Technoarete
e-ISSN: 2583-3472
Technoarete Transactions on Advances in Computer Applications
Vol-1, Issue-2, June 2022

Carrying Out Autonomous Navigation in Both Indoor and Outdoor Settings and Environments

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Abstract

Autonomous navigation in both indoor and outdoor settings and environments is a complex task that requires the development of sophisticated algorithms and technologies. This paper reviews the current state of the art in autonomous navigation, focusing on the difficulties and challenges associated with both indoor and outdoor navigation. We discuss the various approaches for implementing autonomous navigation, including the use of sensors, localization techniques, path-planning algorithms, and motion control systems. We also present a comparison of the different techniques and analyze their strengths and weaknesses. Finally, we discuss the potential applications of autonomous navigation in different scenarios.

Keywords

Autonomous navigation, Navigation Satellite Systems (GNSS), proportional-integral-derivative (PID), proportional-integral-derivative (PID).

INTRODUCTION

Autonomous navigation is the ability of a robot or vehicle to move around in an environment without any external guidance or control. Autonomous navigation can be used in both indoor and outdoor settings and environments. Autonomous navigation requires sensors, software, and hardware to guide the robot or vehicle through its environment. It also requires the ability to detect and avoid obstacles along the way.

In indoor settings, autonomous navigation is typically used for tasks such as cleaning, surveillance, and delivery. In outdoor settings, autonomous navigation is used for tasks such as autonomous driving, search and rescue, and military applications.

In both indoor and outdoor environments, autonomous navigation systems need to be able to accurately map the environment and generate a path to the goal. In outdoor settings, Global Navigation Satellite Systems (GNSS) are used to provide the robot or vehicle with a starting position and heading.

In indoor environments, autonomous navigation typically relies on vision-based navigation systems. These systems use cameras to detect obstacles, landmarks, and other features in the environment. The camera data is then used to generate a map of the environment, which is used to generate a path to the goal. In addition to vision-based navigation, sensors such as lidar, sonar, and infrared can also be used to detect obstacles in the environment.

Once a map of the environment is generated and a path to the goal is determined, the robot or vehicle needs to be able to execute the path. This is done using a variety of control algorithms, such as proportional-integral-derivative (PID) control and model predictive control (MPC). Finally, the robot or vehicle needs to be able to detect and avoid obstacles along the way. This is typically done using a combination of sensors, such as lidar, sonar, and infrared, and algorithms such as the Rapidly Exploring Random Trees (RRT) algorithm.

Overall, autonomous navigation is an important field of robotics and is used in a variety of applications. It requires a combination of sensors, software, and hardware to accurately map the environment, generate a path to the goal, and execute the path while avoiding obstacles.

AUTONOMOUS NAVIGATION IN INDOOR SETTINGS

Sensors

Autonomous navigation typically uses a variety of sensors, including GPS, cameras, laser scanners, and odometry. GPS is used for outdoor navigation, while cameras and laser scanners are used for indoor navigation [11]. Odometry is used for both indoor and outdoor navigation.

In addition, other sensors such as accelerometers, gyroscopes, and magnetometers are often used in combination with the above sensors to provide additional information about the environment. For example, accelerometers can help detect changes in elevation, while gyroscopes and magnetometers can help detect changes in orientation.

