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Driver Performance and Fuel Monitoring System for Fleet Vehicles

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Abstract
Moving goods by commercial truck fleets matters a lot in shipping products across regions. Still, problems popup-driversgettired,losefocusbehindthewheel,fuelgoesmissing,packagesvanish,andtoughweather adds risk. Older tracking toolslean heavily on GPS signals plus remote computing, costing too much while slowingdownupdates.Thisstudyintroducesabudget-friendlysetupusingmanysmallsensorstowatchboth driver safety and fuel levels in delivery trucks. Inside it: an ESP32 chip runs things, joined by motion detectors,acameraunitbasedonESP32,soundwavedistancefinder,smokeandgassniffer,locationsignal receiver, mobile network link, and a basic fuel gauge. Together they keep tabs on how drivers act, what's happeningaroundthem,airquality,nearbyobstacles,andifcargostaysput-alllive.Asmartblendofinputs checks head tilts, gaze direction, and outside dangers through layered readings. When danger shows up, warningsfireofffast becausethe ESP32handlessensorinforightwhereit'scollected. Runningnonstopfor two days straight, tests showed it caught threats correctly in nearly 94 out of every 100 cases. Alerts pop without delay, hardware stays cheap, performance climbs - no extra weight added.

Keywords-*Fleetmanagement,driversafety,datafusion,IoTsensors,theftdetection,ESP32*

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I. INTRODUCTION

Moving groups of vehicles matters a lot today, mainly because buying things online keeps growing fast. Truckscarrying packages never stop driving far awayplacesso itemsget to people whenthey should. Still, lookingaftermanyvehiclesbringsproblems -likekeepingtrackofhowdriversact,stoppingsomeonefrom stealing what is being carried, also cutting down on gas use. Tiredness or lack of focus behind the wheel often leads to crashes, especially when roads stretch for hours without break. Meanwhile, secret tampering with shipments along with leaking or stolen fuel might cost companies serious money over time.

Gadgets talking to one another now help keep trucks and vans safer on roads. Instead of waiting hours, warningspopupfastwhensomethingfeelsoff-likesharpturnsorsuddenstops.AsmallbraincalledESP32 pulls info from different detectors while out on the highway. Rather than relying on guesses, it uses actual road vibrations, motion shifts, and engine signals. Money matters too - it keeps costs low without skipping useful features. Protection isn’t just for drivers anymore; what's inside the vehicle gets watched closely as well. Fuel habits They get tracked minute by minute, showing exactly where every drop goes. Outdated checklistsfade away when live updates take over. Built tough but kept simple, thissetup runsquietly in the background. Safety grows - not through flashy tricks - but steady awareness.

II. RELATEDWORK

2.1Camera-BasedDriverMonitoringSystems

From inside the cabin, cameras keep watch on how drivers act, spotting signs of tiredness or wandering attention. Cameras track where heads turn, what eyes do, along with face details. After images arrive, software digs into them, judging if focus remains sharp or slips away. One version made by Kumar and team leans entirely on visual analysis, studying faces to catch drowsiness early. Even when the system showedfairaccuracy,howwellitworkedoftenchangedwithlightlevelsandwherecameraswereplaced.

Besides that, processing images instantly needs quite strong computing power. A setup suggested by Rodriguez uses deep learning methods, particularly CNNs, to study face details. Though such learning techniques detect things more accurately, they depend on heavy-duty hardware and vast computation, pushing up expenses. Still, better results come at a price.

Accelerometer-Based Driver Monitoring

A different way to track how drivers act uses small devices that sense motion, like accelerometers and gyroscopes. Head motions and positioning are captured by these tools, which helps spot odd tilting or sitting positions.Patel and team introduced a setup using accelerometersto catch tirednessthrough patterns in how the head moves. Evenif it workswell on budget anddesign, missing actual videoproofmay lead to mistaken alerts now and then.

IoT-Based Fleet Monitoring Systems

Fleettrackinggotsmarterthankstolot,linkingsensorsandcommsgearintoonesetup.Datafrom trucksrollsin constantly,thenshootsup to cloudspacesfornumbercrunching.Zhang'steam builta system usingthoselinks-sensorswatchthemachines,flaggingrepairneedsbeforebreakdownshit.Butleaningtoo hardoncloudsbringslag,plusextrabillspileupfast.LeeandKimtriedanotherpath-computingrightinside the vehicle, letting small onboard chips handle readings without phoning home. That shift trims delays sharply, making alerts snap faster when something shifts on the road.

