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REVIEW ARTICLE

A Review of Perception-Based Navigation System for Autonomous Mobile Robots

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Abstract: Perception-based navigation systems have become more popular in robotic applications such as autonomous moving vehicles in hospitals, logistics, packing and forwarding, mines, military, defense, consumer robots, building surveillance, rescuing and carrying a child or physically challenged people, and so on, due to the need, advanced development, and large influence. To improve positioning, localization, and path planning on obstacle-free trajectories, several navigation designs have been developed. In this study, we attempt to analyze various navigation methods and technologies applied by mobile robots in various applications. On paths without obstacles, a number of navigation designs have been created to enhance positioning, localization, and path planning. An overview of many navigation technologies is given in this article. The paper focuses on Measurand-based navigation of mobile robot applications in a diverse environment by taking into account previous research works. Additionally, there is a comparison of technologies, methodologies, applications, algorithms for error reduction, and different kinds of perception systems, in addition to metrics like accuracy and usability. This limited study focuses on the integration of an antenna with an IMU-based navigation system that is suited for all environments, as well as some future trends to detect to aid in the profound-implication of navigation system enhancement in robotic applications.

Keywords: Measurand navigation, environment positioning system, perception systems, antenna, mobile robot, autonomous vehicles.

1. INTRODUCTION

Localization is more crucial in order to rely on a mobile robot application that will display the robot's initial position, the target's location, and any impediments in its way. Autonomous navigation for mobile robots was invented in the 1960s. This classification introduced a number of different control methods. There are two types of robot navigation architecture: hierarchical architecture and behavior-based architecture [1]. When designing the hierarchical architecture, only known and static conditions were taken into account. Dynamic condition behavior-based systems have been proposed to overcome constraints such as an uncertain environment. One of the most difficult aspects of studying mobile robotics is navigating unfamiliar areas. Perception (sensors), location, cognition, and course planning and execution are the primary categories. To get to the destination, the Robotic performs environmental sensing, dynamic decision making, and path planning, among other tasks. An IMU and four ultrasonic sensors are used to predict disturbances, and a Kalman filter is used to calculate the trajectory course. In this study, sonar sensors, which help us locate impediments in a dynamic environment, were used to determine the best sensor for accurate robot location. In factory robot technology, a discrete sensor, such as a camera, was introduced in the 1980s to recognize item position and line identification. Later, in the interior navigation system, magnetic tape-based position sensors were used to determine precise position. Furthermore, in indoor mobile robot navigation, the wireless sensors predicted the system's precise geographical location. Because of the implementation of these wireless sensors, the sensor cost was reduced by eliminating the high-cost cable system, and the interior dynamic condition inaccuracy was reduced when compared to standard navigating robot systems. One of the most important techniques for locating adjacent goods in both indoor and outdoor environments was map-based path prediction. For exact placement, visual inertial SLAM-based techniques were used [2]. Bio-inspired motion-based sensing and vision techniques were used in the past to determine the position and distance between the start and end points. To locate and identify the robot, a vision system with IMU was developed using bio-inspired sensors [3]. A few proprioceptive sensors, such as optical odometer sensors and IMU sensors, were used to place the obstacles. Cameras, laser sensors, and Lidar sensors are expensive, but they provide angular and range measurements in navigation. A visual inertial odometry sensor with non-linear optimization was used to improve navigation accuracy. The location of the robot was determined using a GPS-DR GPS-based system probabilistic localization technique, although signals

