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Obstacle Avoidence and Landslide Detection for Vehicles

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Abstract—

In hilly and isolated areas, landslides and unexpected road obstacles significantly threaten vehicle safety, often hindered by poor visibility and limited communication infrastructure. This study introduces an IoT-based system for obstacle avoidance and landslide detection aimed at vehicles traveling through disaster-prone areas. The system incorporates various sensors, such as ultrasonic sensors for detecting obstacles in real time and MPU6050 accelerometer/gyroscope modules for predicting landslides through vibration analysis. The ESP32 microcontroller processes this data and sends alerts via wireless communication to provide early warnings. By merging local edge- level sensing with IoT-based remote monitoring, the proposed system enhances road safety and aids intelligent transportation systems (ITS).

I. INTRODUCTION

Maintaining road safety in regions with steep terrain and frequent landslides is a persistent and multifaceted problem. Such areas are extremely susceptible to risk due to unstable geological conditions, uneven road surfaces, and rapidly shifting environmental factors. Elements like steep gradients, sharp blind turns, restricted visibility, and fragile soil structures render conventional safety solutions—such as fixed warning signs, reflectors, and road signages—largely inadequate. Sud- den dangers, including rockfalls, loose rubble, slope collapses, or minor ground movements, can arise unexpectedly, leading to serious accidents, vehicle damage, and fatalities. The lack of real-time surveillance and prompt hazard alerts further amplifies the danger for drivers traveling through these regions. Recent progress in the Internet of Things (IoT), embedded electronics, and intelligent sensing has made continuous, automated, and real-time environmental surveillance more attainable than ever. IoT-based sensors allow the collection of localized data, assessment of terrain dynamics, and instant transmission of warnings to users, facilitating preventive rather than reactive safety strategies. Contemporary vehicles can be equipped with smart sensing modules that perform obstacle detection, distance estimation, and environmental monitoring with minimal reliance on external infrastructure, such as roadside units or dedicated weather stations.

Ultrasonic sensors, commonly employed in robotics and autonomous systems, provide a dependable and economical solution for detecting nearby obstacles. Their straightforward design, low energy consumption, and accurate range measurements make them well suited for identifying objects like boulders, fallen branches, temporary roadblocks, or abrupt surface deformations. Complementarily, accelerometers and gyroscopes deliver essential information about ground vibrations, changes in tilt, and rapid variations in a vehicle's orientation—factors that may signal ground weakness or the early development of a landslide. When integrated, these sensors create a robust sensing framework capable of observing both the vehicle's immediate surroundings and the underlying stability of the terrain.

This paper introduces an IoT-enabled embedded safety system that combines real-time obstacle detection with landslide and slope-disturbance monitoring to improve vehicular safety in mountainous and landslide-prone areas. The system is built around an ESP32 microcontroller serving as the central processing unit, taking advantage of its integrated Wi-Fi, high processing performance, and support for interfacing with multiple sensors. It merges data from ultrasonic, accelerometer, and gyroscope sensors to generate prompt alerts, which are transmitted wirelessly to drivers or a central monitoring system.

In contrast to existing methods that typically concentrate on either obstacle avoidance or environmental hazard fore- casting, the proposed architecture employs a dual-layer safety framework. It concurrently evaluates both terrain stability and roadway obstacles directly at the vehicle level, providing real- time situational awareness even where communication infrastructure is limited. This combined strategy delivers a more comprehensive solution and addresses a key gap in current research, where obstacle detection and landslide monitoring are usually implemented as separate systems.

By offering a compact, economical, and easily deployable embedded platform, this work seeks to substantially lower accident risk, enhance driver reaction times, and boost overall safety in hazardous mountain environments. The proposed system underscores the promise of IoT-based intelligent transportation technologies in evolving traditional road safety practices into proactive, data-centric, and context-aware safety solutions.

II. LITERATURE REVIEW

Obstacle detection and landslide monitoring constitute two pivotal research directions in intelligent transportation systems (ITS) and environmental hazard forecasting. As the demand for safer transportation grows, especially in mountainous and disaster-susceptible regions, these domains have advanced markedly in terms of sensing technologies, control strategies, and predictive models. This section surveys the key contributions, emerging trends, and existing gaps in the literature, underscoring the necessity for a unified vehicular safety framework that jointly addresses both obstacle detection and terrain-scale hazard monitoring.

