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RESEARCH ARTICLE

A Survey Paper on Path Navigation Systems

Saeeda E Varawalla[1] and Mrs Sonali Bhutad[2]

[1,2]Department of Computer Engineering, Shah and Anchor Kutchhi Engineering College, Mumbai

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***Corresponding Address:**
saeeda.16771@sakec.ac.in

ABSTRACT

An automotive navigation system is a technological tool that is either built directly into a vehicle or can be added later as an aftermarket product from a third-party manufacturer. It is used to help drivers locate directions and navigate to their intended destinations. Typically, an automotive navigation system acquires its position data from a satellite navigation system, such as GPS (Global Positioning System). This data is then connected to a position on a route, which allows the system to determine the best possible route to reach the driver's intended destination. Routing is a critical function of the navigation system, as it determines the most efficient and safest way to reach the desired destination. However, road conditions and traffic congestion can change rapidly, making the initially recommended route unsafe or impractical. To address this issue, the system needs to be able to adjust the route in real-time based on current traffic conditions and road closures. The primary focus of this paper is to explore the existing navigation systems and identify their drawbacks related to accident prevention. By analyzing these systems, we can develop additional features that could potentially help prevent accidents. One of the main issues with current navigation systems is their limited ability to provide real-time information about potential hazards or accidents on the road. This means that drivers may be unaware of dangerous road conditions, such as road closures, heavy traffic, or accidents, until it is too late to avoid them. To address this issue, we propose adding a feature to the navigation system that provides real-time information about road conditions and potential hazards. This feature could be powered by data from sensors installed on the vehicle or data collected from other sources, such as weather and traffic reports. By alerting drivers to potential hazards and providing them with alternative routes, we can help prevent accidents and improve overall safety on the road. In conclusion, this paper aims to explore the existing navigation systems and identify their drawbacks related to accident prevention. By analyzing these systems and proposing additional features, we can help prevent accidents and improve overall safety on the road. By integrating real-time information about road conditions into the navigation system, we can make driving safer for everyone.

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INTRODUCTION

The discipline of navigation focuses on how to monitor and manage a vehicle's travel from one location to another. Finding the navigator's position in relation to known locations is a fundamental component of all navigational systems. In a more general sense, navigation can refer to any knowledge or skill that involves figuring out one's location and direction. Automotive navigation systems are critical for the advancement of self-driving vehicles. However, the earliest documented use of navigation in a vehicle dates back to 1961, when it was created specifically for military applications. Since then, car navigation systems have advanced significantly. Maps, landmarks, and more recently computer navigation (often known as "satnav," short for satellite navigation), as well as any methods available on water, are commonly used for car navigation and other land-based travel. Computerized navigation frequently employs GPS to determine its present location, a database of usable highways, and algorithms related to the shortest path problem to find the best routes. The majority of contemporary navigation is

based on positions that are electronically established by receivers that get data from satellites. The phrase "Global Navigation Satellite System" (GNSS) refers to satellite navigation systems that offer global positioning. Using time signals delivered along a line of sight by radio from satellites, a GNSS enables small electronic receivers to identify their location (longitude, latitude, and altitude) within a few metres. As a point of reference for scientific research, receivers on the ground in a fixed position can also be used to determine the precise time. More than 20 GPS satellites are in medium Earth orbit, sending signals that enable GPS receivers to locate, track, and steer themselves. For people who own them, modern smart phones and navigational aids serve as personal GPS navigators.

Path Navigation Systems

Key Features of Path Navigation Systems

1. Accuracy -The accuracy of a path navigation system is a critical factor. It determines how well the system can locate the device and provide accurate directions.
2. Speed- The speed at which the path navigation system can provide directions is also an essential factor. It determines how quickly the user can navigate through the environment.
3. Reliability- The reliability of the path navigation system is critical. It determines how well the system can function in adverse conditions, such as poor weather or interference from other devices.
4. Cost- The cost of the path navigation system is another important factor. It determines how accessible the system is to users.

Need for Navigation Systems

A navigation system can perform a variety of tasks related to monitoring and managing a vehicle's travel from one location to another. Some of the key abilities of a navigation system are:

- Determine position: A navigation system can determine a vehicle's position relative to known locations, such as landmarks or other geographic features.
- Provide directions: A navigation system can provide directions and guidance to the driver on the best route to take to reach a destination. This can include turn-by-turn instructions, information on traffic conditions, and estimated arrival times.
- Adjust routes: A navigation system can adjust the chosen route based on real-time information, such as traffic congestion, accidents, or road closures, to ensure the driver is taking the most efficient route.
- Provide alerts: A navigation system can provide alerts to the driver for various road hazards, such as speed cameras, potholes, or construction zones, to help ensure a safe and smooth journey.
- Provide information: A navigation system can provide additional information related to the trip, such as estimated fuel consumption, distance travelled, and expected arrival time.
- Indoor navigation: Navigation systems can also be used to navigate through large buildings, such as airports, shopping malls, and hospitals.
- Obstacle detection: Advanced navigation systems can utilize GPS, sensors, and IoT for obstacle detection and assessment of road conditions in real-time, providing drivers with real-time information on road hazards, allowing drivers to make informed decisions regarding their path and speed, thereby significantly reducing the risk of accidents caused by poor road conditions or other hazards.

