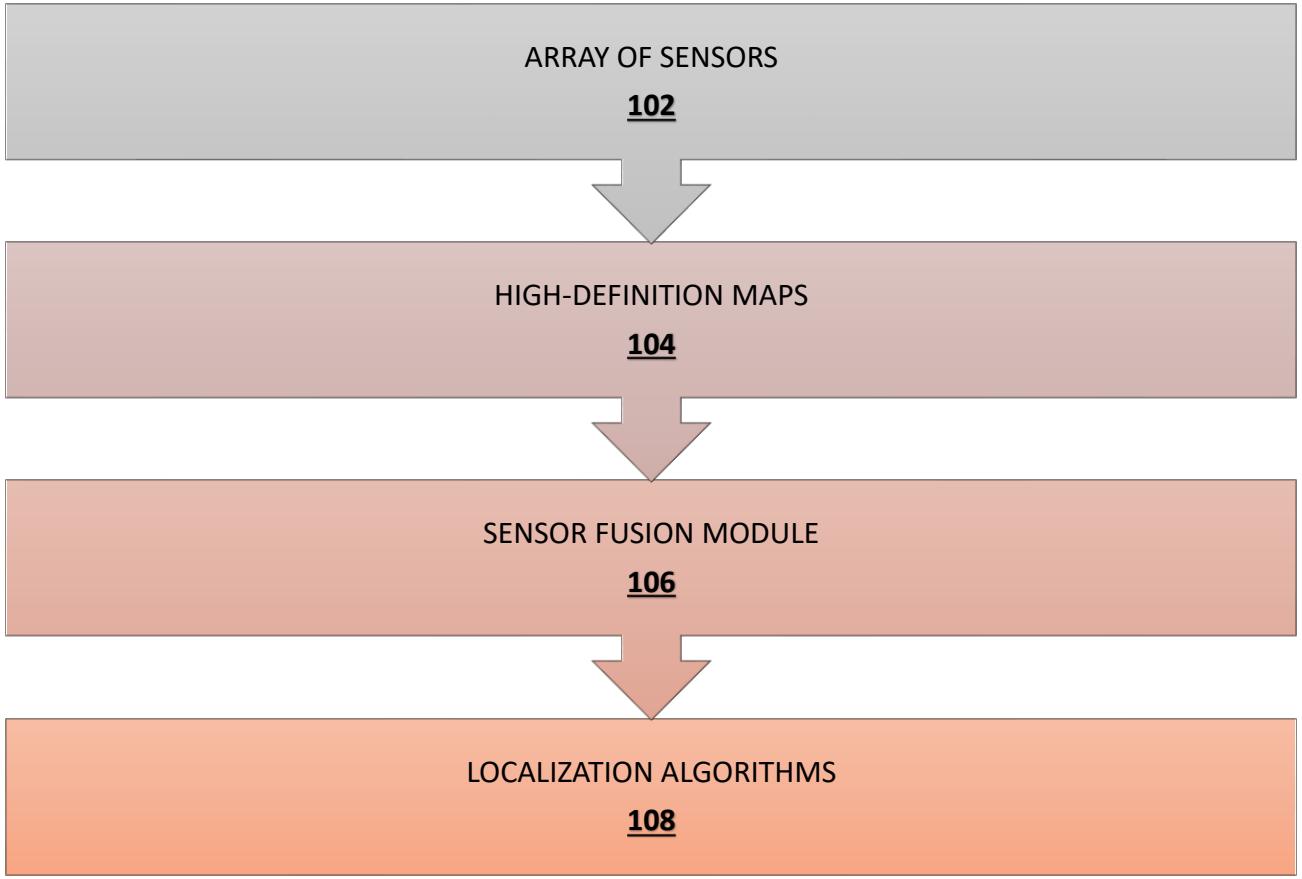


FIG. 1