Obstacle detection has long been recognized as a core requirement for autonomous driving, collision avoidance, and robotic navigation. Traditional approaches primarily depend on combinations of short-range and long-range sensors to estimate the distance to potential road hazards.

Initial research in this area concentrated on ultrasonic sensor–based proximity detection, where acoustic waves are used to measure the distance to surrounding objects. In [1], a wide- angle ultrasonic sensor was combined with a microcontroller platform to detect obstacles across a 180° field of view. The work demonstrated that ultrasonic sensing can provide efficient, short-range, and low-cost distance measurements, making it particularly attractive for vehicular safety applications in spatially constrained scenarios.

With the emergence of advanced machine learning techniques, more resilient detection capabilities have become possible in unstructured environments. Deep learning–driven object detection frameworks such as YOLO, SSD, and Faster R-CNN have markedly enhanced detection performance, es- pecially in challenging scenes with irregular obstacles, non- uniform illumination, or visually cluttered backgrounds. In [2], the authors employed convolutional neural networks (CNNs) for real-time obstacle classification and distance estimation, showing superior robustness compared to conventional sensor- only approaches.

A further important line of work in obstacle detection is based on stereo vision and semantic segmentation. Stereo vision systems utilize two or more cameras to infer depth,

thereby enabling accurate 3D localization of objects. In [3], researchers combined stereo depth estimation with pixel-wise semantic segmentation to differentiate obstacles such as rocks, pedestrians, and road edges. This methodology is particularly advantageous for autonomous vehicles operating in highly dynamic or irregular terrains, where the environment's geometry changes frequently.

However, detecting obstacles in isolation is not sufficient; it must be paired with appropriate control strategies that dictate how a vehicle should react to identified hazards. Consequently, sophisticated control mechanisms have been extensively investigated in parallel with detection technologies. Model Predictive Control (MPC) has seen extensive use be- cause it can forecast future vehicle states and optimize control inputs in real time. The work in [4] introduced a lane-level obstacle avoidance method based on MPC that incorporates vehicle dynamics, lane geometry, and obstacle trajectories. This method showed improved decision-making speed in edge- case scenarios where rapid evasive maneuvers are essential.

Reinforcement learning (RL) has also gained traction as a powerful alternative. RL-based frameworks learn optimal navigation policies via trial-and-error interaction with the environment, giving them strong adaptability to changing conditions. In [5], RL techniques were applied to autonomous navigation over uncertain terrain. The resulting model exhibited robust adaptability to abrupt changes such as shifting rocks, moving debris, and varying road textures—conditions commonly present in mountainous regions.

Together, these methods illustrate the transition from rigid, rule-based navigation systems to intelligent, learning-driven control architectures that can function reliably in complex outdoor environments.

Landslides are highly destructive natural events influenced by factors such as rainfall, soil moisture, ground vibrations, and geotechnical heterogeneity. Conventional warning systems mainly relied on rainfall thresholds, where alerts were issued once precipitation surpassed predefined limits. While widely implemented, these rainfall-based methods frequently overlook localized slope instabilities that precede major collapses.

To address these limitations, more recent research has combined IoT sensing, vibration monitoring, and real-time analytics. MEMS-based accelerometers and gyroscopes now play a central role in identifying subtle ground movements. They capture fine variations in soil vibration signatures, tilt angles, and slope gradient changes—key parameters that serve as precursors for potential landslide events.

In [6], the authors introduced an IoT-driven ground monitoring framework deploying distributed accelerometers along slopes. Data from these sensors were relayed to a central node, enabling continuous observation of slope dynamics. The results indicated that vibration monitoring can reliably detect early-stage slope failures that conventional rainfall-threshold systems frequently miss.

A complementary direction in landslide forecasting lever- ages vision-based terrain assessment. With the growing use of UAVs and drone-based mapping, large-area risk evaluation has

become practical. In [11], researchers utilized UAV imagery paired with machine learning models to identify hazardous terrain regions. Fusing aerial imaging with computational analysis enabled high-resolution terrain characterization and automated recognition of soil displacement patterns. Semantic segmentation and transfer learning methods have also been implemented to identify areas vulnerable to landslides. In reference [7], the researchers utilized satellite images and geographical data to train complex artificial neural networks to classify regions based on their potential for landslide occurrence. This method considerably enhanced the precision of classification in comparison to conventional geotechnical modeling techniques. Despite the considerable advancements made in each area of study—obstacle detection and landslide prediction—one important point stands out: the majority of research done so far tackles these challenges separately.