Road navigation applications can be created for GNSS-enabled mobile devices, standalone personal navigation devices, or in-vehicle navigation systems. These programs frequently rely on local databases and maps, although on occasion web services that provide database updates, extra dynamic data (like traffic information), or even specific navigational features help them out. Despite not requiring it, these road navigation devices can nonetheless gain internet access in order to get real-time traffic information that the routing algorithms can use. The device may use Bluetooth to connect to the driver's phone or it may directly access the internet (particularly in the case of applications running on mobile phones).

The process normally followed by these applications is:

- By specifying a destination, the user configures the application. There might be limitations on the way you can get there (e.g. use of tolled road).
- The programme determines the optimal route in accordance with the user configuration and restrictions using street and road maps (vectorial maps).
- The application will use audible and visual cues to instruct the driver turn by turn.
- The application will recalculate the route if the user deviates from the advised route.
- A point-of-interest (POI) database with information on hotels, restaurants, petrol stations, and other landmarks is typically included in these apps.
- The pedestrian navigation offered by these apps is typically limited to street and road sidewalks (and typically excludes public transportation, pedestrian walkways, and indoor navigation).

These applications typically offer 2 routing algorithms:

- Fastest Route: Calculates the fastest route from source to destination depending on the speed categorization of the streets and roads.
- Shortest Route: Calculates the shortest route from source to destination.

These applications usually provide 2 road views modes:

- 2D Map View: The 2D view of the map is the one from above. Depending on the movement's direction, the map rotates (up corresponds to forward).
- 3D Bird's Eye: A simulated 3D perspective of the map is taken from above the road, pointing in the direction of the movement.

Indoor Navigation Systems

Indoor navigation systems are designed to help people navigate within indoor environments, such as buildings or public transportation systems. Due to the weak GPS signals indoors and the rise in navigation needs, particularly in confined spaces like parking garages and large complexes of buildings, indoor navigation systems have become increasingly popular. There are already several indoor navigation systems in use. Each of them is built on a unique technology that adheres to the particular conditions and limitations of the environment it is intended to navigate

in. We presume that any solution has both functional and technical constraints. The majority of solutions have constrained abilities, poor accuracy, inconsistent reliability, complex designs, lax security, and significant configuration costs. Similar to GPS, indoor positioning techniques pinpoint a device's location indoors. IPS cannot rely on satellites, as GPS does. Satellite waves are ineffective indoors because they are blocked by walls and roofs.

IPSs have to rely on a different set of technologies. These include:

- Wi-Fi: Indoor navigation can use Wi-Fi access points to determine a user's location. Wi-Fi signals are transmitted and received by smartphones and other devices, and the strength and location of the signals can be used to estimate a user's location.
- Bluetooth: Bluetooth beacons are small wireless devices that can be placed throughout indoor environments to help determine a user's location. Bluetooth signals can be used to estimate a user's position in the environment and provide directions.
- Inertial measurement units (IMUs): IMUs are devices that can measure the orientation, acceleration, and rotation of an object. In indoor navigation, IMUs can be used to track a user's movement and estimate their location.
- Magnetic fields: Some indoor navigation systems use the Earth's magnetic field to determine a user's location. Magnetic field sensors can be used to detect changes in the magnetic field caused by walls, obstacles, or other features in the environment.
- Computer vision: Computer vision technology can be used to identify and track visual features in an indoor environment, such as landmarks or objects. This information can be used to determine a user's location and provide directions.

Overall, indoor navigation systems use a combination of these and other technologies to provide accurate location information and help users navigate within complex indoor environments.

Existing Outdoor Path Navigation Systems

A few existing Outdoor Path Navigation Systems are listed below along with their pros and cons. This gives us a good view of what the existing systems are lacking and the enhancements that can be included in these systems.

Google Maps

Google Maps is one of the most popular path navigation systems, with millions of users worldwide. Here are some of the pros and cons of Google Maps:

Pros:

- Comprehensive maps: Google Maps provides comprehensive maps of the world, including street maps, satellite imagery, and 360-degree panoramic views of various locations. This makes it easy for users to get a clear understanding of their surroundings and find the best route to their destination.
- Accurate directions: Google Maps provides accurate directions based on real-time traffic data, helping drivers to avoid traffic jams and find the fastest route to their destination. The app also provides information on public transportation options, such as bus and subway schedules.
- Easy to use interface: Google Maps has a user-friendly interface, making it easy for users to enter their destination and get directions. The app also provides voice-guided turn-by-turn directions, which helps drivers keep their eyes on the road.
- Integration with other Google services: Google Maps is integrated with other Google services, such as Google Search and Google Assistant. This makes it easy for users to find places of interest and get recommendations based on their search history.
- It offers automatic rerouting due to traffic, accidents, or other road circumstances and real-time ETAs based on traffic conditions.