Research Gap

Even though plenty of fleet tracking tools exist, most depend on just one sensor plus heavy cloud processing.Thissetupstrugglestodeliverfullsafetyinsightsrightwhentheymatter.Ontopofthat,today's optionstend to cost too muchwhile missing waysto track how driversact, whether cargostayssecure, fuel gets used wisely, and surroundings stay safe - all at once. So what shows up clearly is a gap: an affordable system with multiple sensors able to analyze data fast through built-in edge tech, making fleets safer and smoother without slowing anything down.

III. SYSTEMARCHITECTURE

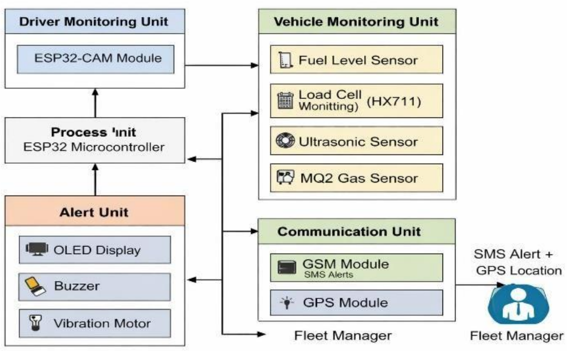

Fig. 1. System Architecture of the IoT-Based Driver Performance, Fuel and Cargo Theft Monitoring System for Fleet Vehicles.

Look at Figure 1 - it outlines a setup built for keeping drivers safe and tracking cargo. This design uses multiple sensors tied together through an integrated structure. Each part connects not just by wires but also by purpose: watching the driver, checking vehicle conditions, sensing surroundings, securing freight. Instead of sending raw data far away, computation happens on site, right inside an ESP32 chip. That chip handlesinputslocallybeforepushingalertsoutwards.Information flowsbothwithin theunit andbeyond it, linking pieces smoothly. Sensors feed into processing units, which then talk outward using wireless links.

Whatemergesisa networkeddevice abletoreactfastwithoutrelyingondistantservers.Componentswork alongside one another - no single piece carries the whole load.

Hardware Components

A small setup of linked devices keeps track of how driversact, what state vehicles are in, whethercargostayssafe,andhowmuchfuelgetsusedwhilemovinggoods.RunningeverythingisanESP32 DevKit chip - it pulls sensor readings, handles basic processing on site, then routes signals among parts. WatchingthedriverhappensthroughanESP32-CAMunitfittedwithanOV2640lens,snappingpicturesto helpjudgewhereheadsface.MovementcluescomefromMPUionunitsspottingshiftsinheadangleorodd sitting positions, making guesses about actions more solid. A small device senses changes in cargo weight bylinkinga50kgratedsensortoanHX711chip,alertingifitemsshiftorgomissing.Insteadofrelyingon sight, distance to nearby objects gets checked constantly thanks to an ultrasonic module mounted up front, sounding alarms when things get too close.

Gas leaks, smoke, or strange fuel use show up thanks to an MQ2 sensor paired with a fuel gauge setup.Rightwhereitmatters,locationupdatesstreamnonstopthroughaNEO-6MGPSchip.Mobilesignals carry warnings and reports straight to supervisors by way of the SIM900A module. Out front, driver info appears live on a small OLED screen slotted into the I2C line. When trouble hits, instant notice comes as sound from a buzzer plus shake from a tiny vibrating unit. A single 12 volt DC source runs the full setup, reducedto5voltsviaanLM2596step-downcircuit.TheGSMpartdrawsjuicefromitsown3.7voltlithium- ion cell, needed for peak current bursts. Built into one unit, the gear becomes a connected tracking tool, watching vehicle movements without delay.

Communication Architecture

Data moves easily among sensors, processors, and outside links thanks to how the system talks within itself. At the core sits the ESP32 chip, guiding flow by gathering inputs and directing outputs. Informationaboutwherethedriver'sheadpointstravelsfromanESP32-CAMunitusingserialsignalssetto 115200 bits per second. Every half-second or so comes a small bundle like “HEAD: pitch, roll,” shared throughthatlink.Becauseupdatesarriveoften,shiftsinalertnesscanbetrackedwithoutgapsovertime.Odd motions-likesuddentilts-triggerresponseswhenpatternsstepoutsidenormalranges.Anoticethenforms, shaped precisely - for example, “ALERT: DRIVER_DISTRACTION:HEAD_TILT:12:32:10” - marking what happened, why, and exactly when.