The main emphasis of obstacle detection studies is on risks to vehicles, such as boulders, other cars, or roadblocks. Landslide monitoring studies focus on environmental risks like shifts in the ground or patterns of vibration. However, a combined strategy is required in mountainous areas because the development of obstacles (rockfalls, road debris) and ground movement (unstable slopes) are related. It is not enough to rely on just one system to guarantee the safety of drivers. Furthermore: Numerous landslide monitor- ing systems call for permanent installations that are costly and inappropriate for isolated locations. Deep learning-based obstacle detection systems need a lot of processing power, which makes it difficult to install them on small, lightweight platforms. Current IoT systems hardly ever combine vehicle hazard detection with terrain data. Real-time warning capabilities are restricted by communication delays or reliance on outside infrastructure. Therefore, the lack of a comprehensive, vehicle-mounted, dual-safety design is still a significant area in need of research. This research seeks to fill that void by combining ultrasonic obstacle detection with slope instability detection using accelerometers and gyroscopes into an IoT- based platform for vehicles. This combination offers a number of benefits: Real-time detection of risks at both the road and terrain levels. No reliance on sizable infrastructure. Affordable installation appropriate for remote and mountainous areas. Quick wireless alerts using simple IoT communication. Localized sensing that lowers reliance on cloud prediction. The suggested system integrates both functionalities into a single design, unlike studies that consider obstacle detection and landslide monitoring to be distinct issues, which promotes a more complete strategy for road safety in dangerous terrains.

III. METHODOLOGY

The proposed setup acts as a comprehensive safety mechanism utilizing IoT technology. It's engineered to promptly identify dangers on roads and anticipate potentially unstable terrain that could signal an impending landslide. The approach encompasses a continuous process of data collection, processing, communication, and alert dissemination. As the central component for processing and communication, the system incorporates an ESP32 microcontroller. The complete process is structured into a series of sequential steps, as detailed below. Upon initiation, the ESP32 microcontroller activates all hardware elements, configures communication channels, and establishes preset safety thresholds. These thresholds encompass a defined range for detecting obstacles, a specified vibration intensity indicative of unstable ground, and a set tilt angle for an imbalanced slope. Once initialized, the ESP32 establishes a Wi-Fi connection for cloud connectivity. The GPS module is also activated to provide real-time location data, ensuring that any identified hazard is associated with precise location information.

Obstacle detection forms the initial safety measure in the process. The ultrasonic sensor (HC-SR04) is employed due to its high accuracy, cost-effectiveness, and proficiency in close- range object detection. The sensor emits ultrasonic waves and assesses the time it takes for the echo to return after striking an object. This duration is converted into distance via an equation. The ESP32 continuously monitors this distance within a loop. Should the measured distance fall below the established threshold, the system interprets this as a potential collision. Key functionalities of the obstacle detection feature include continuous surveillance of the area ahead of the vehicle, refining distance readings to mitigate errors using moving average techniques, swift detection of any object entering the danger zone, and immediate alert dissemination to prevent a collision.

Upon detecting an obstacle, the system issues a high- priority alert. This alert can be conveyed through an on-vehicle display or buzzer for the driver, a cloud-based notification for remote monitoring, or motor control to decelerate or halt the vehicle in automated systems. This ensures immediate driver notification prior to a collision. In the absence of obstacles, the system proceeds to the second safety measure—assessing ground stability. This is achieved using the MPU6050, which integrates a 3-axis accelerometer and a 3-axis gyroscope.

The accelerometer identifies subtle ground vibrations trans- mitted through the vehicle. These vibrations, when analyzed over time, reveal whether the ground beneath or nearby is becoming unstable. Vibration intensity surpassing the set threshold indicates soil loosening, minor rock displacement, and initial signs of slope instability. The gyroscope monitors fluctuations in the vehicle's tilt angle. Abrupt or anomalous angle variations may indicate an uneven or unstable road surface, vehicle movement due to ground shifting, or subsurface disturbances frequently preceding landslides. The ESP32 processes these readings through complementary filtering, threshold-based sorting, and pattern recognition in time-series data. A combination of significant vibrations and tilt changes triggers a landslide warning.