Cons:

- Dependence on internet connection: Google Maps requires a strong internet connection to function properly. This can be a problem in areas with poor connectivity or when traveling abroad, where users may incur expensive roaming charges.
- Battery drain: Using Google Maps for an extended period of time can drain a smartphone's battery quickly, which can be inconvenient for users who rely on their phone for other tasks.
- Inaccurate data: While Google Maps is generally accurate, there are instances where the app provides inaccurate data, such as incorrect directions or outdated information on businesses and landmarks.
- Data privacy concerns: Google Maps collects a significant amount of data on its users, including location data and search history. This has raised concerns about data privacy and the potential misuse of user data.

Waze

Waze is a popular navigation app that provides real-time traffic and road information. Here are some of the pros and cons of Waze:

Pros:

- Real-time traffic updates: Waze provides real-time traffic updates, helping drivers avoid traffic jams and find the fastest route to their destination.
- User-generated content: Waze allows users to report accidents, road closures, and other hazards, which can be seen by other users in real-time. This user-generated content makes the app more accurate and useful.
- Community-driven: Waze has a strong community of users who contribute to the app's accuracy by providing real-time information on traffic and road conditions. This creates a sense of community and helps users feel connected to other drivers.
- Fun and engaging: Waze has a fun and engaging interface, with features such as voice navigation and customizable avatars that make the app more enjoyable to use.

Cons:

- Dependence on internet connection: Waze, like Google Maps, requires a strong internet connection to function properly. This can be a problem in areas with poor connectivity or when traveling abroad, where users may incur expensive roaming charges.
- Battery drain: Using Waze for an extended period of time can drain a smartphone's battery quickly, which can be inconvenient for users who rely on their phone for other tasks.

- Inaccurate data: While Waze is generally accurate, there are instances where the app provides inaccurate data, such as incorrect directions or outdated information on businesses and landmarks.
- Distraction while driving: Waze's real-time updates and user-generated content can be distracting while driving, as users may be tempted to check their phone while on the road. This can be a safety concern and may contribute to accidents on the road.

MAPS.ME

Maps.me is a solid option for those who want a simple and user-friendly offline navigation app, but it may not be the best choice for those who need more advanced features or high accuracy.

Here are some of its pros and cons:

Pros:

- Offline navigation: Maps.me allows users to download maps for offline use, making it a great option for travelers who may not have reliable internet access.
- Detailed maps: The app offers highly detailed maps, including footpaths and cycle routes, and can be used for navigation in remote or rural areas.
- User-friendly interface: The app is easy to use and offers simple navigation features, making it a good option for those who want a straightforward navigation experience.
- Search functionality: Maps.me has a search function that can be used to find specific places, such as restaurants or tourist attractions, making it a useful tool for travelers.

Cons:

- Limited features: Compared to other navigation apps, Maps.me offers fewer features, such as real-time traffic updates and route optimization based on traffic conditions.
- Limited social interaction: The app does not offer social features, such as the ability to see and interact with other users, which may be a drawback for some users.
- Limited customization: The app does not offer a lot of customization options, such as the ability to adjust the color scheme or interface layout, which may be a drawback for some users.
- Limited accuracy: The accuracy of the maps and navigation features may not be as high as some other apps, which could result in incorrect routing or difficulty finding certain locations.

Copilot GPS Navigation

CoPilot GPS Navigation is a popular navigation app that offers a range of features for both Android and iOS devices. Here are some of its pros and cons:

Pros:

- Advanced route planning: CoPilot offers a range of route planning options, including the ability to plan multi-stop trips, avoid toll roads, and find the most fuel-efficient routes.
- High accuracy: The app uses high-quality maps and real-time traffic data to offer accurate and up-to-date navigation.
- User-friendly interface: The app has a clear and easy-to-use interface that makes it simple to navigate and use while driving.
- Offline navigation: CoPilot allows users to download maps and use the app offline, making it a good option for those who travel to areas without reliable internet access.

Cons:

- Limited free features: Although the app offers a free trial, many of its advanced features require a paid subscription.
- Limited customization: The app does not offer a lot of customization options, such as the ability to adjust the color scheme or interface layout.
- Limited social interaction: The app does not offer social features, such as the ability to see and interact with other users.
- Limited maps: While the app offers a range of maps, including detailed street maps and topographical maps, some users may find that it doesn't offer maps for all areas.

Tomtom Go Navigation

TomTom GO Navigation is a popular navigation app that offers turn-by-turn directions, real-time traffic updates, and the ability to download maps for offline use.