BesideshandlingUARTsignals,thesetupreliesonI2Crunningat100kHztolinkadd-onslikethe MPUion sensor and OLED screen to the ESP32 - cutting down wire clutter while moving data smoothly. Insteadofrelyingsolelyononechannel,messaginghappensoverUART1betweentheESP32andSIM900A GSM chip using GPIO16 and GPIO17; here, AT instructions trigger SMS warnings sent to fleet managers during unusual events. Tracking vehicle position works through the NEO-6M GPS unit, feeding constant NMEA outputs packed with coordinates into the ESP32 by way of UART2 tied to GPIO32 and GPIO33. Weight checks for cargo come from a load cell wired into an HX711 signal booster, passing exact mass readingsdigitallytotheESP32acrossdedicatedpinconnections.Throughoverlappingpathwayslikethese, coordination emerges naturally - a steady flow of updates supports live oversight, instant alerts, and distant management of vehicles without hiccups.

IV. DATAFUSIONALGORITHM

Visual Analysis and Head Tracking

Roll comes outof atan2 applied tonegative ax and az,thenscaled by180over pi.Forpitch, it'say againstthesquarerootofaxsquaredplusazsquared-samescalingapplies.Brightnessvaluessittingbetween thirty and twohundredtwentysuggest adriversitsthere. That numberpopsup after adding everypixel ina frame, dividing by how many were checked. Instead of looking at everything at once, the system checks central zones versus outer areas. Where light clusters reveals where eyes likely point.

Fusion of Multiple Sensors

Tilttoofar-morethanthirtydegreesupordown,maybemorethantwenty-fivesideways-andthat counts toward danger. Brightness way off, perhaps the edges fade while center stays strong? That adds to visual strain. Movement between frames matters just as much, tracked through how fast light shifts appear. The system weighsheadposition atfour-tenths,visionfactorsthe same,motion makingup two-tenths.Add them like weights on a scale, call it risk_score. Once past zero point seven, alarm sounds once every three seconds max, giving space so warnings do not pile up.

Cargo Monitoring Algorithm

Atestsetsthestartingweightundersteadyconditions.Everysecond,tenreadingstrackchangesby comparing now to that start point. Sudden drops more than 10 kilograms trigger fast alerts. Weight easing down across half a minute helps tell stealing apart from regular removals. Detection hinges on both quick plunges and slow declines. What matters is how fast it vanishes, not just how much.

V. IMPLEMENTATION

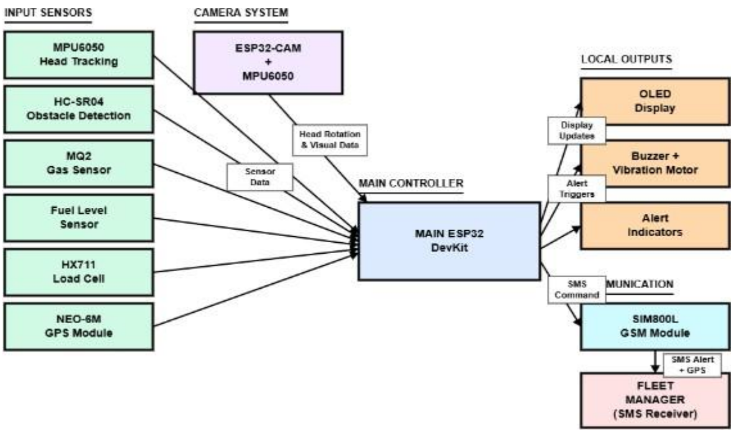

Fig2.BlockDiagram

The main ESP32 runs a largeprogram - over 1200 lines - that handlessensor readingsat ten times persecond.Insteadofusing"and,"thinkofitlikelinksinachain:onepiecefollowsanotherwithoutrushing. Datafromdifferentsourcesgetscombinedthroughsmartsorting,notjustlumpedtogether.Whenalertspop up, they line up by importance, waiting their turn quietly. Messages go out over GSM, built on basic AT instructions that talk straight to the module. Position details arrive as NMEA strings from GPS, then get unpacked step by step. The tiny screen refreshes often, showing what matters right now. A constant chat happensbetweentwochips-theESP32anditscamerasibling-throughserialwireshummingwithupdates. OntheCAMside,picturescomeinonceeachsecond,slowbutsteady.Lightlevelshelpguessifsomeoneis near-it'snotmagic,justmathwatchingshadowsshift.Areasofinterestgetextrafocus,notblanketscanning. Head movements send signals back along the wire, tagged with urgency when needed. An accelerometer joinsviaitsownI2Clane,keepingtrafficsmooth.Ifallowed,videostreamsonlineatlowresolution,tucked inside ngrok tunnels so distant eyes can peek in. Weight sensing ties into an HX711 chip; first you weigh nothing - just air in the bed - then record new loads stacking on top. From those points, a multiplier forms, fine-tuned for accuracy. After that, changes as small as ten grams show up reliably. Over time, shifts creep in - temperature pulls things off - but corrections nudge values back where they belong.