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are reflected and faulty geometry produces inaccuracies of more than 20 meters in dense environments like cities and forests, making it unsuitable for robot navigation [4]. A differential GPS with numerous positional sensors was fused and marketed as a navigation system to overcome these constraints and increase navigation accuracy. For the accurate location, the MEMS-based inertial sensor system (GPS+ gyro sensor + two accelerometers) calculates pitch and roll angle. A hybrid indoor navigation system was created by combining high-sensitivity GPS with positioning sensors such as inertial sensors, magnetometers, ultrasonic sensors, Doppler radars, and image sensors. In transportation, even vehicle license plate localization is possible [5]. Indoor localization of data, and error prediction are performed using various algorithm techniques (PLA- EKF localization, Monte Carlo localization), (SLAM- EKF slam, FAST SLAM, Rao-Blackwell Zed Particle Filter (RBPF), Graph SLAM). The algorithm must be correctly programmed in order to find the best method for a given situation while also dealing with unexpected environment. The collection of data both indoors and outdoors, as well as the prediction and elimination of errors, is a difficult challenge. Based on the findings of the research, the paper recommends a navigation system and its benefits.

2. ROBOT NAVIGATION SYSTEM

Robot navigation includes a wider spectrum of cutting-edge technologies and commercial uses. The three types of mobile robot navigation are personal navigation, local navigation, and global navigation [5]. Robot navigation can be divided into two categories: environment-based navigation and measurement-based navigation. Environment-based navigation systems come in two different varieties: indoor and outdoor. There are various different kinds of measurement-based navigation systems, including position-based navigation, velocity-based navigation, acceleration-based navigation, range-based navigation, and vision-based navigation. In this work, the environmental conditions and constraints are employed to distinguish Measurand-based navigation systems. The Robot navigation is more difficult to maintain in busy areas or heavily populated urban areas [3]. In mobile robots, the linear kinematic based navigation system has made the robot reach the goal using basic linear navigation laws stated as (Eq. 1):

$$\theta_r = M\varphi_{gr} + C_1 + C_0 e^{-at} \quad (1)$$

Where the line-of-sight angle of the final goal destination, and variables are the unconventionality terms describing the final preferred orientation angle of the robot and indicating the initial orientation of the robot. This term is a navigational parameter, and the specified positive gain is represented by t [6]. The ultimate objective of mobile robot navigation is to anticipate current location, avoid obstacles on a pre-defined path, and travel the shortest distance to a destination [7]. Robotic navigation integrates a number of technologies, opening the door for the development of measurand-based technology in both outdoor and indoor settings. Currently, applications including transportation, logistics, and industry use self-driving vehicles more frequently. In the transportation sector, communicating amongst vehicles is a challenging task. To prevent collisions when travelling to the customer's location, the route plan is first developed and then compared to a global map by the vehicle [8]. By utilising navigational solutions that are formally known as measurement-based navigation systems, such as location, orientation, grid mapping, and vision mapping, the complexity of this challenging task may be lessened. Fig. (**1**) depicts the robot navigation system's (RNS) technical classification. The navigation system is the brains of mobile robots, but choosing the best technique for a given application or situation can be challenging.

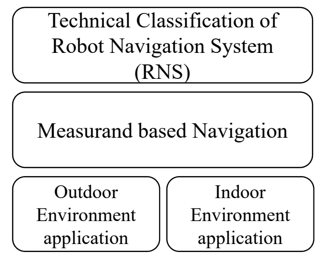

Fig. (1). Technical classification of RNS.