Here are some pros and cons of using TomTom GO Navigation:

Pros:

- User-friendly interface: TomTom GO Navigation is easy to use, with simple menus and clear directions.
- Offline maps: Maps can be downloaded and stored for offline use, making it possible to navigate even when there is no cellular or Wi-Fi connection.
- Real-time traffic updates: The app provides real-time traffic updates, helping drivers avoid congestion and delays.
- Speed camera warnings: The app warns drivers when they are approaching speed cameras, helping them avoid costly fines.
- Points of interest: TomTom GO Navigation provides information on nearby points of interest, such as restaurants, gas stations, and attractions.

Cons:

- Price: TomTom GO Navigation is not a free app, and users must pay a subscription fee to access certain features.
- Limited voice commands: Unlike some other navigation apps, TomTom GO Navigation does not support extensive voice commands, which can be inconvenient for some users.
- Navigation issues: Some users have reported issues with the app's navigation, including inaccurate directions and slow response times.
- Battery drain: Using the app for an extended period of time can drain the battery of the user's device quickly, which can be a problem for long trips or when there is no access to a power source.

Obstacle Detection

The current path navigation systems do a commendable job of providing users with the most efficient route from their starting point to their destination, taking into account factors such as traffic conditions and roadblocks. However, there is a need for additional features to be integrated into these systems to improve road safety.

One such feature could be the ability to detect obstacles or assess road conditions in real-time. In India, road safety is a major concern due to the high number of fatalities that occur on a daily basis as a result of problematic roads and road hazards. This issue has become even more important with the introduction of Automated Vehicles (AVs),

2.5 Literature Survey:

Topic	Author	Year of Publication	Publication	Technology used	Description
A route navigation system with a new revised shortest path routing algorithm and its performance evaluation	W. Wen & S. W. Hsu	2005	WIT Press	GPS + Traffic Information Server	This paper [22] proposes a modified algorithm for a route navigation system that can tackle challenges such as one-way roads, no left (or right) turns, and traffic congestion on road networks. The performance of the modified algorithm was evaluated using a prototype system called Route. As a result of the study, a navigation system called RNS was developed and tested. The physical demonstration of the system architecture showed its effectiveness in addressing road congestion and providing faster responses. The final findings of the performance analysis revealed that the RNS not only offers an effective solution to road congestion but also responds considerably faster.
Artificial Intelligence in GPS Navigation Systems	Jeffrey L. Duffany	2010	IEEE	GPS + AI	The focus of this paper [6] is on an AI-based enhancement for the existing GPS Navigation System (GNS) that utilizes actual GPS location, date, and time information to determine the optimal route. The paper highlights that the distance between two locations is not the only factor affecting travel time, but other factors such as traffic, traffic signals, individual driving styles, weather, day of the week, and season can also impact it. The proposed method involves breaking down the completed journey into route segments and analyzing the time taken to travel each segment using interpolation and extrapolation. This enables the creation of a more precise model for feature extraction, which is more accurate than the default data.
Autonomous Rover Navigation Using GPS Based Path Planning	Abul Al Arabi, Hasib Ul Sakib, Pranabesh Sarkar, Tanjina Piash Proma, Jahedul Anowar, M Ashraful Amin	2017	IEEE	GPS + PID control algorithm	This paper [1] proposes the development of a navigation system for the Space rover that solely relies on GPS coordinates that is a simple, cost-effective, and uncomplicated process. The system uses the GPS coordinates of target spots, which are provided to the rover by a control station. The rover creates a route between its current location and the intended destination by capturing its own GPS signal. Then, it calculates the deviation from its current route, direction, and position. To correct any errors or deviations, the system employs the PID control loop feedback mechanism.
Design and Implementation of Vehicle Navigation System in Urban Environments using Internet of Things (Iot)	Bhavana Godavarthi, Paparao Nalajala, Vasavi Ganapuram	2017	ICMAEM - IOP Publishing	GPS+IOT	The paper [10] suggests an instantaneous monitoring and tracking system for cars, which periodically transmits updated real-time vehicle data to the server to facilitate continuous monitoring. The system uses GPS to determine the vehicle's current location, GPRS to transfer tracking information to the server, and GSM to send alert messages to the car owner's mobile device.
Interactive Voice & IOT Based Route Navigation System For Visually Impaired People Using Lifi	Gowtham S U, Gokulamanikandan M, Pavithran P, Gopinath K	2017	International Journal of Scientific Research in Computer Science, Engineering and Information Technology	LIFI+IOT	An indoor navigation system for the visually impaired that uses LiFi and is based on voice commands has been proposed in this paper [11]. Additionally, an indoor visible light positioning system has been developed that accounts for multipath reflections in a standard room, with an ultrasonic sensor identifying obstacles.
IoT Platform Based Smart Parking Navigation System with Shortest Route and Anti-Collision	Dae-hyun Kim, Sung-hyun Park, Seungwoon Lee, Byeong-hee Roh	2018	IEEE	IOT	The aim of this paper [4] is to suggest a smart parking system based on the IoT platform to tackle the issue of parking shortages and reduce the frequency of intersection accidents in parking lots. The proposed system employs ultrasonic sensors placed in each parking space to determine occupancy and locate available spots. To guide users to an available parking space, real-time indoor location recognition using Bluetooth Beacon and NFC reader is feasible.