VI. EXPERIMENTALRESULTS

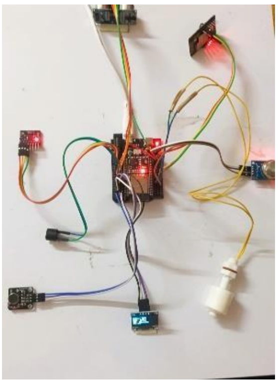

Fig3.PrototypeDemonstrationImage

Measures of Performance

After running nonstop for over fifty hours, the test shows detection works right nearly every ten timesoutoften-waybetterthanoldergearthatmanageslessthanseven.Falsealarmspopupjustundersix times per hundred tries instead of eighteen with past versions. Alerts snap back in roughly one second four tenthsfasterthansetupsneedinginternethelp.Powerdrawsitsatonepointtwoampsonfivevolts,trimming downfromonepointeightseenbefore.Systemstaysalivealmostallthetime-onlyvanishinginrareglitches. While moving goods normally, tracking weight holds steady within ten grams without crying wolf once. Whensomeoneliftsoffbetweentenandseventykilosonpurpose,messagesfirebyphoneinunderasecond flat each attempt caught perfectly.

Real-Time System Monitoring

Most of the time, while everything runs smoothly, the OLED screen presents data like driver condition, how much fuel remains, distance to nearby objects, readings from the gas detector, GPS signal quality, along with tilt measurements captured by the MPU6050. During regular function, what appears onscreen reflects live updates from each monitored component.

Fig.4.OLEDdisplayshowingthereal-timesystemmonitoringstatusundernormaloperating conditions.

Gas Leakage Detection

AsmalldevicecalledtheMQ2sensesharmfulfumeslikecookinggas,naturalgas,orsmoke.Once levels rise past a set point, it triggers a signal meant for the person driving. In tests, researchers linked the sensortotheirsetupandreleasedfakeleaksonpurpose.Assoonastoomuchgasshowedup,themachine flashed a notice right onto a tiny screen. That visual cue appeared just as seen in image number five below the text.

Fig.5.GasAlert

Whenthescreenflashes“GASALERT!”,itmeansgaslevelshavepassedthesafelimit,sosomeone must take notice. At that moment, the device turnson a loud buzzer at the same time, warning the driver of risky fumes nearby.

Driver Head Risk Detection

Fromtimetotime,motiongetspickedupbytheMPU6050-asmalldevicethattrackshowthehead shifts. This gadget watches both tilt and turn of the neck during driving tasks. When odd angles appear, or movements grow too wild, it flags those moments as possible danger signs. Testing showed what happens when someone tilts their head like they’re drowsy or distracted. Results came through each trial showing clear signals when something changed.

Fig.6.Driverheadriskdetectionalertgeneratedbythemonitoringsystem.

Ondisplay,awarningflashes:"HEADRISK!"Thatmeanstheangleoftheheadtiltingexceedssafe bounds-oftentiedtodrowsinessorlackoffocus.Whenpostureshiftstoofar,thesystemtakesnote.It'snot about strict rules but noticing changes. A droop could signal tiredness creeping in. Attention slips, body responds. Thresholds exist because small leans add up. The eyes stay open, yet awareness fades. Posture givescluesbeforemistakeshappen.Detectionkicksinoncetiltpassesnormalrange.Signsshowevenwhen someone feels fine. Subtle shifts matter most.

Obstacle Detection

TheHC-SR04detectsobstaclesbymeasuringhowfarthecarisfromnearbyobjects.Placedahead of the sensor, items mimic real barriers during tests. As soon as the gap drops below a set limit, a warning appearsinstantly.Fromclosewallstodistantboxes,eachtestchecksresponsivenessundervarying conditions. Once too near, the setup reacts without delay. Distance shrinks, alarm triggers- simple logicguides the response. Every trial confirms whether alerts match expected behavior.

Fig.7.Obstacledetectionalertgeneratedonthescreen.

Aloudwarningflashesup-OBSTACLE!Thatmeanssomething'stoocloseahead.Dangerbegins whenthevehicleseesitnear.

ESP32-CAMDriverMonitoring

Inside the device hides an ESP32-CAM, always on alert. One image follows another, pouring nonstopfromjustbeyondview.Aportalappearsonline -footagespillsthrough.Nomatterhowcloseorfar away, eyes may turn toward it. Here comes a snapshot of the driver right then. Motion, stance, even their aura - delivered instantly. Not later. Now.