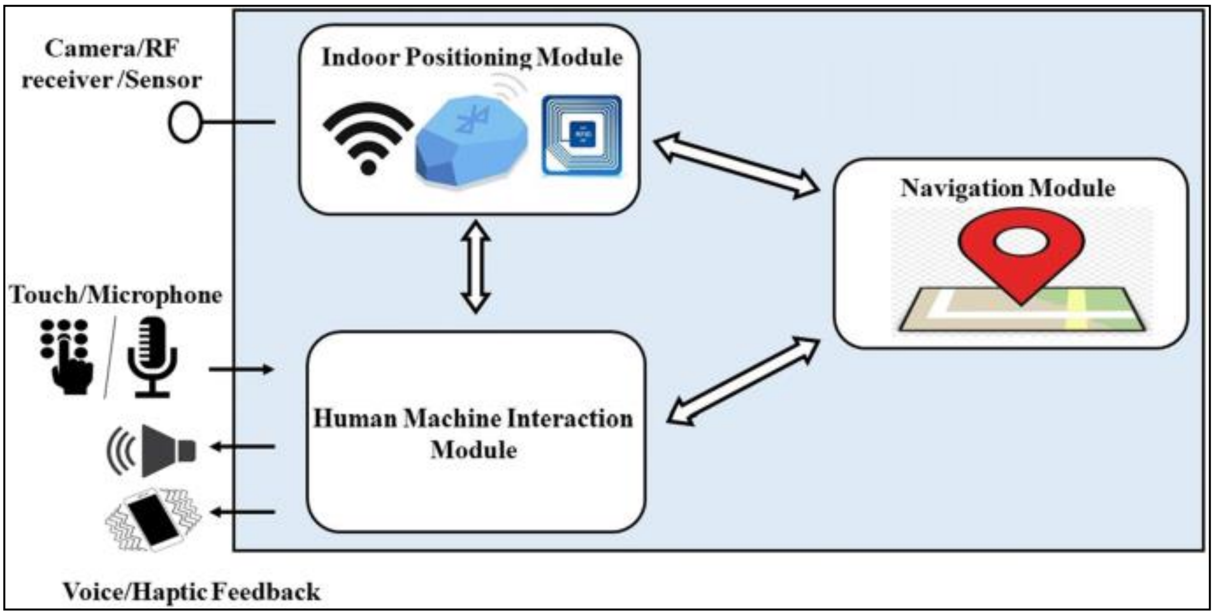

Figure 1: Indoor positioning Module
(Source: Shah, Dhruv, et al. 2021 [13])

Autonomous navigation in both indoor and outdoor settings and environments typically relies on a combination of sensors and computer vision algorithms. For example, a robot may use a variety of sensors, such as cameras, laser scanners, light detection and ranging (LIDAR), infrared, ultrasonic, and inertial measurement units (IMUs), depending on the type of environment it is navigating [13]. These sensors are used to detect obstacles and other features in the environment, and to map out the area in order to create a path for the robot to follow. Computer vision algorithms can then be used to analyze the data from the sensors and to identify and track objects and landmarks that the robot needs to avoid or approach.

Autonomous navigation in both indoor and outdoor settings and environments can be achieved using a variety of sensors such as cameras, lidar, ultrasonic, infrared, and GPS. Cameras are used to provide a visual representation of the environment, while lidar and ultrasonic sensors can detect obstacles and measure distances. Infrared sensors can be used to detect temperature and humidity, while GPS can be used to provide precise positioning information [15]. Additionally, inertial measurement units (IMUs) can be used to measure orientation and acceleration, providing further data for navigation.

Autonomous navigation in both indoor and outdoor settings and environments requires a variety of sensors. In indoor settings, sensors such as LIDAR, camera, and ultrasonic sensors can be used to detect obstacles and map the environment. For outdoor navigation, GPS, IMU, and camera sensors can be used to localize the robot and detect obstacles. Additionally, other sensors such as pressure, temperature, and wind speed can be used to provide additional environmental data for navigation.

Autonomous navigation in both indoor and outdoor settings and environments requires a variety of sensors to be effective. These sensors typically include laser scanners, cameras, GPS, inertial measurement units, and ultrasonic sensors [17]. Laser scanners are used to create a 3D map of the environment, enabling the robot to navigate around obstacles. Cameras help the robot detect its surroundings and can be used for object recognition. GPS is used to determine the robot's exact location and speed. Inertial measurement units measure the robot's acceleration and angular velocity, which helps the robot determine its current position and heading. Finally, ultrasonic sensors measure the distance to nearby objects and help the robot avoid obstacles.