All gathered data—including proximity to objects, vibration intensity, tilt angles, and GPS-derived locations—is routinely transmitted to an online IoT hub (such as Blynk or Firebase). This enables remote monitoring by authorities or road management systems, retrospective data analysis for identifying high- risk areas, and automated generation of hazard maps using GPS location data. The internet connection also facilitates real-time updates, enabling rapid alert dissemination to nearby vehicles or command centers.

A GPS module is integrated to enhance the precision of hazard reports. Each instance of obstacle detection, vibration surge, or anomalous tilt is marked with latitude, longitude, and timestamp data. This is instrumental in creating hazard location maps, identifying frequently unstable sites, and informing predictive modeling for future safety initiatives. Precise location identification is crucial on mountain roads, where hazards can manifest in highly localized areas. The ESP32 initiates appropriate actions based on the severity of the detected hazard.

Immediate proximity alerts include displaying warnings on a small screen (LCD/OLED), generating an audible buzzer to promptly alert the driver, and activating flashing lights to indicate the level of danger. Remote alerts include transmitting updates via online IoT platforms, automatically generating reports on online dashboards, and distributing warnings to other vehicles in the vicinity. For automobiles that possess partial autonomous driving capabilities or are still in the experimental phase, the mechanism has the capability to govern the powertrain to curtail velocity, engage the braking system, or bring the vehicle to a standstill in circumstances involving substantial peril. This averts the vehicle from proceeding into a hazardous location. The entire framework functions on a cyclical schedule, which involves perceiving information pertaining to impediments and the topography, rectifying and processing the data on the ESP32, making determinations ac- cording to predetermined parameters and amalgamating sensor data, transmitting sensor information to the digital storage, and triggering notifications and regulating the powertrain. By integrating the detection of objects in close proximity with the forecasting of potential landslides, this methodology guarantees the presence of a comprehensive safety protocol functioning in real-time.

The framework affords safeguards through a dual approach, by detecting impediments and observing for potentially un- stable earth. Anticipatory risk recognition utilizing vibrational and inclinal assessments is conducted through the employment of vibrational evaluations and gradient scrutinization to foresee upcoming perils. Locale-attentive cautions are disseminated by means of GPS unification, and by the utilization of GPS innovations, warnings are discharged depending on precise geographical placement. Cloud-facilitated supervision guarantees dependable distant oversight and data accumulation, in which distant observation and data preservation are dependably assisted via distributed computing technology.

IV. PERFORMANCE EVALUATION METRICS

The effectiveness of the suggested setup is judged through a collection of well-defined measures. These measures precisely assess the correctness, speed, steadiness, and communication effectiveness of the parts that find obstacles and watch for landslides. Collectively, these measures reveal the system's

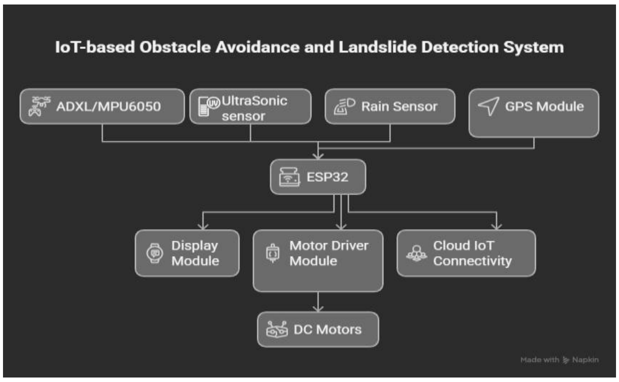

Fig. 1. System Architecture

suitability for real-time application in vehicle settings, where being safe and making quick choices is very important.