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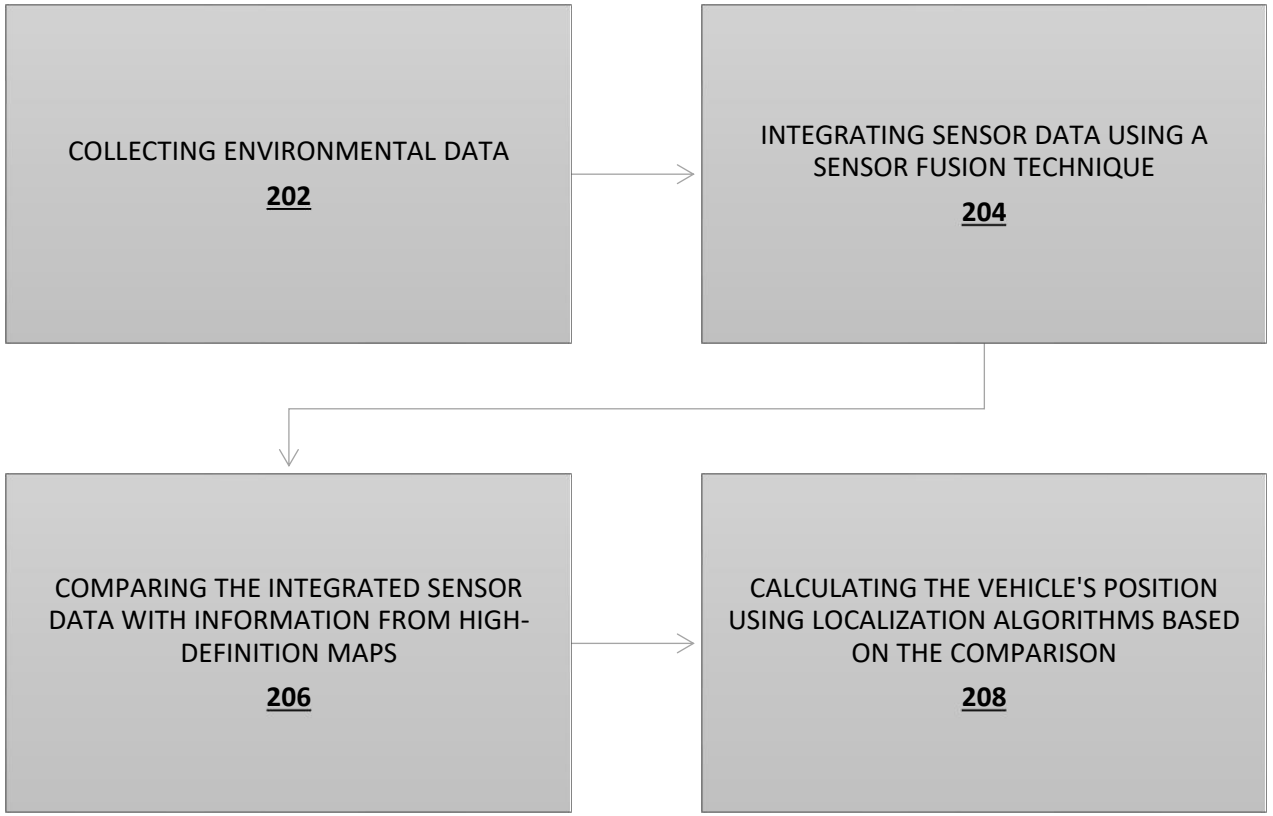