Autonomous navigation in both indoor and outdoor settings and environments can be achieved through the use of a variety of sensors. For example, two of the most common sensors used in autonomous navigation are LIDAR (Light Detection and Ranging) and GPS (Global Positioning System). LIDAR is an active remote sensing technology that uses laser light pulses to create a 3D map of the environment, providing accurate real-time information about the surroundings and obstacles. GPS, on the other hand, is a passive remote sensing technology that relies on satellites to triangulate the position and orientation of a device, allowing it to determine its location in the world [19]. In addition, other sensors such as ultrasound, infrared, and cameras can be used to provide additional data about the environment.

Mapping

Autonomous navigation in both indoor and outdoor settings and environments requires a robust mapping system that can accurately capture the environment and its relevant features. This mapping system can include static objects such as walls, furniture, and other objects that may be present in the environment. It can also include dynamic objects, such as people and other moving entities [12]. Additionally, the mapping system should be able to accurately identify any obstacles, as well as any paths or trajectories that the robot can take. Once the mapping system has been established, the robot can use it to autonomously plan a route through the environment, avoiding any obstacles and taking the most efficient path possible.

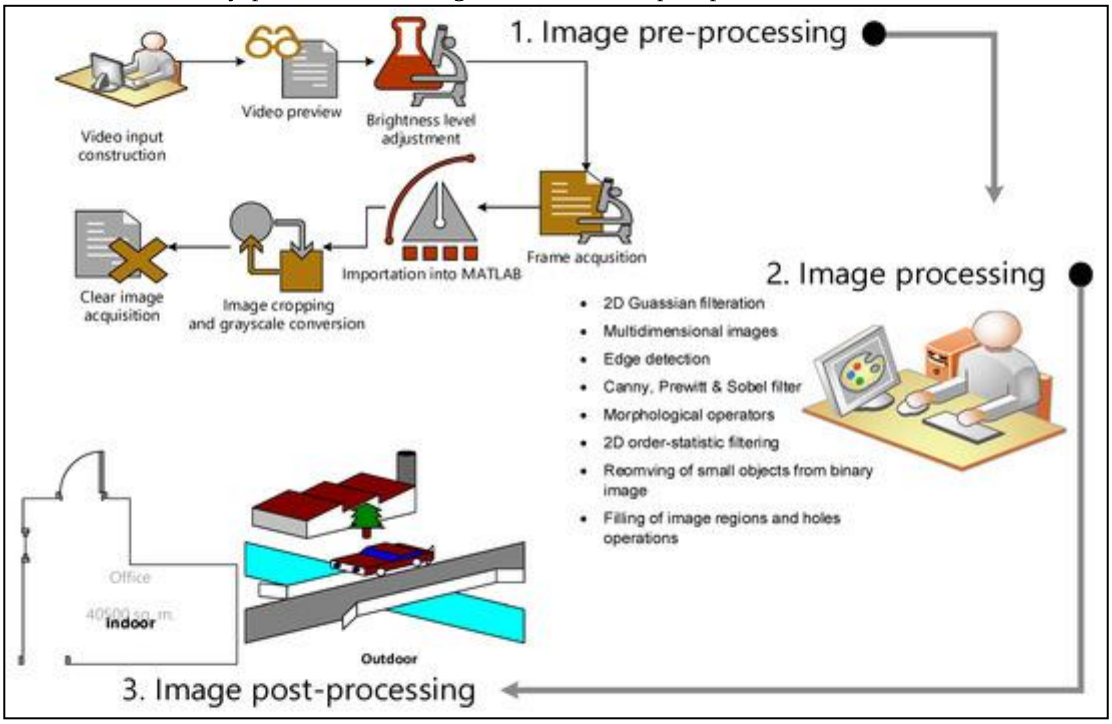

Figure 2: processing of image
Source: (Queralta et al. 2020 [16])

Autonomous navigation in both indoor and outdoor settings involves the use of mapping technology to create a map of the environment. This map is then used by the autonomous system to plan its path and respond to changing conditions. For outdoor navigation, advanced GPS systems can be used to generate a detailed map of the environment. For indoor navigation, a variety of sensors may be used to create a map of the environment, including cameras, laser rangefinders, and ultrasonic rangefinders. Once the map is generated, the autonomous system can use it to plan a path to its destination and detect and respond to any changes in the environment. Additionally, autonomous navigation systems may use artificial intelligence techniques to learn and refine their navigation capabilities over time.

