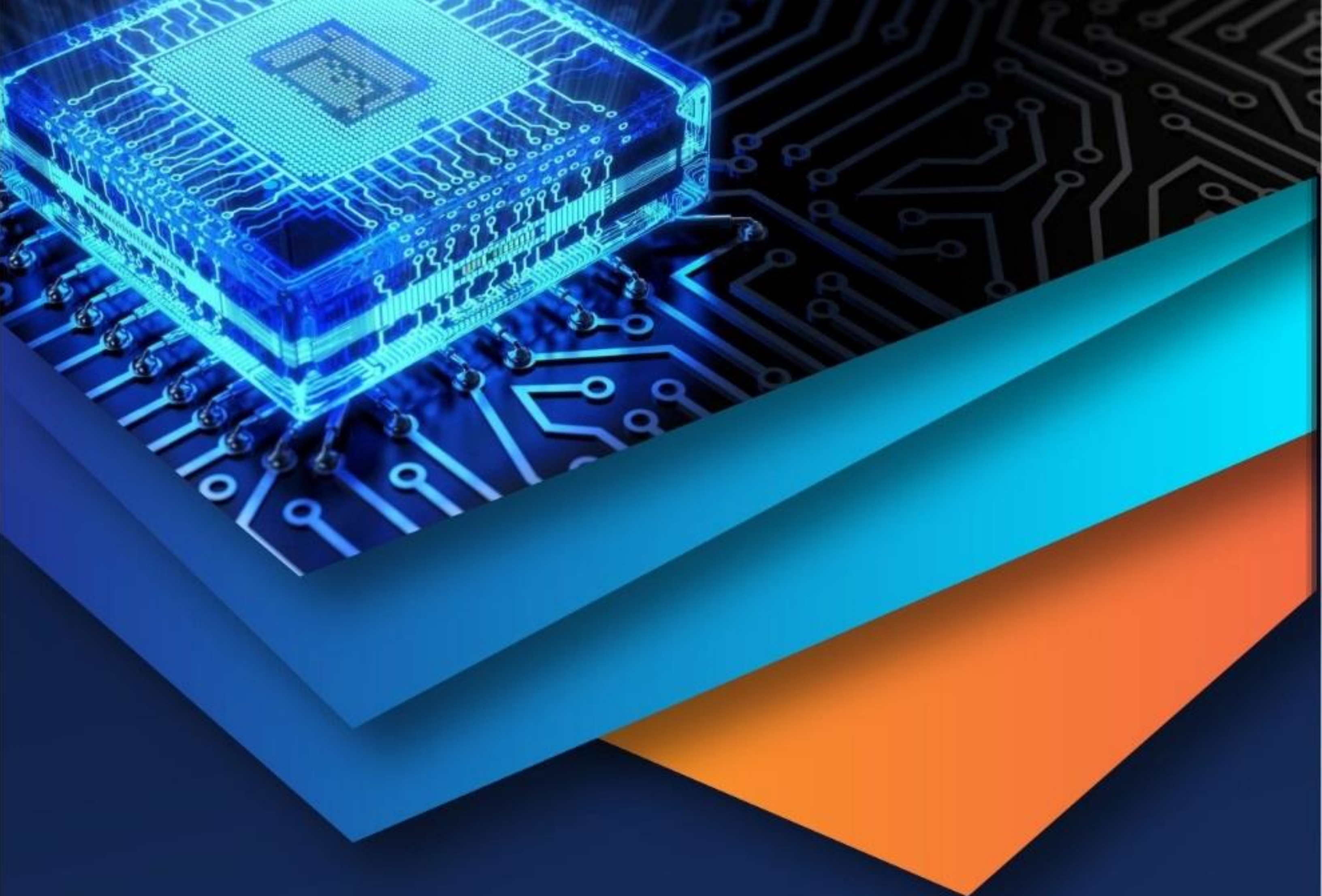

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