FIG. 2

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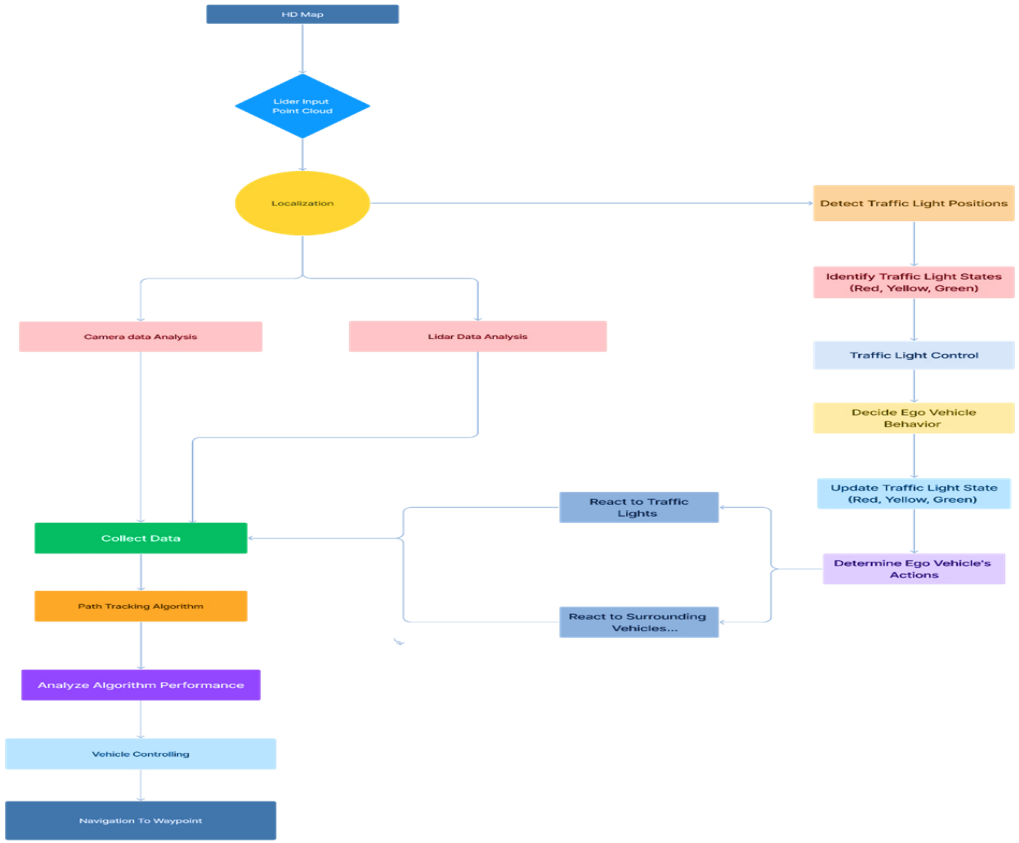


FIG. 3

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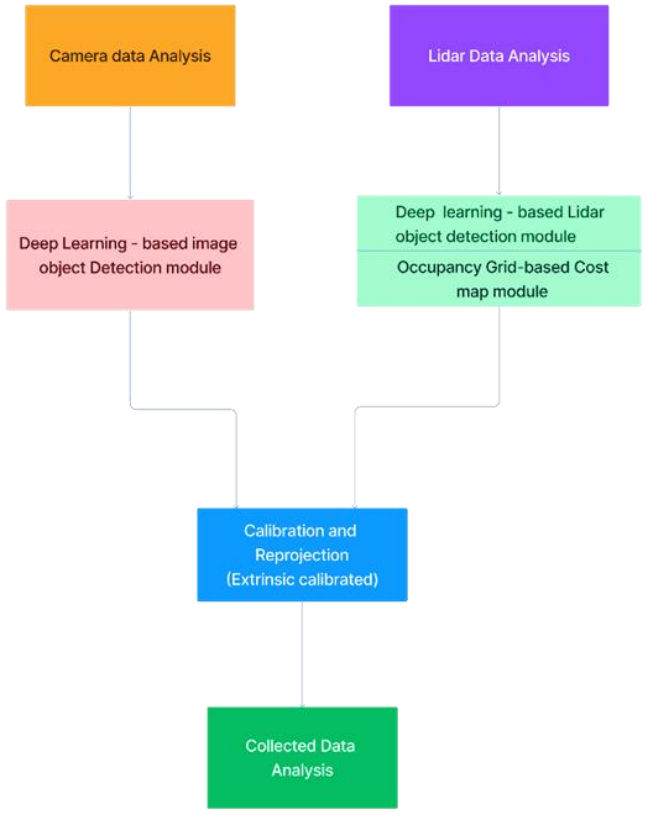


FIG. 4

December 8, 2023

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FORM 2

THE PATENTS ACT, 1970

(39 of 1970)

&

THE PATENTS RULES, 2003

COMPLETE SPECIFICATION

1. TITLE OF THE INVENTION

High-precision localization system for autonomous vehicles

2. APPLICANT(S)

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3. PREAMBLE TO DESCRIPTION

COMPLETE SPECIFICATION -The following specification particularly describes the invention and the manner in which it is to be performed.

High-precision localization system for autonomous vehicles

Field of the Invention

[0001] The disclosure pertains to high-precision localization system for autonomous vehicles, focusing on advanced navigational technologies that enable precise and reliable vehicle positioning.

Background

[0002] The background description includes information that may be useful in understanding the present invention. It is not an admission that any of the information provided herein is prior art or relevant to the presently claimed invention, or that any publication specifically or implicitly referenced is prior art.