Research on the In-Vehicle Routing and Navigation System (IRANS) Field Test based on Big Data	Liu Yan	2019	IEEE	GPS/GPRS	The proposed content of this paper [16] includes the framework of IRANS as well as its primary methodology. IRANS, or Intelligent Road Assistance and Navigation Systems, offer traffic updates and guidance to help drivers navigate from one location to another. With the aid of IRANS, drivers can be directed away from traffic congestion and accidents, leading to shorter travel times and improved efficiency in road transportation.
IoT enabled Navigation System for the Blind	Nirmal A Kumar, Yazin Haris Thangal, Sunitha Beevi. K	2019	IEEE	IOT	This paper [18] proposes a wearable device designed for blind individuals to navigate indoor and outdoor environments with 90% accuracy. The aim is to provide a cost-effective, user-friendly device for visually impaired individuals. The device utilizes a Raspberry Pi camera to detect obstacles and an ultrasonic sensor to measure distance. Text-to-speech conversion is built into the Raspberry Pi to provide audio guidance in the form of spoken signals, and the final audio output, including obstacle distance, is transmitted through headphones. This project can be worn as a wearable device or integrated into a cane for the convenience of the user.
Personalized Route Navigation System: Utilizing Available Static and Live Data for Preference-Based Recommendation	Alec A. Souders, Mohammad S. Almalag, Christopher Kreider	2021	IEEE	Tom Tom Developer API and GraphHopper Directions API	This paper [21] aimed to develop a personalized route navigation algorithm that considers individual preferences while utilizing relevant data from previous studies, without the need for external hardware or sensors. This is because current route guidance systems often lack the ability to factor in user-specific information.

which have increased the demand for higher safety requirements. This is especially relevant in a country like India, where even paved roads can be in poor condition. Therefore, the integration of additional safety features into existing navigation systems is necessary to enhance their reliability and improve road safety for all users.
The following section shows a literature survey of pothole detection systems.

Proposed Architecture

Real-time alerts about road conditions are crucial for improving road safety, and one potential solution is to integrate an application into the current path navigation system that provides advance notice of road conditions. This could involve using a sensor to detect road hazards, and then using machine learning algorithms to process the signal and deliver an appropriate alert to the user.

One type of sensor that could be used is a camera, which can be placed on the vehicle to capture images of the road ahead. These images can then be analyzed using machine learning algorithms to detect road hazards such as potholes, debris, and other obstacles. The algorithms can be trained to identify specific patterns in the images that indicate a potential hazard, such as changes in colour or texture, and then generate an alert that is sent to the driver.

Once the sensor has detected a hazard, the machine learning algorithms can then generate an appropriate alert to the user. For example, if the hazard is a pothole, the alert could include a message that says "Pothole ahead, slow down," and provide the driver with an option to choose an alternative route or slow down.

To ensure that the system is effective, it is important that the machine learning algorithms are accurate and reliable. This requires training the algorithms on a large dataset of road hazard images or signals to help the system recognize patterns and identify hazards accurately. The algorithms also need to be constantly updated and improved as new hazards emerge on the road.

In conclusion, an integrated application that provides real-time alerts about road hazards is a promising solution for improving road safety. By using sensors and machine learning algorithms to detect hazards and generate alerts, drivers can be warned in advance and make safer decisions on the road.

Conclusion

The importance of improving current navigation systems to account for deteriorating road conditions and unforeseen obstacles cannot be overstated. Navigation systems that only rely on GPS data may not be able to accurately predict road conditions, as they cannot take into account the dynamic and unpredictable nature of the road. This is where sensor-based systems and IoT technologies come in.

Research papers have proposed using sensors to detect obstacles, potholes, and other road conditions that may pose a risk to drivers. These systems use data collected from sensors on the vehicle, such as cameras or accelerometers, to detect road conditions in real-time. Additionally, IoT technologies can be used to collect data from various sources, such as weather reports and traffic data, to provide a more comprehensive view of road conditions.