Autonomous navigation in indoor and outdoor settings and environments requires the use of a range of different mapping techniques. These techniques include high-resolution 3D mapping, real-time localization, obstacle avoidance, and path planning. High-resolution 3D mapping is necessary to accurately map the environment and identify potential obstacles [16]. Real-time localization is used to determine the exact location of the autonomous vehicle at all times. Obstacle avoidance ensures the vehicle safely avoids any potential obstacles in its path. Finally, path planning is used to determine the most efficient route from the starting point to the goal. All of these techniques are essential for autonomous navigation to work effectively in any environment.

Autonomous navigation in both indoor and outdoor settings and environments requires the use of advanced mapping techniques [14]. These include the use of global positioning systems (GPS) to determine the location of the vehicle and other objects in the environment, as well as the use of lidar and other sensors to map the surrounding environment. Additionally, computer vision techniques are used for object and obstacle detection, allowing the vehicle to safely navigate around obstacles. Machine learning algorithms are also employed to continuously improve the accuracy and speed of the navigation system. Finally, control algorithms are used to determine the optimal path for the vehicle to take. All of these techniques are used together to allow autonomous vehicles to navigate both indoor and outdoor settings and environments.

Autonomous navigation in both indoor and outdoor settings and environments requires the use of mapping techniques. Mapping is the process of creating a virtual representation of a physical area or environment. This virtual representation can be in the form of a two-dimensional or three-dimensional map. The map is then used as a reference by autonomous agents such as robots or drones to navigate through the environment. To create a map, the environment must be scanned and recorded using sensors such as Lidar and cameras. The data from these sensors are then used to construct a virtual representation of the physical environment [18]. Once the map is created, the autonomous agents can use it to plan their route and navigate through the environment, avoiding obstacles and reaching their destination.

Autonomous navigation in both indoor and outdoor settings and environments involves a variety of technologies, such as map-making, route planning, and motion control. Map-making involves building a digital map of the environment, which can then be used to plan routes and decide the best way to move around. Route planning involves determining the best path to take between two points, based on the map. Motion control is used to direct the robot to move along the planned route while avoiding obstacles. All of these technologies work together to enable autonomous navigation in both indoor and outdoor settings and environments.

Path Planning

Autonomous navigation in indoor and outdoor settings and environments can be achieved through a variety of techniques, such as path planning and localization. Path planning is the process of finding a safe, efficient, and cost-effective route between two points [1]. Path planners use a variety of algorithms, such as graph search and probabilistic methods, to find the most efficient and cost-effective route. Localization is the process of determining the position of a robot within a given environment. This is typically done by using sensors like cameras or lasers to map out the environment and then using algorithms to determine the robot's position. Localization is important for autonomous navigation since it allows robots to understand their environment and plan their path around obstacles.

Autonomous navigation in both indoor and outdoor settings and environments involves the use of path planning algorithms. Path planning algorithms allow robots to navigate an unknown environment by finding the optimal path between two points. The algorithms take into account both static and dynamic obstacles, as well as the cost of motion and the robot's capabilities in order to determine the best path. Once the path is determined, the robot can use sensors such as cameras, laser rangefinders, and ultrasonic sensors to detect obstacles and adjust its course accordingly. Additionally, the robot can use AI techniques such as deep learning to build a map of the environment and help it navigate more efficiently.

Autonomous navigation in both indoor and outdoor settings and environments can be accomplished through path planning [2]. Path planning is the process of determining a path for an autonomous robot to take from its starting point to its desired goal. This process involves taking into account various environmental factors such as terrain, obstacles, and other objects. Path planning algorithms can be used to generate a path that is both safe and efficient. In addition, path planning algorithms can account for the robot's current state, such as its speed and battery life, to generate a path that is suitable for the robot's current conditions [3]. Path planning algorithms can be used in both indoor and outdoor environments, allowing robots to navigate autonomously in a variety of settings.