2.1. Outdoor Navigation System

The movement of vehicles, people, animals, and other species, among others, is predicted using navigation. The human navigation involves measuring the distance between the starting and the destination distance (x) and orientation (θ) in every change in dynamic point dx/dt and dθ/dt. Navigation is the identification of movement along a predetermined path from the starting point to the destination. The study topic in the mobile robotics application has been the evolution and expansion of outside localization and navigation [9]. The journey from single point contact in the inception was navigated in large part thanks to cognitive mapping [10]. It is probable that cognitive mapping alone won't be sufficient to determine the path; additional information, such as position, orientation, and geographic location information, paired with a user interface, will be necessary to guide the user precisely [11]. With the help of a satellite-based navigation system and Wi-Fi connectivity, mobile phones are now frequently used to determine the system's external position [12]. The lack of Wi-Fi and other infrastructure improvements in building construction has caused satellite signals to be disrupted at the receiving end, resulting in a localization error that occurs while attempting to determine the present position [13]. In the 2000s, navigation applications like those for military and defence vehicles were revolutionised by the celestial navigation system, which makes use of satellite signals like GPS, LORAX, and GLONASS [13-15]. For navigation, many apps combine GPS-GLONASS and GPS-LORAX-C signals [16]. Precise localisation was made possible by these navigation systems working with various location sensors. To increase accuracy in outdoor navigation systems, GPS and GLONASS are frequently combined with radio frequency sensors, magnetic sensors, inertial positioning sensors, ultrasonic sensors, visual positioning sensors, beacons, and mapping tools like LIDAR [17]. The development of a 360-degree lidar technique allows the robot to be positioned even when it deviates from its initial position by scanning the environment and converting 2D data into 3D data [18]. The user's dynamic location and orientation are appropriately established using a variety of sensors once the current position is first determined using GPS satellite location [19, 20]. With the advent of Lidar and IMU-based navigation systems, GPS and GNSS-based navigation systems in autonomous ground vehicles could be effectively replaced [21, 22]. A Vision-based SLAM navigation system could take the place of any mobile robot or vehicle that has to go through a tunnel, dense forest, or areas without GPS [23]. A modified positioning system has to be developed for outdoor navigation because GPS with encoder-based odometry was often employed for mobile robot state prediction [24]. The choice of a dead reckoning system with GPS improves the accuracy of detecting the wheel mobile robot at many point changes by taking current data status into account [25, 26]. IMU and GPS are sometimes combined in applications to precisely locate mobile robots [27]. Even in the absence of GPS and GNSS signals, the RFID-based localization solution for micro devices and robots based on signal strength and connection techniques still functions. The receiver picks up signals based on mobility and the periodic beacons act as an intermediate point along the preset itinerary. The spacing between two nodes affects localization accuracy [28]. The sequential and progressive data relating to position and navigation of the system were measured in an autonomous land vehicle using a combination of GPS, stereo vision-based system, and IMU [29]. Numerous applications, including Google Car, military applications, surveillance applications, and logistic applications, have made extensive use of low-cost GPS for outdoor navigation in mobile robots [30]. The usage of the Xbox 360 Kinect sensor to replace the costly Lidar mapping and navigation sensor for road mapping is an application for autonomous vehicles [31]. Numerous studies have demonstrated that indoor navigation systems are less sensitive than outdoor navigation systems when using GPS-based location. The direct line of sight between the GPS satellite and the receiver is weak in dynamic conditions, but in other experiments, GPS with a very sensitive receiver was used for indoor localization [32, 33]. According to the researchers, one drawback of GPS and other UWB-based localization systems is that they are not always dependable and helpful. Establishing an alternate RF-based localization approach is necessary in semi-outdoor and GPS-risky situations.

2.2. Indoor Navigation System

Indoor positioning and navigation systems for mobile robotics and vehicles, like outside navigation systems, have gained a lot of interest. The outdoor navigation system for mobile robots and autonomous vehicles used the differential GPS system globally [34]. On the other hand, the drawbacks of using GPS in an inside system led to the creation of new technologies and indoor locating systems. Perception-based positioning systems are used to assess distance, velocity, angle, and range of tracking the robot's present position, as shown in Fig. (**2**). A wired conventional sensor and a controller that allowed moving robots to turn right or left originally made up the internal navigation system. Different applications have been created in the existing environment. Without GPS, navigating an area is challenging and time-consuming.

2.2.1. Position Based Navigation

The position and orientation of a mobile robot or vehicle based on kinematic order depend on the identification of the trip point. The mobile robot prefers data from odometers and encoders, infrared sensors, sonar, and ultrasonic sensors for position-based navigation. The accuracy of IR-based location sensors degrades with increasing distance. Therefore, combining IR with other technologies may enhance prediction [35]. The hyperbolic trilateration approach is used by the IR-based mobile robot to calculate the differential distance between the previous positions. The mobile robot's position is verified by these sensors, and its location is ascertained by comparing that position to a specified value [36]. The local position sensor system is further separated into frequency-based perception systems, mechanical, magnetic, acoustic, optical, and mechanical components. The ultrasonic sensors were widely used to locate the obstacle over the path and further control to avoid the obstacle to reach the target [37].