[0003] The development of high-precision localization systems for autonomous vehicles is an area of rapid advancement, driven by the growing demand for safer and more efficient transportation solutions. Said systems represent a vital component in the evolution of autonomous driving technology, where accurate and reliable vehicle positioning is paramount.

[0004] Traditional navigation systems, like those used in conventional vehicles, largely rely on GPS technology. While GPS offers a good level of accuracy for general navigation purposes, the precision can be significantly affected by factors such as signal blockage in urban canyons, dense foliage, or atmospheric conditions. For autonomous vehicles, where precision in positioning is for safe operation, the limitations of GPS alone present a significant challenge.

[0005] To address said challenges, the field has seen the integration of various sensor technologies. LiDAR (Light Detection and Ranging) has become a cornerstone in autonomous vehicle design, providing high-resolution, three-dimensional information about the vehicle's

surroundings. LiDAR's ability to generate precise environmental maps is crucial for path planning and obstacle avoidance. However, LiDAR systems also have limitations, particularly in adverse weather conditions like heavy rain or fog, which can obscure the sensor's view.

[0006] Radar technology complements LiDAR by offering robust performance in poor weather conditions and the ability to detect objects at a greater distance. Radar sensors are less affected by environmental factors but provide less detailed data compared to LiDAR. Cameras add another layer of environmental perception, capturing visual information that is essential for tasks like traffic sign recognition and lane following. However, cameras are limited in low-light conditions and can be affected by direct sunlight or reflections.

[0007] The concept of sensor fusion has emerged as an aspect of high-precision localization systems. By integrating data from LiDAR, radar, cameras, and GPS, sensor fusion techniques create a and redundant system that can operate reliably under a wide range of conditions. The approach leverages the strengths of each sensor type while mitigating their individual weaknesses.

[0008] The integration of high-definition (HD) maps represents another significant advancement. HD maps provide detailed information about the road network, including lane markings, traffic signs, and even the exact curvature of the roads. When combined with sensor data, said maps allow for highly accurate localization and navigation, essential for autonomous driving.

[0009] The use of advanced localization algorithms is the final piece of the puzzle. Said algorithms process the integrated sensor data and HD map information to precisely determine the vehicle's position and orientation. They are designed to work in real-time, constantly updating the vehicle's location and making split-second decisions.

[00010] Prior art in the field includes various attempts to enhance vehicle localization accuracy. For example, systems that rely solely on GPS and basic maps have evolved into more

complex arrangements involving multiple sensor types and advanced computational techniques. Companies in the automotive and technology sectors have been at the forefront of said developments, investing heavily in research and development to create more reliable and efficient autonomous driving systems.

[00011] Thus, the development of high-precision localization systems for autonomous vehicles is marked by a shift from single-source navigation solutions to multifaceted systems that integrate diverse technologies. The integration addresses the limitations of individual components and paves the way for safer and more autonomous driving experiences. The ongoing advancements in sensor technology, data processing, and HD mapping continue to drive the field forward, promising even greater levels of precision and reliability.

Summary

[00012] The disclosure pertains to high-precision localization system for autonomous vehicles, focusing on advanced navigational technologies that enable precise and reliable vehicle positioning. The field integrates various sensor technologies, including LiDAR, radar, cameras, and GPS, along with sophisticated data processing techniques such as sensor fusion and specialized algorithms. The system is designed to accurately determine the vehicle's location within complex and dynamically changing environments, utilizing detailed high-definition maps and real-time data analysis. The system is particularly relevant to the development and enhancement of autonomous driving systems, aiming to improve safety, efficiency, and reliability in autonomous vehicle navigation.

[00013] The following presents a simplified summary of various aspects of this disclosure in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects, and is intended to neither identify key elements nor delineate the scope of such aspects. Its purpose is to present some concepts of this

disclosure in a simplified form as a prelude to the more detailed description that is presented later.

[00014] The following paragraphs provide additional support for the claims of the subject application.

[00015] The high-precision localization system for autonomous vehicles represents a significant leap in navigational technology, combining a range of sophisticated components to ensure unparalleled accuracy in vehicle positioning. Central to the system is an array of advanced sensors, including LiDAR, radar, cameras, and GPS. Said sensors work collaboratively to gather a wealth of real-time environmental data. LiDAR offers precise distance measurements and detailed three-dimensional mapping, radar provides reliable detection capabilities under various weather conditions, cameras capture visual cues necessary for navigation, and GPS offers broad-scale positioning.