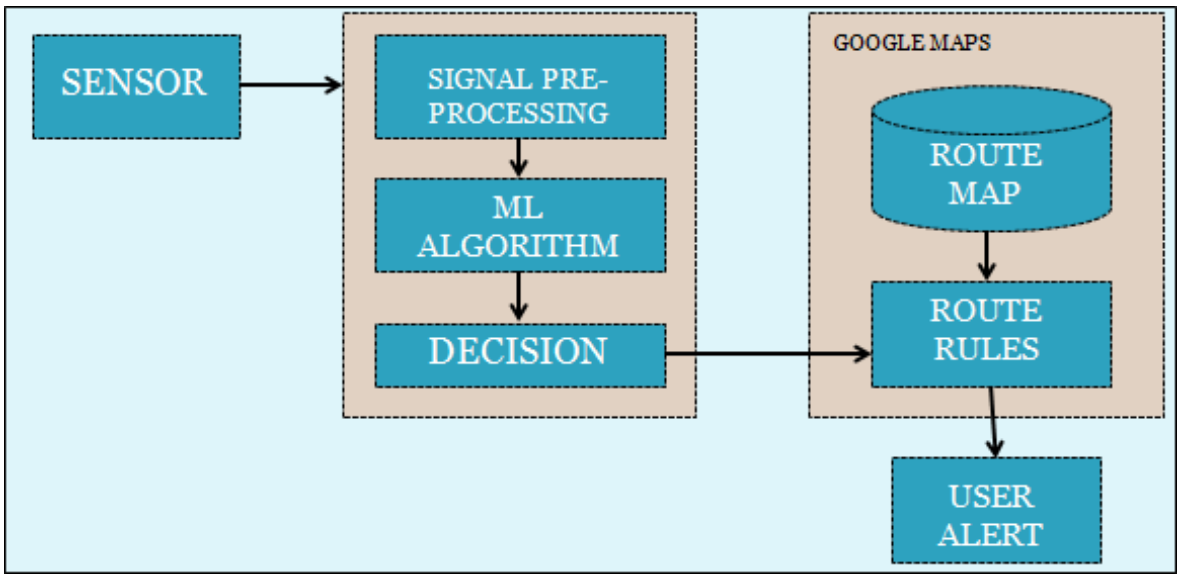
By combining these systems, an advanced navigation system could be developed that takes into account additional factors while navigating a route. For example, the system could alert drivers to potholes or other obstacles in their path, and provide alternative routes to avoid these hazards.

However, some research papers have proposed systems for pothole detection that do not provide real-time data. These systems rely on government officials to repair potholes that are reported through the proposed system. This approach may not be effective in preventing accidents caused by poor road conditions, as it does not provide drivers with advance warning of the road conditions they are driving on.

3.1 Literature Survey:

Topic	Author	Year of Publication	Publication	Technology used	Description
Path Hole Detection to Assist the Visually Impaired People in Navigation	Md. Milon Islam and Muhammad Sheikh Sadi	2018	IEEE	CNN	The purpose of this paper [14] is to introduce a path hole detection system that employs a Convolution Neural Network (CNN) to identify path holes on the road surface. The system can be particularly beneficial for visually impaired individuals as it allows them to avoid stumbling into a hole while walking. The CNN model was trained and evaluated using two benchmark datasets, namely KITTI ROAD and Pothole detection, for 20 and 30 epochs, and performance metrics such as accuracy, precision, and recall were calculated for both training and testing phases. The results indicate that the CNN-based path hole detection system achieves high accuracy.
Cost Effective Surface Disruption Detection System for Paved and Unpaved Roads	Mumbere Muyisa Forrest , Zhigang Chen, Shahzad Hassan, Ian Osolo Raymond and Karim Alinani	2018	IEEE Access	Ultrasonic Sensors	This paper [8] proposes an innovative and inexpensive approach to identifying Road Surface Disruptions (RSD) using ultrasonic sensors. The proposed model utilizes distance measurements obtained from ultrasonic sensors to estimate potholes and bumps on surfaces, and generates a 2D map of the road's condition. The ultrasonic sensor beam collects distance measurements between the RSD scanning device and the road, which are then fed into the algorithm for RSD detection. The method is intended to detect RSDs, including potholes, on both paved and unpaved roads, which have distinct and diverse requirements.
Deep Learning Based Pothole Detection and Reporting System	Ganesh Babu, Chellaswamy C, Surya Bhupal Rao M, Saravanan M, Kanchana E, Shalini J	Nov-20	IEEE	CNN-DL	This paper [2] presents a highway pothole detection and information system using the CNN-DL algorithm. To compare signals, two sensors (accelerometer and ultrasonic sensor) are mounted on a vehicle, and the algorithm decides whether a pothole has been detected and, if so, records its location. The control room will be notified with an alert, and necessary action will be taken based on the collected pothole information on highways.
Vision-Based Deep Learning Algorithm for Detecting Potholes	K Gajjar, T van Niekerk, Thomas Wilm and P Mercorelli	2021	IOP Publishing	Faster R-CNN, SSD and YOLOv3	This paper [9] aims to determine the most appropriate deep learning algorithm for identifying potholes while driving, determining their GPS location, displaying them on a map as a pin, and sending the data to a cloud server for storage and sharing. While Faster R-CNN had higher accuracy and precision, YOLOv3 was considered the most suitable for real-time application due to its lowest average detection time per image.
A Real-time Pothole Detection Based on Deep Learning Approach	Anas Al-Shaghouri, Rami Alkhatib, Samir Berjaoui	2021	ISAIC 2020 Journal of Physics: Conference Series	SSD, YOLOv3, YOLOv4	The method proposed in this paper [20] has several potential benefits, including aiding in the reporting of road potholes to government agencies, increasing driver safety by detecting potholes in advance, and improving the performance of self-driving cars to ensure safe trips for passengers. The YOLOv4 object detector architecture was found to be robust, capable of functioning in real-world conditions and processing data quickly. With the proposed pothole detection system, potholes can be detected from a distance of up to 100 meters, helping drivers avoid them.
Pothole Detection under Diverse Conditions using Object Detection Models	Syed Ibrahim Hassan , Dympna O'Sullivan and Susan Mckeever	Jan-21	SCITEPRESS – Science and Technology Publications	Faster RCNN	The purpose of this paper [12] is to suggest a technique for the automated detection of potholes in images that also accounts for real-world scenarios that may occur during pavement assessment. The study aimed to identify factors that could affect the development of a comprehensive model for pothole detection, such as image size, camera type, lighting conditions, and camera distance. The findings indicate that the distance between the camera and the pothole is a crucial factor in creating a generalized model for pothole detection.