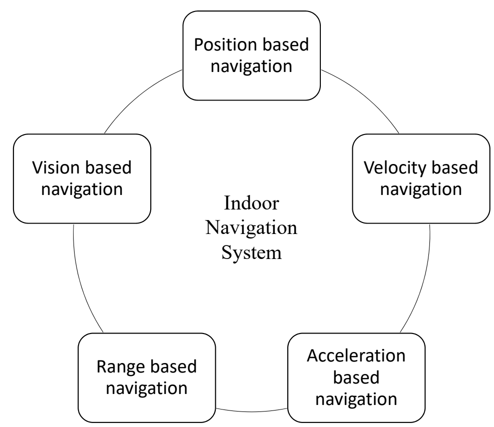

Fig. (2). Indoor navigation system classification**.**

Obstacles are located using a portable ultrasonic beacon-based location sensor in interior applications. When ultrasonic sensors are used alone, issues like blind spots (an illusion that occurs when barriers and ultrasonic sensors are at an angle) can arise [38]. Sonar rings are used to detect the borders of walls in order to better predict the environment. Most often now, moving robots employ broadband ultrasonic sensors to measure their positions. These kinds of broadband systems are used in robot navigation to get over the narrow band transducer restrictions [39]. Ultrasonic sensors can be used to determine the local position of the robot under dynamic conditions as well [22]. The introduction of triangulation or trilateration method is precise to find the orientation and positioning of robot in non-GPS environment.

2.2.2. Velocity and Acceleration Based Navigation System

The velocity-based navigation technology is involved to determine the proprioceptive signals like travelling object velocity, displacement change heading to the orientation relate with velocity vector parameters [40]. These kinds of navigation could be installed in mobile robot using Dead reckoning system. The dead reckoning system was initially emerged as a replacement of a GPS based navigation system which has poor accuracy in the indoor system [41]. The dead reckoning is defined as determination of current position from the estimated path segment of previous position without aid estimated data [42]. The dead reckoning system was more popular in mobile robots as it identifies the robot location with minimal error compared with the position sensor system. The dead reckoning system comprises of various sensors based on application like gyro sensor with a differential encoder to reduce encoder error and gyro error on the positioning system [43]. The inertial measuring unit (IMU) [44] was so popular integration of multiple sensors dead reckoning system. Generally, the IMU consist of minimum tri axis gyro sensor, Tri axial accelerometer and at least dual axial magnetic sensor. The integrated inertial platform evaluates and estimates the position and orientation of mobile robots in industrial application. Further Inertial Navigation Sensor (INS) [45] encompassed accelerometer and gyro sensor for measurement of altitude and position from previous data. But the stability of the system was poor as a major limitation in many robotic applications. Using many error reduction algorithms along with INS systems was broadly used in the robotic field. The INS system not only measured the altitude, but also calculated the angular velocity of the robot using a low-cost inertial system of two accelerometers and three gyro sensors. These paved a way for development of strapped down inertial positioning sensor (SINS), commonly known as IMU system [46]. The Integration of Inertial sensor data with vision sensor data might improve the robotic system stability and accuracy [47, 48].