[00016] Complementing said sensors are high-definition maps that contain exhaustive details about the road network, including lane markings, traffic signs, and other crucial navigational information. Said maps are continuously updated to reflect real-time traffic conditions and environmental changes, ensuring the data remains current and reliable.

[00017] A pivotal aspect of the system is the sensor fusion module. The module employs advanced computational techniques to merge data from the diverse array of sensors, creating an integrated and environmental model. Sensor fusion is essential for overcoming the limitations of individual sensors and providing a more robust and accurate localization solution.

[00018] The processing unit within the system executes sophisticated localization algorithms, which are the cornerstone of the system’s precision. Said algorithms analyze the integrated sensor data in conjunction with the high-definition maps to determine the vehicle's exact position and orientation. The processing unit continuously updates the vehicle's position, factoring in real-time sensor data and dynamic map information. The constant updating is

crucial for the safe navigation of autonomous vehicles, particularly in complex and rapidly changing driving environments.

[00019] Additionally, the system includes a communication module. The module plays a dual role of receiving timely updates for the high-definition maps, ensuring the vehicle has the most current data available, and transmits the vehicle's precise location to external systems. The feature is particularly important for fleet management, traffic monitoring, and in scenarios where vehicle-to-infrastructure communication is necessary.

[00020] Thus, the high-precision localization system for autonomous vehicles is an integration of technologies and data processing techniques. Said the high-precision localization system marks a significant advancement in autonomous vehicle navigation, offering enhanced safety, efficiency, and reliability. The system's ability to accurately determine a vehicle's position in a wide range of scenarios and conditions is pivotal for the advancement of autonomous driving technologies.

[00021] The method for high-precision localization of an autonomous vehicle incorporates a approach using advanced technologies to ensure accurate vehicle positioning. The process begins with the collection of environmental data via an array of sophisticated sensors. LiDAR sensors provide detailed three-dimensional mapping of the vehicle's surroundings, radar offers reliable detection capabilities under various weather conditions, cameras capture essential visual details, and GPS provides broad-scale positioning.

[00022] A crucial step in the method is sensor fusion, where data from said diverse sensors are integrated using advanced techniques. The integration involves filtering and weighting different sensor inputs, enhancing the accuracy and reliability of the combined data. The sensor fusion process ensures that the limitations of individual sensors are mitigated, resulting in a more accurate and robust environmental perception.

[00023] The integrated sensor data is then compared with information from high-definition maps. Said maps contain detailed and dynamic information about the road network, including lane markings, traffic signs, and other navigational data. They are continuously updated based on real-time data collected from the vehicle's sensors, ensuring the information remains current and accurate.

[00024] Localization algorithms play a pivotal role in the method. Said algorithms process the sensor data in conjunction with the high-definition maps to calculate the vehicle's exact position. The algorithms are designed to be dynamic, adjusting the localization process based on changing environmental conditions and real-time traffic data. The adaptability is key to maintaining high precision in localization under various driving scenarios.

[00025] Another important aspect of the method is the wireless transmission of the vehicle's precise location to external systems, such as a traffic management system. The feature enables real-time traffic monitoring and management, contributing to overall road safety and efficiency.

[00026] Hence, the method for high-precision localization of autonomous vehicles represents a blend of advanced sensor technologies, sophisticated data processing techniques, and dynamic mapping solutions. The method ensures that autonomous vehicles can accurately determine their position in a wide range of environmental conditions, enhancing their safety and reliability. The method is a significant advancement in autonomous vehicle navigation, promising to revolutionize the realm of transportation.

Brief Description of the Drawings

[00027] The features and advantages of the present disclosure would be more clearly understood from the following description taken in conjunction with the accompanying drawings in which:

[00028] FIG. 1 diagrammatically depicts a skeletal framework of a high-precision localization system for an autonomous vehicle, according to some embodiments of the present disclosure.

[00029] FIG. 2 figuratively showcases a detailed flow chart of a method for high-precision localization of an autonomous vehicle, according to some embodiments of the present disclosure.