The key things looked at to judge how well the obstacle avoidance part works include how correct it is, how fast it reacts, and how often it wrongly identifies things. How correct it is shows if the system can properly spot obstacles nearby within the distance the ultrasonic sensor can reach. When it is more correct, the driver is more aware and there is less chance of crashes. How fast it reacts is the time between when an obstacle is spotted and when a warning is sent out. This time should be short, just a few milliseconds, so the driver has time to avoid the obstacle. How often it wrongly identifies things shows how often the system warns about obstacles that are not there. This helps stop unnecessary warnings that could take the driver's attention away or make them trust the system less. Extra things such as the sensor's range, how steady it is at spotting things at different angles, and how well it works in different weather (like rain or dust, or on rough ground) can also be checked. This makes sure the system stays reliable in various real-world conditions.

To judge how well the landslide prediction and monitoring part works, we use several measures to see how effective the MPU6050 sensor is. Sensitivity measures the system's ability to pick up even small ground movements that could mean a landslide is about to happen. Vibration threshold reliability checks if the system can consistently tell the difference between normal, everyday ground movements and unusual, dangerous patterns. The stability index measures how consistent the sensor readings are over time, making sure it stays reliable for a long time in tough areas. Also, drift compensation accuracy is looked at to make sure the MPU6050 gyroscope and accelerometer measurements stay accurate without building up big mistakes.

Lastly, IoT data transmission latency and network reliability are used to determine how well the cloud-based alert delivery works and how strong it is.

V. LITERATURE SURVEY

TABLE I: Summary of Literature Survey on Obstacle Detection and Landslide Monitoring Systems

Sl. No	Paper Title	Year	Methodology Used	Findings
1	Detecting and Keeping Tabs on Landslides Using IoT Tech	2023	A sensor array for ground moisture and acceleration, connected to a NodeMCU (ESP8266); measurements are sent through MQTT to a Raspberry Pi hub and shown on the ThingSpeak internet platform. When moisture and ground movement levels go past set safety points, a system makes choices and sends warnings.	**Pros:** It provides constant, up-to-the-minute checks on how likely landslides are, with dash- boards and alerts online, making it good for faraway mountain places. **Cons:** A huge number of sensor units are a must to properly cover large hillsides, which makes setting up, tuning, and keeping everything running harder.
2	Better Ways to Spot Lanes and Things Blocking the Road Using 3D LiDAR for Helping Drivers	2023	Precise 3D LiDAR data sets are handled using lane-spotting computer programs taught using the LiSV-3DLane data; it puts together shape details and light signs to find lane lines and where objects are on well-organized city roads.	**Pros:** It sees everything around, spots lanes and things blocking the way well under all sorts of light, and is very exact for ADAS uses. **Cons:** It is mainly for roads with clear lane markings; it does not look much at how well it works in rough, off-road, or hilly areas.
3	A System That Uses Internet of Things to Spot Obstacles and Warn Drivers with Ultrasonic Sensors	2024	Several HC-SR04 ultrasonic sensors are set on a servo that goes from 0 to 180 de- grees and hooked up with Arduino. Space readings are cleaned up and passed through an IoT platform to warn drivers on their phones or car screens.	**Pros:** The hardware is super cheap, easy to make a test version, gives distance guesses right away, and quickly tells the driver about stuff nearby. **Cons:** Ultrasonic sensors get thrown off by noise and weather; they have short reach and do not cover much space, especially when the car goes faster.
4	Using LiDAR to Find Holes and Low Spots in Or- chards	2024	A tilted solid-state LiDAR is put on farming vehicles; the shape of the data points is used to find things like holes and gaps between rows. Height changes and slope rules are used to name risky spots.	**Pros:** It really cuts down on blind spots (from about 3 meters to just 0.21 meters) and makes it safer to drive in orchards with bumpy ground. **Cons:** The way it works is set for planned orchard designs; LiDAR is not cheap, and it might not work as well when there are lots of leaves or dust.
5	Review of Combining Sensors with LiDAR to Avoid Obstacles	2024	A look at how to combine LiDAR with other sensors (camera, radar, IMU) in ADAS. It goes over different ways to mix data (early, mid, late), how to match up data, and how to see things to stay away from obstacles.	**Pros:** It gives a big picture of the best ways to combine data, showing how using different types of sensors makes spotting things more right and solid in hard traffic. **Cons:** Combining data takes a lot of computer power and needs careful setup and timing of different sensors, which makes the system cost more and harder to build.
6	Highly Reliable 3D Object Identification in ADAS Systems	2024	A multi-faceted 3D object identification network is assessed under conditions of sensor disruption, blockages, and variations in environmental conditions. The focus of the experimentation lies in analyzing how disruptions in LiDAR and camera inputs influence the detection of objects within ADAS environments, along with introducing metrics for measuring robustness.	**Pros:** Focuses on practical dependability by evaluating resilience as opposed to mere correctness; valuable for ensuring the secure deployment of object identification models in vehicles. **Cons:** Primarily designed for self-driving applications within city settings; it does not specifically tackle land-based risks like landslides or falling rocks.