2.2.3. Range Based Navigation System

In an interior navigation system for autonomous mobile robots, range-based localization is increasingly used in the robotics sector. The range-based system employs wireless measuring technologies as well as methods for identifying the position of the robot. A few navigational strategies include Received Signal Strength Indicator (RSSI), Time of Arrival (TOA), Time Difference of Arrival (TDOA), and Angle of Arrival (AOA) [49]. The Received Signal Strength Indication (RSSI) is based on the measurement of known signal strength, a comparison of the transmitted and received signal strengths from (RSSI), and a calculation of the actual signal loss between the transmitter and receiver to determine the user's actual position using distance loss data across RSSI. To put it another way, RSSI measures the strength of the signal that is received to calculate the distance and determine the user's location using the distance information, as stated in Eq. (2). The shadow issue and various signals picked up in the surroundings made signal-based position estimation inaccurate [50], however, RFID technology is used in mobile robot applications as high precision RSSI tags for interior navigation. In this autonomous mobile robot application, the robot accurately navigates between two sites as indicated below [51] by sensing the list of tags.

$$\{RSI_{tagid} | RSI_{tagid} S \in [0,1]; where\ i \in [1,n]\} \quad (2)$$

The number of ID tags present in the indoor environment, n, is given where I is an integer. The IR beacon-based location method was quite popular for indoor robot navigation, much like RFID [52]. In hospitals, cargo applications, and other industries, the interior positioning system of mobile robots became more practical and efficient with the addition of 3IR sensors and RFID cards [53]. Robotic navigation approaches are improved by WLAN's location identification approach, which is extremely accurate in both static and dynamic conditions. Depending on the system status (static or running), the WLAN indoor positioning accuracy ranges from 2m to 5m [54]. To improve higher accuracy than Wi-Fi based navigation system, the Robotic indoor navigation system chooses FM based RSSI position of the user in predefined environment. When compared to Wi-Fi-based navigation, accuracy levels may rise by as much as 83% [55]. A Bluetooth navigation system is preferred for position tracking of robots at a low cost [56]. The angle of Arrival, depending on node signal, can determine the robot's direction of travel while receiving data from a neighboring node. This forecasts the robot's movement along the planned route. The triangulation approach is used by the AOA to estimate the robot's bearing from its neighbor's reference position [57]. AOA triangulation, a wireless sensor network-based localization and dead reckoning technology are used to navigate the robot's path. Robots were used in coal mining applications for surveillance and monitoring, and the WSN with Zigbee communication system predicted their location and orientation [58]. In robotic applications, the Kinect sensors use image processing and other IMU-based sensor fusion technology to direct the robot's location. In some applications where precision is not carefully measured, the depth of the obstacle can be predicted. The XBOX 360 Kinect technology is utilised for depth image measurement in low-level indoor applications [59-61].

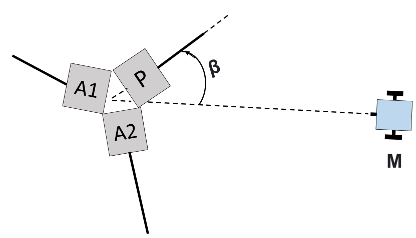

Fig. (3). Angle of Arrival (AOA). (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

As illustrated in Fig. (**3**), the Time of Arrival (TOA) or Time of Flight (TOF) primarily concentrates on the distance between two points across the aim and destination. The time it takes for the transmitter to receive a signal from sensors connected to the robot and the reference point along the predetermined path is referred to as the TOA [9]. As with AOA, which was designed for angle-based navigation, mobile robot inside applications frequently utilised distance-based navigation. Time of flight (TOF) is used in front and rear parking systems to determine the distance between the car and the parking space utilising piezo ceramic material, such as in a BMW [62]. TOF is related to distance measurement with a transmitter to deliver signals. A new wireless navigation revolution in robotic and autonomous vehicle applications is created by the combination of ultra-wide band and WSN location sensors with finger print localisation.

Table 1. Indoor navigation comparison.