[00030] FIG. 3, showcases a flowchart that outlines the localization process for an autonomous vehicle.

[00031] FIG. 4 illustrates the processes involved in the implementation and analysis of camera and LiDAR data for an autonomous vehicle system.

Detailed Description

[00032] In the following detailed description of the invention, reference is made to the accompanying drawings that form a part hereof, and in which is shown, by way of illustration, specific embodiments in which the invention may be practiced. In the drawings, like numerals describe substantially similar components throughout the several views. These embodiments are described in sufficient detail to claim those skilled in the art to practice the invention. Other embodiments may be utilized and structural, logical, and electrical changes may be made without departing from the scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the appended claims and equivalents thereof.

[00033] The use of the terms “a” and “an” and “the” and “at least one” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The use of the term “at least one” followed by a list

of one or more items (for example, “at least one of A and B”) is to be construed to mean one item selected from the listed items (A or B) or any combination of two or more of the listed items (A and B), unless otherwise indicated herein or clearly contradicted by context. The terms “comprising,” “having,” “including,” and “containing” are to be construed as open-ended terms (i.e., meaning “including, but not limited to,”) unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., “such as”) provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[00034] The disclosure pertains to high-precision localization system for autonomous vehicles, focusing on advanced navigational technologies that enable precise and reliable vehicle positioning. The field integrates various sensor technologies, including LiDAR, radar, cameras, and GPS, along with sophisticated data processing techniques such as sensor fusion and specialized algorithms. The system is designed to accurately determine the vehicle's location within complex and dynamically changing environments, utilizing detailed high-definition maps and real-time data analysis. The system is particularly relevant to the development and enhancement of autonomous driving systems, aiming to improve safety, efficiency, and reliability in autonomous vehicle navigation.

[00035] Pursuant to the "Detailed Description" section herein, whenever an element is explicitly associated with a specific numeral for the first time, such association shall be deemed

consistent and applicable throughout the entirety of the "Detailed Description" section, unless otherwise expressly stated or contradicted by the context.

[00036] Presented herein a high-precision localization system 100 for autonomous vehicles is a complex and nuanced endeavour, involving the integration of various technologies and methodologies to ensure that the vehicle can accurately determine the position within a given environment. The system 100 is crucial for autonomous vehicles, forms the backbone of their ability to navigate safely and efficiently.

[00037] According to a pictorial elucidation of FIG. 1, illustrating an architectural setup of the system 100 that can comprise functional elements, yet not limited to an array of sensors 102, high-definition maps 104, a sensor fusion module 106, and localization algorithms 108. A person ordinarily skilled in art would prefer those elements or components of the system 100, to be functionally or operationally coupled with each other, in accordance with the embodiments of present disclosure.

[00038] In yet another embodiment, the first component of said system 100 is an array of sensors, which includes LiDAR (Light Detection and Ranging), radar, cameras, and GPS (Global Positioning System). Each of said sensors plays a key role in gathering real-time environmental data, which is essential for the vehicle to understand the surroundings.

[00039] LiDAR sensor uses pulsed laser light to measure distances to objects. By emitting laser beams and measuring the time taken for the light to reflect back, LiDAR creates a high-resolution, 3D maps of the vehicle's surroundings. LiDAR sensor is crucial for detecting and navigating around obstacles, other vehicles, and pedestrians. Radar sensors use radio waves to detect objects and measure their speed and distance from the vehicle. Radar sensors are particularly effective in adverse weather conditions where optical sensors like cameras might be hindered.

[00040] Referring to the preceding embodiment, the cameras provide a visual overview of the vehicle's environment, capturing crucial details like road signs, traffic lights, lane markings, and other vehicles. Advanced image processing algorithms can interpret the visual data, further aiding in navigation and decision-making. GPS provides geospatial positioning, offering a broad sense of the vehicle's location. While not as precise as other sensors, GPS is configured for general navigation and provides a baseline for the vehicle’s global position.

[00041] High-definition maps are another vitalelement of the system. Unlike standard navigation maps, said maps contain detailed information about the road network, including lane markings, traffic signals, road geometry, and elevation data. They provide a foundational layer over which sensor data can be overlaid and interpreted.