A Smart App for Pothole Detection Using Yolo Model	Rajeshirkar Hiremath, Komal Malshikare, Manish Mahajan, Radhika V. Kulkarni	Jan-21	Research Gate / Springer	YOLO and Google Maps API	This paper [13] presents a method that uses a smartphone application to help citizens and the civic body to identify the condition of road surfaces. The app is user-friendly and straightforward, allowing the user to take photos of potholes and upload them. The application can detect potholes and display their locations. Google Maps API is integrated into the system, and the YOLO algorithm is used to identify potholes in the image uploaded by the user.
Enhanced pothole detection system using YOLOX algorithm	Mohan Prakash and Sriharipriya K.	31-Aug-22	Springer	YOLO, YOLOX	The objective of this paper [15] was to evaluate the effectiveness of the YOLOX model for pothole detection. The model was trained using a dataset of pothole images and the performance was assessed by calculating accuracy, recall, and model size. The results were then compared to other YOLO algorithms. The findings indicated that the YOLOX nano model was highly suitable for pothole detection due to its small size, which makes it easy to deploy with minimal storage and power consumption. Furthermore, the model showed high precision compared to other models.
Artificial Intelligence Powered Pothole Detection, Reporting and Management Solution	Aditya Prakash Devrukhkar, Aditya Anand Dethe, Sugamkumar Patel, Swapnil Fulkant Londhe	April – 2022	International Journal of Innovative Science and Research Technology (IJISRT)	YOLOv2 and Google Maps API	The aim of this paper [5] is to assess the effectiveness of modern neural network algorithms, namely YOLO and Faster R-CNN with VGG16 and ResNet-18 architectures, in quickly and accurately identifying potholes. Additionally, an updated version of YOLOv2 is proposed to address the class imbalance issue between "pothole" and "regular road" categories. The performance of this updated model is compared to existing object recognition algorithms, taking into account metrics such as accuracy, recall, intersection over union, and frames processed per second (FPS). The proposed model can be utilized for real-time geotagged pothole recognition from images, particularly in autonomous vehicles.
CNN-Based Object Recognition and Tracking System to Assist Visually Impaired People	Fahad Ashiq, Muhammad Asif, Maaz Bin Ahmad, Sadia Zafar, Khalid Masood, Toqeer Mahmood, Muhammad Tariq Mahmood And Ik Hyun Lee	January 31, 2022, date of current version February 10, 2022	IEEE Access	CNN based MobileNet for object detection	The system proposed in this paper [7] includes a digital signal processing (DSP) board with GSM and GPS modules, a camera, headphones, and a live video feed. The DSP board captures the video feed and sends it to the object detection and recognition module, which is based on a CNN model. The model identifies objects in the video frame and communicates their names to the text-to-speech converter (SAPI) module, which pronounces them through the headphones. Additionally, the system offers an on-demand function for users to share their location with family members.



To address this issue, a real-time data collection and reporting system could be developed that allows drivers to report road conditions as they encounter them. This system could be integrated into the navigation system, providing drivers with real-time information on road conditions while they are driving. By giving drivers advance warning of potential hazards and allowing them to make informed decisions regarding their path and speed, the risk of accidents caused by poor road conditions or other hazards can be significantly reduced.

In conclusion, an advanced navigation system that utilizes sensor-based systems and IoT technologies can significantly improve road safety by providing drivers with real-time information on road conditions and potential hazards. However, it is crucial that these systems provide real-time data to drivers, rather than relying on government officials to repair reported potholes. By combining these systems and providing real-time data to drivers, an advanced navigation system can help prevent accidents and improve overall road safety.

REFERENCES

Al Arabi, H Ul Sakib, P Sarkar, TP Proma, J Anowar and MA Amin, 2017. "Autonomous Rover Navigation Using GPS Based Path Planning," 2017 Asia Modelling Symposium (AMS), Kota Kinabalu, Malaysia, 2017, pp. 89-94, doi: 10.1109/AMS.2017.22.