References	Application	Vision Position Sensors	Strategy	Error Reduction Algorithm
[1]	Indoor industrial application	Kinet + 1 RGB camera+2 IR CMOS camera	Steering control and stabilization of robot in 3D Euclidean space	Extended Kalman Filter (EKF)
[81]	Museum guided robot: MINERVA	Camera + Laser	Localization based on occupancy & texture mapping	Markov Localization algorithm
[82]	Indoor mobile robot	Ceiling pin hole camera	Track the image velocity of robot	Jacobian matrix-based image processing algorithm
[83]	Indoor obstacle avoidance	Single camera vision system	Navigation and obstacle avoidance in the test environment	PSOBA +HASBA
[84]	Multi mobile robot localization	Pixy camera (cmu cam 5) +RF transceiver	Landmark based on color codes.	---
[85]	Mobile robot localization and spacecraft	RGB-D + Lidar	Robust localization at one tracker fail condition	KF + Visual tracking algorithm
[86]	Indoor localization robot	Webcam	Locate the tracked robot using IBDMS & PLDMS	Low pass filter +Online background updating method
[2]	Home cleaning robot	Low-cost camera	Performance robustness in consumer robots	EKF + SLAM algorithm
[87]	Leader-Follower indoor robots	Single pin hole camera + GVPS	Adaptive vision-based control robot	Lyapunov method
[88, 89]	Indoor robotic system	Stereo camera	Error reduction in Indoor navigation	EKF
[11]	Robot environment mapping	Two stereo cameras	Indoor & outdoor mapping	Markov graph-SLAM
[90]	Obstacle and landmark prediction	Set of Camera	Error minimization and improved accuracy	Triangulation algorithm
[45]	Human robot collaboration	Depth camera + Kinect sensor	Collision avoidance and positioning	Active collision avoidance

Due to the fact that the precision is not precisely mentioned in the tunnel navigation application, [63-65] the Wi-Fi sensors and other sensors were combined to find the robot in the suitable range point in a mine rescue robot within tunnel application based on TOA technique [66, 67] in order to increase accuracy inside the tunnel application. The TOA-based approaches, however, have a greater NLOS signal error, making the system less accurate and more complex [68]. Using laser beacons, a secure laser-based localization of robot positions and obstacle positions was achieved in an industrial setting [69]. To reduce this complexity many localization algorithm schemes were introduced like Fingerprint localization, iterative minimal residual (IMR), Modified mean filter, various Kalman filters, particle filter, Markova approach and so on [70, 71] (Eqs. 3 and 4).

$$\Delta x = v\Delta t \tag{3}$$

$|\nabla \mathrm{T}| = v$, which states

$$v_{i1,j1} = \begin{cases} N^{\|x_{i1j1}-x_{i2,j2}\|} & for\ x_{i1,j1} \in F, x_{i2,j2} \in 0 \\ 1 & otherwise \end{cases} \tag{4}$$

The relative position of the robot is determined by the time difference between the propagation of the transmitter and receiver signals in the TDOA distance position localization system, which is similar to TOA [9]. To precisely synchronize the time between the target and intermediate places, the time difference between the communication signal's travels must be measured [51]. A more precise LED-based positioning system was created using TDOA for indoor robotic localization applications [72]. When multiple robot localization and synchronization are required, TDOA is widely employed in UAV applications. In the field of precision and error reduction in the interior navigation system, approaches and technology had their own advantages, as indicated in Table **1**.

3. VISION/MAP NAVIGATION SYSTEM

Range based localization system cannot calculate its self-position *i.e.*, it cannot recognize the landmark position of the robot when it is lost the intermediate position point, [73]. To avoid these limitations, mapping and vision-based navigation are introduced in robotic applications. A discrete sensor like the camera was introduced in 1980’s to identify the object position, line identification in robot technology in factories. The image is provided a large amount of reference data than the normal navigation using other positioning systems. The vision-based system is applicable for both outdoor and indoor robotic navigation environments [74]. In outdoor navigation, the vision sensors were used to detect the