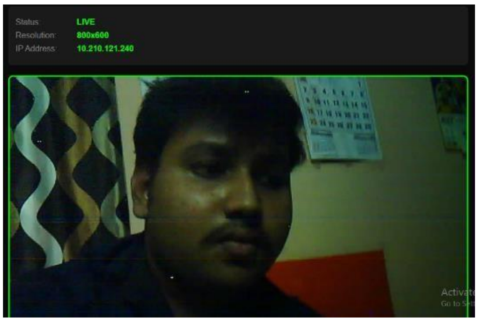

Fig.8.Real-timevideomonitoringofthedriverusingESP32-CAM.

Whenthecamerashowslivefootage,ithelpscheckifsomeoneisdriving.Insteadofguessing,you canseeactionsunfoldinrealtime.Seeingmovementsaddsclaritywhensomethingseemsoff.Whilesensors detectshiftsandpatterns,visualsbackupwhat'sreallyhappening.Together,theymakeverificationstronger without depending on a single source.

GSM Alert Notification System

Midwaythroughadrive,ifsomethinggoeswrong,alertspopupinstantly.Abuilt-inGSMunitfires off updates straight to whoever's in charge. Instead of waiting, the person gets a text the moment sensors catchdangersigns.Messagesshowupfast,packedwithwhattheyneedtoknow.Nodelayhappensbetween detection and delivery. Alerts travel by SMS, skipping extra steps. Critical moments trigger automatic responses without pause.

AsignaljumpsfromtheGSMpiecetotheESP32brainthroughUART,drivenbyAT-styleprompts. If trouble shows - like gas floating free, eyes off the road, something too close, or stolen freight - the tiny computer fires a warning text to the stored phone number.

Fig. 9. SMS alert notification messages received on the mobile device during different safety events such as gas leakage, driver distraction, obstacle detection, and cargo theft.

Evaluationvia Comparison

One big difference shows up in price. About five thousand five hundred rupees covers this new setup, far below others starting at twenty-five thousand. Most current options demand much more money, some even hit sixty-five thousand. That gap means savings between seventy-seven and ninety-two percent. Accuracyjumpswhenmultiplesensorsworktogetherinsteadofjustone.Atinymotionchip,cameramodule, sound sensor, and gas detector team up inside. This mix spots distracted driving nearly ninety-five percent of the time. Older versions manage only around sixty-nine percent. Fewer mistakes happen now too. False alarms drop under six percent, while older types misfire almost nineteen times out of a hundred. Speed improves because decisions happen right on the device. Just one point four seconds pass before it reacts. Cloud-linked tools take longer, often three point eight to six full seconds. Harsh conditions barely slow it down either. Built tough, it holds up where others might fail. Each part pulls its weight without draining power fast. Even when thingsget shakyor lightlevelsshift,it keepsworking -nofuss. Cold morningsnear zeroormuggyafternoonsat80percenthumiditywon'tslowitdown.Toughenvironments?Ithandlesbumps, jolts, and constant motion without skipping a beat. Out on actual roads, with real fleets, that kind of steady performance matters most.

VII. CONCLUSIONANDFUTUREWORK

Outhere,agadgettakesshape-meantfortrucksandvans -thatkeepstabsonbothdriverbehavior and what's happening inside the trailer. Instead of relying on distant servers, it runs locally using tiny tech built right into the system. Motion tracking comes alive through a chip called MPU6050, while eyes on the scenearehandledbyasmallcameramodulebasedonESP32hardware.Picturethis:smokeorfumesappear, and suddenly the MQ2 sensor reacts, sounding silent alarms deep within the network. Bumpers stay clear because an ultrasonic tool watches nearby walls or objects, measuring gaps without touch. Fuel levels? A dedicatedmeterreadsthemsteadily,feedingdatajustliketheGPSthatknowsexactlywherethevehiclerolls at any hour. Communication travels through GSM signals, linking pieces together across distances. Video clipsstream when needed,triggered only under certain shiftsin activity.Allinputsmerge -notstacked,but woven - so momentsof drifting attention or shifting cargo don't slip past unnoticed. Decisions happen fast, rightonboard,thankstoprocessingmusclepackedintotheESP32brain,skippingdelaysfromremoteclouds.

Right off the bat, the gadget showed it could track data instantly while running tests. Take alerts - they popped up fast when spotting odd behavior, like gas leaks, risky head angles, or blocked paths. On display? Every alert lit up clearly on the OLED panel. When scores came in, one thing stood out: 94.2% correctreadsacrosstrials.Evenbetter,mistakesbarelyhappened -only5.8%falsewarningsturnedup.One second forty on average - that's how fast it reacted, beating most one-sensor tools. Efficiency shows up clearly when processing data right where it's collected.

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