Path planning is a key part of autonomous navigation in both indoor and outdoor settings. Path planning involves using algorithms and data structures to determine the optimal path for a robot or vehicle to take from a starting point to a destination. Path planning can take into account environmental constraints such as obstacles and terrain, as well as the type of terrain and environment the robot or vehicle will be navigating. Path planning can also involve computing the shortest path from the starting point to the destination. Path planning algorithms are typically used in robotic navigation, but can also be applied to other types of autonomous navigation.

Autonomous navigation in both indoor and outdoor settings and environments can be achieved using various methods, such as path planning algorithms, obstacle avoidance, and visual navigation. Path planning algorithms typically use a graph search technique to find the shortest or optimal path between two points. These algorithms can also be used to identify obstacles in the environment and to determine the best route to take around them. Obstacle avoidance is a technique used to avoid collisions with obstacles in the environment. This is usually done using sensors such as LIDAR or cameras which detect the presence of obstacles and then the robot can adjust its path accordingly [5]. Visual navigation involves using images or video to detect landmarks or objects in the environment that can be used as reference points in order to navigate. This method is useful for navigating in unfamiliar environments where GPS signals are not available.

AUTONOMOUS NAVIGATION IN OUTDOOR SETTINGS

Sensors

Autonomous navigation in both indoor and outdoor settings requires a range of sensors to detect the environment and process data. These include:

- Cameras (stereo vision, infrared, and ultrasonic)
- Inertial Measurement Units (IMUs)
- GPS
- LiDAR
- Radar
- Ultrasonic sensors
- Sonar
- Compasses
- Odometry
- Magnetometers

Autonomous navigation in indoor and outdoor settings requires different types of sensors to provide the necessary information. For indoor navigation, sensors such as cameras, infrared, and ultrasonic sensors are used [4]. Outdoor sensors require a combination of GPS, inertial navigation systems, and/or laser scanners to provide reliable data. Additionally, other sensors such as pressure sensors, temperature sensors, and accelerometers can be used to collect data about the environment.