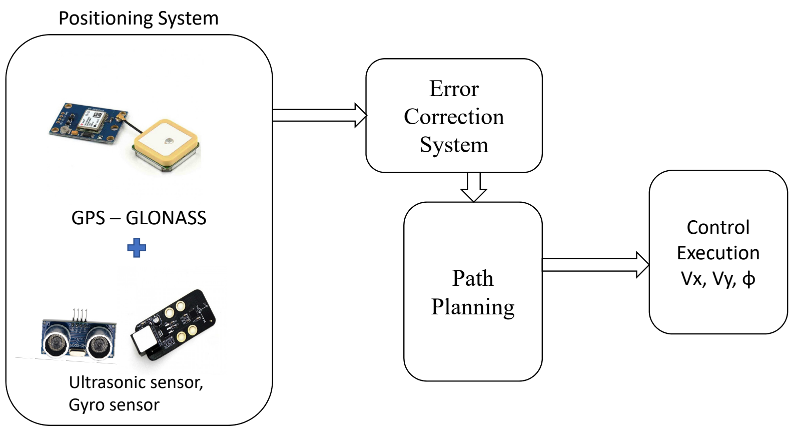

Fig. (4). Navigation system for indoor and outdoor AGV in logistic applications [80]. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

Table 2. Vision based position survey results.

References	Technology (Indoor)	Positioning Techniques	Application	Range of Accuracy	Position Algorithm
[57]	WSN	AOA	Urban area localization of robot	Few meter distance range	Triangulation
[62, 63]	UWB based WSN	TOA	Mine application vehicles	Few meter position accuracy	Finger Print Localization
[63]	UWB + Optical	TDOA	Indoor Logistic	range accuracy about 30cm.	Two ways Ranging
[64, 65]	WiFi	TOA	Mine rescue robot	2.4m position accuracy in tunnel	Finger Print Localization
[62]	IR & WiFi	RSSI	Mobile robot path tracking	Few meters distance range	Hyperbolic trilateration
[41]	IR Beacons	RSSI	Indoor obstacle avoidance	Few mm distance accuracy	Triangulation
[13]	FM	RSSI	Indoor navigation system	higher accuracy than WiFi	Wireless finger print
[49]	RF-ID	RSSI tags	Autonomous mobile robot application	0.5mm distance range	Trilateration
[55]	RIPS	AOA	Tracking mobile robot	Position accuracy 0.9m.	Triangulation
[56]	Bluetooth	RSSI	Indoor localization	Position accuracy 2.5m	Triangulation
[67]	Security Laser	TOA	Indoor industry application	Few meters accuracy	Contour mapping
[70]	Optical LED's	TDOA	Indoor robot positioning	Error reduction less than 1cm	---
[58, 59]	Kinect sensor	AOA	Obstacle avoidance	Accuracy range over 20m.	Gaussian motion model

landmark to locate the robot's initial position and orientation and reach the destination by locating the path coordinate value acquired from differential GPS system. The single, double and Omni directional camera was used to track the landmark and follow the path to reach the goal [75]. Ultimately the video d recorded and motion processing to avoid obstacles and identify the landmark and so on [76], [77]. The vision-based perception provides rescuing and identifying people inside a coal mine with a single camera and IR sensors for positioning and localization purposes in underground mobile robots [78]. TV camera based optical sensor with image processing technique was used on the vehicle in front obstacles. Camera based vision sensors are advanced technology in robot navigation and perception in the industrial environment [79, 80].

An autonomous wheelchair was developed by camera and ultrasonic range finder for identifying the path, but the current localization was not happening in this work, consider only to locate the obstacle to avoid while carrying humans. An RGB camera-based image is used to predict the obstacle and helps the robot to localize an obstacle and trouble-free path. Even cameras are fitted along with the GPS module to enable the robot's indoor navigation system through global positioning. Computer vision sensing with edge detecting image processing techniques improve the accuracy of the positioning system in robotic obstacle avoidance application [81]. Most of the industrial applications were converted into values and map the environment in 2D or 3D to localize the system. The vision system was chosen to reduce conversion error and acquire more data from the environment with less