Chellaiah C, M Surya, M Saravanan, E Kanchana, S Jayaraman, 2020. Deep Learning Based Pothole Detection and Reporting System.

Coronel Eduardo Pojomovsky, Alexis, G Federico, 2015. Reliable navigation-path extraction system for an autonomous mobile vehicle. 175-181. 10.1109/ICDIM. 2015.7381882.

Kim DH, SH Park, S Lee and BH Roh, 2018. "IoT Platform Based Smart Parking Navigation System with Shortest Route and Anti-Collision," 2018 18th International Symposium on Communications and Information Technologies (ISCIT), Bangkok, Thailand, 2018, pp. 433-437, doi: 10.1109/ ISCIT.2018.8587957.

Devrukhkar AP and S Patel, 2022. Artificial Intelligence Powered Pothole Detection, Reporting and Management Solution.

Duffany JL, 2010. "Artificial intelligence in GPS navigation systems." 2010 2nd International Conference on Software Technology and Engineering 1 (2010): V1-382- V1-387.

Ashiq F et al., 2022. "CNN-Based Object Recognition and Tracking System to Assist Visually Impaired People," in IEEE Access, vol. 10, pp. 14819-14834, 2022, doi: 10.1109/ACCESS.2022.3148036.

Forrest MM, Z Chen, S Hassan, IO Raymond, K Alinani, 2018. Cost effective surface disruption detection system for paved and unpaved roads. IEEE Access, 6, 48634-48644.

Gajjar K, T Van Niekerk, T Wilm, P Mercorelli, 2022. Vision-based deep learning algorithm for detecting potholes. In Journal of Physics: Conference Series (Vol. 2162, No. 1, p. 012019). IOP Publishing.

Godavarthi B, N Paparao and G Vasavi, 2017. Design and Implementation of Vehicle Navigation System in Urban Environments using Internet of Things (Iot). IOP Conference Series: Materials Science and Engineering. 225. 012262. 10.1088/1757-899X/225/1/012262.

Gowtham SU, M Gokulamanikandan, P Pavithran and K Gopinath, 2017. Interactive Voice & IOT Based Route Navigation System For Visually Impaired People Using Lifi. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 2(2).

Hassan SI, D O'Sullivan and S Mckeever, 2021. Pothole Detection under Diverse Conditions using Object Detection Models. IMPROVE, 1, 128-136.

Hiremath R, K Malshikare, M Mahajan and RV Kulkarni, 2021. A Smart App for Pothole Detection Using Yolo Model. In ICT Analysis and Applications: Proceedings of ICT4SD 2020, Volume 2 (pp. 155-164). Springer Singapore.

Islam MD and M Sadi, 2018. Path Hole Detection to Assist the Visually Impaired People in Navigation. 10.1109/CEEICT. 2018.8628134.

KC S, 2022. Enhanced pothole detection system using YOLOX algorithm. Autonomous Intelligent Systems, 2(1), 22.

Liu Y, 2019. "Research on the In-Vehicle Routing and Navigation System Field Test based on Big Data," 2019 4th International Conference on Cloud Computing and Internet of Things (CCIOT), Changchun, China, 2019, pp. 48-52, doi: 10.1109/CCIOT48581.2019.8980311.

Lazarowska A and A Żak, 2022. Real-time path planning for Autonomous Navigation Systems of Unmanned Surface Vehicles. In 2022 26th International Conference on Methods and Models in Automation and Robotics (MMAR) (pp. 408-413). IEEE.

Nirmal AK, YH Thangal and KS Beevi, 2019. "IoT Enabled Navigation System for Blind," 2019 IEEE R10 Humanitarian Technology Conference (R10-HTC)(47129), Depok, West Java, Indonesia, 2019, pp. 186-189, doi: 10.1109/R10- HTC47129.2019.9042483.

Rezwan Sifat and Choi Wooyeol, 2022. Artificial Intelligence Approaches for UAV Navigation: Recent Advances and Future Challenges. IEEE Access. 10. 26320-26339. 10.1109/ACCESS.2022.3157626.

Shaghouri AA, R Alkhatib and S Berjaoui, 2021. Real-time pothole detection using deep learning. arXiv preprint arXiv:2107.06356.

Souders AA, MS Almalag and C Kreider, 2021. Personalized Route Navigation System: Utilizing Available Static and Live Data for Preference-Based Recommendation. In 2021 IEEE Global Conference on Artificial Intelligence and Internet of Things (GCAIoT) (pp. 62-68). IEEE.

Wen W and SW Hsu, 2005. A route navigation system with a new revised shortest path routing algorithm and its performance evaluation. *WIT Transactions on The Built Environment, 77*.

Zantalis F, G Koulouras, S Karabetsos, D Kandris, A Review of Machine Learning and IoT in Smart Transportation. Future Internet 2019, 11, 94. https://doi.org/10.3390/fi11040094