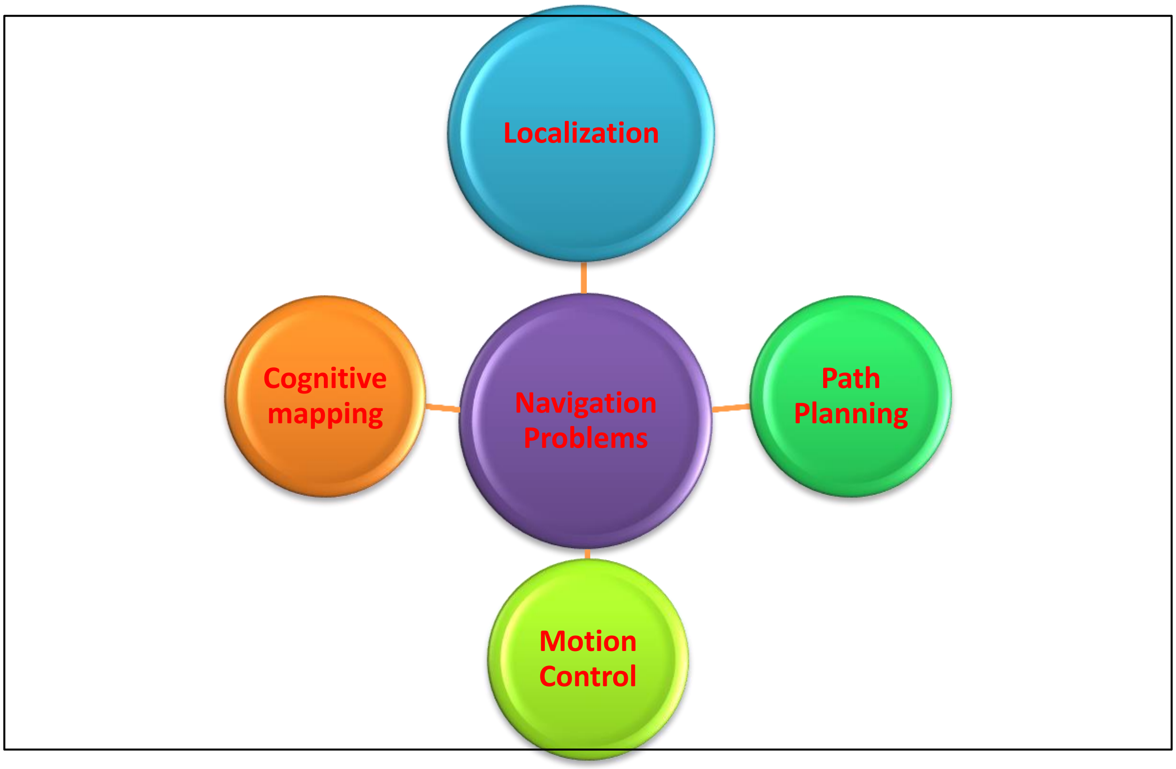

Figure 3: Different types of navigation problems
(Source: Guerreiro, João, et al. 2019.[10])

Autonomous navigation in both indoor and outdoor settings and environments can be achieved using a variety of sensors. For indoor navigation, sensors such as infrared sensors, laser rangefinders, ultrasonic sensors, and computer vision can be used to detect obstacles and create accurate maps of the environment [10]. For outdoor navigation, sensors such as GPS, inertial navigation systems, and cameras can be used to detect obstacles, track position, and create maps of the environment. Additionally, some autonomous navigation systems use a combination of sensors to achieve greater precision and accuracy.

Autonomous navigation in both indoor and outdoor settings and environments requires the use of various sensors, such as cameras, lidar, radar, ultrasound, infrared, and GPS. Cameras provide visual information to the robot, while lidar and radar use reflected radio waves to detect objects [21]. Ultrasound sensors measure the distance of objects, while infrared sensors measure temperature and detect motion. Finally, GPS provides global navigation satellite system (GNSS) coordinates to the robot.

Autonomous navigation in both indoor and outdoor settings requires the use of a variety of sensors. For indoor navigation, these sensors typically include ultrasonic, infrared, and laser range finders, as well as cameras and other optical sensors. For outdoor navigation, the sensors may include GPS, inertial navigation systems, radar, lidar, and other types of imaging sensors [8]. Additionally, some autonomous navigation systems may also incorporate inertial measurement units or IMUs to measure the robot's orientation as it moves through its environment.

Autonomous navigation in both indoor and outdoor settings and environments can be achieved using a variety of sensors, such as GPS, LIDAR, optical cameras, IMU, and ultrasound. GPS is used to provide exact positioning in outdoor environments, while LIDAR, optical cameras, and ultrasound are used to detect obstacles and build a 3D map of the environment. IMU, or inertial measurement unit, is used to measure acceleration and orientation, helping to track the robot's position and orientation relative to its environment. All of these sensors are combined to provide the robot with the necessary information to successfully autonomously navigate its environment.

Autonomous navigation in both indoor and outdoor settings and environments requires the use of sensors to sense the environment and navigate the robot [6]. Sensors can include cameras, laser rangefinders, radar, and ultrasonic sensors. Cameras are used to detect objects and obstacles, while laser rangefinders provide accurate measurements of short-range distances. Radar is useful for detecting objects over long distances, while ultrasonic sensors can be used to detect objects in close proximity. Other sensors, such as infrared, can be used to detect changes in temperature, while magnetometers can be used to sense magnetic fields.

Mapping

Autonomous navigation in both indoor and outdoor settings and environments can be achieved through the use of mapping techniques. Mapping techniques involve creating a representation of the environment, typically through the use of sensors and other data acquisition techniques. This representation can then be used to facilitate autonomous navigation by providing the robot with information about its location and the locations of obstacles and other objects in its vicinity [9]. Mapping can also be used to create virtual walls, which can be used to guide the robot and keep it from wandering off its intended path. Additionally, mapping can be used to create detailed maps of the environment, which can be used to plan and execute autonomous navigation tasks more efficiently.