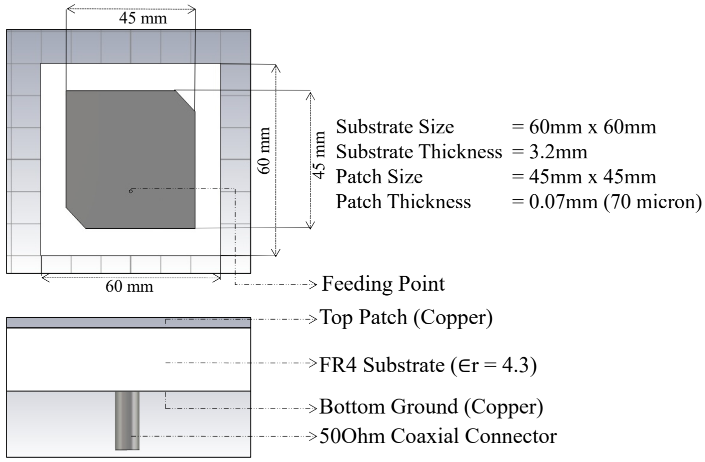

Fig. (5). Antenna design for AGV vehicle navigation [80]. (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

temporal lag and better modal accuracy in real time navigation of AV's [91].

4. DISCUSSION AND SOLUTIONS

The position-based localization technology is developed to improve the accuracy of localizing mobile robot. In such conditions, the technology change may increase the cost and complexity in controlling the system. Table **1** represents the indoor navigation approach using various error reduction algorithms and their applications. Based on many studies, the Kalman filter techniques blended with other techniques used to reduce the error in measured values from the perception system and error correctness happened to plan the trajectories more accurately and effectively. Among the numerous outdoor navigation options, combining GPS and GLONASS frequency range measuring systems will be able to cover larger coordinates with at least two satellites in line of sight. The triangulation method of transmitter and receiver control technique with Stanley and PID controller is more exact for an indoor approach. The navigation system for combining the indoor and outdoor scenario was explained in Fig. (**4**).

The error prediction and correctness algorithms applied in vision-based mobile robots are shown in Table **2**. From the study, a separate navigation system was followed in AGV vehicles. The best solution for this AGV navigation, especially in Logistics applications, and the antenna design were shown in Fig. (**5**) [80]. To solve this issue, the introduction of GPS and GLONASS integrated navigation system along with IMU will help the multi-tasking robot to navigate the positions and plan its path. Additionally, the proper sensor selection and the transfer of data collected are essential for the security of a mobile robot.

CONCLUSION

A thorough review of perception-based navigation systems for mobile robots and AGV vehicles in both indoor and outdoor contexts was covered in this study. The viewer was able to select the best approach and technology for the given challenges by considering the environment and application strategy, which were displayed in tabulations, thanks to the metric analysis of all the techniques. The researcher was able to identify the appropriate answer with great accuracy using a combination of multi-technique systems in a basic setting. Although the cost of implementation is fairly high, vision-based navigation and range-based navigation will be the primary techniques used in robotic applications of developing technology. Based on tabulated data, an analysis of the application environment for various metrics and evolving technologies, techniques, and algorithms was performed to give a wide range of navigation for mobile robot applications. One of the best options for a universal navigation system is the integration of GPS-GLONASS antenna-based navigation.

LIST OF ABBREVIATIONS

AOA	=	Angle of Arrival
EKF	=	Extended Kalman Filter
GPS	=	Global Positioning system
IMU	=	Inertial Measurement Unit
LIDAR	=	Light Detection and Ranging
RBPF	=	Rao-Blackwell Zed Particle Filter
RNS	=	Robot Navigation System's
RSSI	=	Received Signal Strength Indication
SLAM	=	Simultaneous Localization and Mapping
TDOA	=	Time Difference of Arrival
TOA	=	Time of Arrival
TOF	=	Time of Flight
UWB	=	Ultra-wide Band
WSN	=	Wireless Sensor Network

CONSENT FOR PUBLICATION

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The authors declare no conflict of interest, financial or otherwise.

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