Sl. No	Paper Title	Year	Methodology Used	Findings
7	Efficient Transformer-Based Model Lights-Transformer for Landslide Segmentation	2024	A transformer encoder-decoder design customized for segmenting landslide zones from images taken remotely. Self-attention mechanisms are utilized to identify long- range linkages and broad-scale context, im- proving boundary accuracy.	**Pros:** Sets a new standard in segmentation accuracy and effectively interprets widespread terrain features, rendering it appropriate for mapping landslides across wide areas. **Cons:** Demands extensive, detailed datasets that have been marked up, along with substantial com-putational power from GPUs; both training and fine-tuning require significant computing resources.
8	Light-weight Landslide Detection from Satellite Imagery	2024	A streamlined, fully integrated convolutional model engineered for use on plat- forms with limited resources. It analyzes satellite images of intermediate resolution to differentiate between pixels showing landslides and those that do not, employing simplified feature extraction methods.	**Pros:** Preserves a high level of detection pre- cision while considerably reducing processing demands, thus allowing implementation on basic devices or budget servers for continuous monitoring. **Cons:** Needs pristine satellite im- agery free of cloud cover and may have difficulties identifying very small or heavily concealed landslide incidents.
9	Multi-Source Fusion Network (MSFD-Net) for Landslide Detection	2024	The MSFD-Net framework employs a DeformNet base, integrating topographic maps, deformation measurements, and visual imagery. This multi-branch network learns unique traits from each source, en- abling a more distinct categorization of landslides.	**Pros:** Offers a more complete representation of textures and terrain by merging diverse data types, which enhances detection capabilities on intricate slopes. **Cons:** Calls for thorough pre- processing and synchronization of multiple data streams; gathering and storing data across all types can be costly.
10	UNet-CBAM for Landslide Deformation Monitor- ing via Remote Sensing	2025	A UNet-based framework that includes an encoder-decoder structure, enhanced by a Convolutional Block Attention Module (CBAM). This attention mechanism empha- sizes key areas in remote-sensing images to track subtle changes in shape associated with landslide activity.	**Pros:** Capable of discerning minute terrain shifts and initial deformation patterns, thus im- proving sensitivity to the preliminary phases before a collapse. **Cons:** The model requires substantial memory and processing power, ne-cessitating advanced hardware or offline analy- sis for real-time processing.
11	Rapid Landslide Detection from Sentinel-2 Using Tasseled Cap Technique	2025	The Tasseled Cap Transformation (TCT) is applied to multiple Sentinel-2 satellite images collected over time; alterations in brightness, greenness, and wetness are then detected to pinpoint regions impacted by landslides.	**Pros:** Boasts minimal computational needs, uses readily accessible satellite data, and is well-suited for quick assessments across large areas. **Cons:** Its effectiveness diminishes on rocky or bare slopes and is susceptible to fluctuations in weather and atmospheric conditions between image captures.
12	LV-DOT: LiDAR-Visual Dynamic Obstacle Detection & Tracking	2025	Fuses LiDAR with RGB-D visual data; em- ploys Kalman filtering and data association for real-time tracking of moving obstacles. Designed mainly for indoor robots and au- tomated platforms.	**Pros:** Accurate dynamic obstacle tracking with smooth trajectories; lightweight implementation suitable for embedded robotic platforms. **Cons:** Evaluated largely in indoor or short-range scenarios; not directly optimized for outdoor long- range vehicle environments.
13	Smart IoT System for Landslide Prediction and Monitoring	2025	Integrated IoT platform combining multiple environmental sensors (e.g., rainfall, soil moisture, vibration) with centralized alert logic and remote monitoring dashboard accessible via web/mobile applications.	**Pros:** Accurately detects early landslide indica- tors, offers low-cost and scalable deployment, and enables real-time notifications for authorities and residents. **Cons:** Continuous operation depends on stable communication networks and reliable power sources in remote areas.