Autonomous navigation in both indoor and outdoor settings and environments can be achieved by using various mapping techniques. For indoor settings, SLAM (Simultaneous Localization and Mapping) algorithms such as Extended Kalman Filter and Particle Filter can be used to create a map of the environment and to localize the robot within it. In outdoor settings, GPS and other satellite-based navigation systems can be used to accurately map and navigate the environment [7]. Additionally, the robot can use sensors such as cameras, lidar, and ultrasonics to create a detailed map of the environment and to localize itself within it.

Autonomous navigation in indoor and outdoor settings involves the use of sensors, robots, and software to map out their environment and safely navigate around obstacles. This type of navigation requires the robot to be able to detect and interpret the objects it encounters, such as walls, furniture, and other obstacles [22]. Once the robot has mapped out the environment, it can use that data to determine the best path to take. Additionally, autonomous navigation may involve obstacle avoidance and other advanced techniques, such as planning for multiple goals and avoiding collisions. In outdoor settings, autonomous navigation often involves the use of GPS, inertial measurement units, and other sensors to help the robot determine its location.

Autonomous navigation can be carried out in both indoor and outdoor settings and environments by using various methods. For indoor settings, indoor mapping can be used to create a digital representation of the environment. This can include mapping out hallways, rooms, and other features in the building [30]. For outdoor settings, mapping can be done using GPS or other location-tracking technologies. This can include creating digital maps of roads and other features of the environment. Additionally, autonomous robots can use sensors like cameras, lidar, and radar to detect obstacles in the environment and plan a safe path around them.

Autonomous navigation in indoor and outdoor settings requires the use of mapping techniques that can accurately identify the environment, obstacles, and any potential hazards. This mapping process involves using a variety of sensors such as cameras, LiDAR, and GPS to build a detailed model of the surrounding area. This model is then used to plan and navigate through the environment, avoiding any potential dangers. Additionally, machine learning algorithms can be used to learn and adapt to changing environments, allowing for more reliable and efficient navigation.

Carrying out autonomous navigation in both indoor and outdoor settings and environments requires mapping technologies [26]. These technologies include SLAM (Simultaneous Localization and Mapping), which uses sensors to collect data about the environment and create a map of the surroundings. Additionally, image recognition and machine learning algorithms can be used to enable robots to identify objects and navigate around them. These technologies can be used in both indoor and outdoor environments, allowing robots to safely and accurately navigate their surroundings.

Path Planning

Autonomous navigation in both indoor and outdoor settings and environments requires the use of path planning algorithms in order to determine the most efficient route from one point to another. Path planning involves the use of algorithms to analyze and calculate the shortest or most efficient route from a starting point to the destination [23]. Path planning algorithms can take into consideration factors such as terrain, obstacles, and the environment in order to generate the most optimal path. Autonomous navigation systems usually rely on complex algorithms to analyse the environment and generate a path. The path generated by these systems is then used by the navigation system to guide the robot or vehicle along its route.

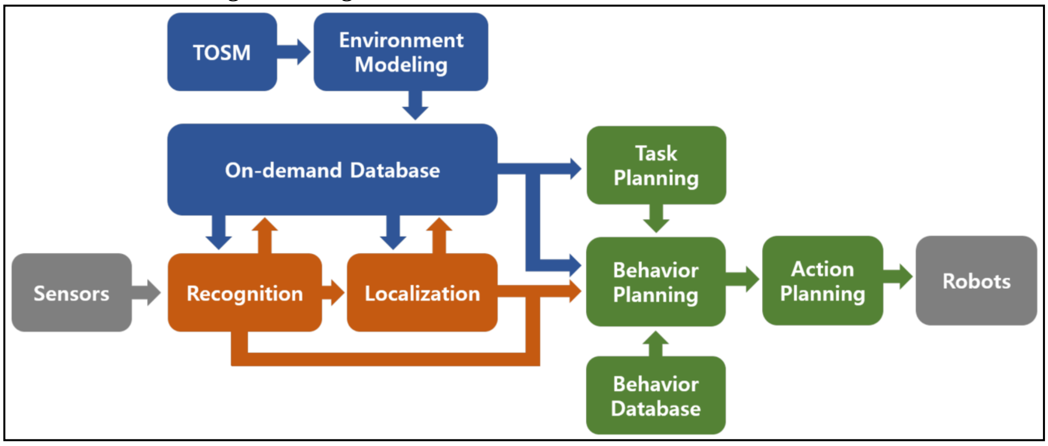

Figure 4: Path planning of the image
(Source: Muñoz–Bañón et al. 2019 [24])

Autonomous navigation in both indoor and outdoor settings requires the use of path planning algorithms, which are used to plan the robot's path from its current location to its desired destination [24]. Path planning algorithms take into account a variety of factors such as obstacles, terrain, and environment constraints, and use them to generate optimized paths for the robot to follow. Path planning algorithms use various search algorithms such as A*, Dijkstra's algorithm, and Rapidly-Exploring Random Trees (RRTs) to generate paths that are safe, efficient, and reliable. Additionally, path planning algorithms may also incorporate machine learning techniques such as deep learning to improve the accuracy of the paths generated [25]. Once a path is generated, the robot can then use its sensors and onboard controllers to follow it autonomously.

Autonomous navigation in both indoor and outdoor settings and environments requires a combination of path planning and obstacle avoidance. Path planning is the process of creating a path for a robot or vehicle to travel from one point to another. Path planning algorithms calculate the best route for the robot or vehicle to take, taking into account the environment, obstacles, and other constraints [28]. Obstacle avoidance is the process of detecting and avoiding obstacles in the environment, such as walls and other objects. Obstacle avoidance algorithms allow the robot or vehicle to detect and avoid obstacles in its path, helping it to safely navigate the environment. Autonomous navigation in indoor and outdoor settings and environments can be achieved by combining these two technologies to create a safe, efficient navigation system.

Obstacle Avoidance

Autonomous navigation in both indoor and outdoor settings and environments requires the ability to detect and avoid obstacles [27]. This requires the use of sensors to detect any potential obstacles in the environment. Sensor data is then used to generate a map of the environment and to identify any potential obstacles that may be in the path of the autonomous vehicle. The vehicle can then use this data to plan a safe path around the obstacle while still reaching its destination. Additionally, the vehicle may employ algorithms to identify and avoid obstacles that may be hard to detect with sensors, such as people or animals.

Autonomous navigation in both indoor and outdoor settings and environments requires the use of obstacle avoidance. This involves the use of sensors to detect obstacles and then make decisions about how to safely navigate around them. This can be achieved through a combination of vision-based navigation, GPS-based navigation, and/or the use of range finding or proximity sensors [29]. For indoor applications, vision-based navigation or range finding can be used to detect walls, furniture, and other objects, allowing the robot or vehicle to determine the best path to reach its goal. For outdoor applications, GPS-based navigation or range finding can be used to detect obstacles such as trees, rocks, and buildings. In both cases, the obstacle avoidance algorithms must be able to process the sensor data and make decisions in real-time.

Conclusion

Autonomous navigation in indoor and outdoor settings and environments requires a combination of sophisticated sensing and control systems. These systems must be able to identify and interpret information from a variety of sources, such as GPS, cameras, and Lidar, and then use this information to plan a path and follow it successfully. Autonomous navigation can be used in a variety of applications, such as self-driving cars, robots, and drones, and can help to improve safety and efficiency in many industries. However, the complexity of autonomous navigation makes it a challenging task, requiring research and development in a variety of fields, such as computer vision, artificial intelligence, and robotics, among others.

Autonomous navigation in both indoor and outdoor settings and environments is an important part of robotics and automated systems. Autonomous navigation involves using sensors, computer vision, and algorithms to navigate an environment without direct human interaction. This technology can provide a range of benefits including improved safety, cost savings, and increased efficiency. Autonomous navigation in both indoor and outdoor settings offers unique challenges, but with the right technology, these challenges can be overcome. By using sensors and computer vision to identify objects and obstacles, robots and automated systems can successfully navigate their environment.

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