Sl. No	Paper Title	Year	Methodology Used	Findings
14	Prototype Design of Landslide Early Detection System Using LoRa and IoT	2025	Uses HC-SR04 ultrasonic sensor for soil movement indication and moisture sensing nodes; communicates via LoRa for long- range, low-power transmission to a base station or Android app for visualization and alerting.	**Pros:** Provides reliable communication up to about 250 m with low energy consumption, enabling early warning in remote or hard-to-access slopes. **Cons:** LoRa bandwidth limits high- frequency data streaming; terrain and obstacles can reduce effective communication range.
15	Obstacle Avoiding Robotic Car Using Arduino with Bluetooth and Voice Control	2025	Robotic car platform controlled via Blue- tooth and voice commands using mobile apps (AMR Voice, Bluetooth RC Con- troller). Ultrasonic sensors handle obstacle avoidance; Arduino IDE used for coding and Proteus for circuit simulation and vali- dation.	**Pros:** Demonstrates efficient obstacle avoidance combined with interactive voice/Bluetooth control, showcasing applicability for assistive or educational robots. **Cons:** Prototype-scale system with limited sensing range and speed; not directly suitable for full-scale vehicular safety without significant adaptation.
16	DeepFusionNet: Real-Time Obstacle Detection via Multi-Sensor Fusion for Off- Road Use	2023	A CNN-based approach merges LiDAR depth data, IMU-based stabilization, and stereo vision disparity for dependable obstacle detection in off-road conditions. Spatiotemporal fusion is achieved through attention layers.	**Pros:** Shows high dependability in terrains with dense vegetation and irregular surfaces, offering strong generalization. **Cons:** Demands substantial computational power; real-time performance relies on the GPU specifications.
17	Early Warning System for Slope Stability Monitoring Based on IoT with MEMS Tilt Sensors	2024	Slopes are equipped with MEMS tilt sensors; LoRaWAN is used for communication; adaptive Kalman filtering minimizes noise.	**Pros:** Consumes minimal power and allows for extended communication range, making it suit- able for detecting gradual slope changes. **Cons:** Cannot effectively capture high-frequency vibrations and is susceptible to temperature variations.
18	Hybrid Vision System Using YOLO and LiDAR for Obstacle Detection in Autonomous Vehicles	2024	YOLOv8 vision detection combines with LiDAR point-cloud clustering; depth cor- rection uses bounding-box fusion.	**Pros:** Delivers high accuracy in real-time (30–50 FPS) and enhanced detection capabilities in congested areas. **Cons:** Necessitates frequent alignment of camera and LiDAR; consumes significant memory.
19	Mapping Landslides with UAVs Using Multispectral Imaging and Analysis of DEMs	2023	Digital Elevation Models (DEMs) are in- tegrated with multispectral imagery from UAVs; NDVI, slope angle, and moisture index are used to calculate susceptibility.	**Pros:** Provides precise mapping of both active and inactive landslides across extensive ter- rains. **Cons:** Encounters limitations in heavily forested areas; UAV functionality is compromised by adverse weather conditions.
20	Real-Time Obstacle Detection for Autonomous Drones Using Depth Estimation and Optical Flow	2022	Real-time collision avoidance is achieved by combining monocular camera-derived optical flow divergence with depth estimation.	**Pros:** Has a lightweight design and uses little power, making it ideal for smaller drones. **Cons:** Has issues with surfaces that are reflective or lack texture and is sensitive to abrupt changes in lighting.

VI. CONCLUSION

The suggested IoT-based system effectively integrates obstacle detection with landslide prediction to enhance vehicle safety in hilly and disaster-prone regions. Utilizing ultrasonic and MPU6050 sensors, the system offers real-time monitoring and notifications via the ESP32 microcontroller. This dual-safety strategy improves driver awareness and minimizes the risk of accidents. The prototype showcases affordability, portability, and rapid response time, rendering it appropriate for incorporation into intelligent transportation systems and future Advanced Driver Assistance Systems (ADAS) applications.

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