[00042] In yet another embodiment, the sensor fusion module is at the heart of data integration. The sensor fusion module combines data from the various sensors to create a, unified view of the environment. The module uses advanced computational techniques to process and merge the data, accounting for the strengths and weaknesses of each sensor type. For example, said fusion module might use LiDAR data for precise distance measurements while relying on camera data for object recognition and radar data for velocity measurements in low-visibility conditions.

[00043] Localization algorithms are software components that process the integrated sensor data and map information to ascertain the vehicle's precise position. Said algorithms are designed to analyze the sensor data in the context of the high-definition maps, allowing the vehicle to understand exactly where the vehicle is on the road. Said algorithms must be robust, capable of handling discrepancies and uncertainties in sensor data.

[00044] In yet another embodiment, the accuracy of the data integration from multiple sensors is enhanced through advanced computational techniques. Said advanced computational techniques might include machine learning algorithms for pattern recognition, probabilistic

models like Kalman filters for estimating vehicle position and motion, and algorithms for reconciling inconsistencies between sensor data and map information.

[00045] In yet another embodiment, the processing unit within the vehicle is configured to execute said localization algorithms. The unit is typically a high-powered computer capable of handling large volumes of data at high speeds. The unit continuously updates the vehicle's position based on real-time sensor data and map information, ensuring that the vehicle's understanding of the environment is as current and accurate as possible.

[00046] In yet another embodiment, the high-definition maps in the system include dynamic elements such as real-time traffic conditions and environmental changes. The dynamicity ensures that the vehicle can respond to changes in the environment, like traffic jams, accidents, or road construction, in real-time.

[00047] In yet another embodiment, the system includes a communication module. The module allows the vehicle to receive updates for high-definition maps, ensuring that the vehicle's map data is always current. The module also enables the vehicle to transmit the location and other relevant data to external systems, such as traffic management systems or other connected vehicles.

[00048] In yet another embodiment, the integration of said components results in a highly sophisticated localization system. Such a system is not only crucial for the basic navigation of autonomous vehicles but is also integral to their ability to make complex decisions in real-time, such as route planning, obstacle avoidance, and adherence to traffic laws. The precision and reliability of the system directly impact the safety and efficiency of autonomous vehicles, making a cornerstone of their functionality.

[00049] In yet another embodiment, the application of the technology goes beyond individual vehicles. When integrated into a broader network of connected vehicles and

infrastructure, the system contributes to more efficient traffic management, reduced congestion, and enhanced road safety.

[00050] Referring to one or more preceding embodiments, the detailed exploration of a high-precision localization system 100 for autonomous vehicles underscores the intricacies and research at play in the realm of autonomous vehicle technology. Each component, from the array of sensors to the advanced computational techniques used in data integration, plays a pivotal role in ensuring that autonomous vehicles can navigate and operate with an unprecedented level of precision and safety.

[00051] The high-precision localization of an autonomous vehicle is a multifaceted method 200 that integrates various technologies and methodologies. The method 200 ensures the vehicle accurately determines the position and navigates safely in the environment. In consideration of a diagrammatic portrayal put forth in FIG. 2, representing a flow chart of the method 200 that can comprise steps of, yet not restricted to, (at step 202) collecting environmental data, (at step 204) integrating sensor data using a sensor fusion technique, (at step 206) comparing the integrated sensor data with information from high-definition maps, and (at step 208) calculating the vehicle's position using localization algorithms based on the comparison. Said steps of the method 200 can be performed or executed, collectively or selectively, randomly or sequentially or in a combination thereof, in accordance with the embodiments of current disclosure.

[00052] In yet another embodiment, the first step involves collecting environmental data using an array of sensors, each playing a key role in capturing different aspects of the vehicle’s surroundings. For instance, LiDAR sensor provides detailed 3D maps of the environment by emitting pulsed laser light and measuring the reflection time. LiDAR sensor is particularly effective in identifying the shape, size, and distance of objects, aiding in creating a spatial understanding. Using radio waves, radar sensors detect objects, their speed, and

distance. Their effectiveness in poor visibility conditions, like fog or rain, makes them indispensable for consistent environmental assessment.

[00053] Referring to the preceding embodiment, the cameras capture visual data, crucial for recognizing road signs, traffic lights, lane markings, and moving objects like pedestrians and other vehicles. Advanced image processing techniques are employed to interpret the data. GPS provides basic geolocation data, essential for broad navigation purposes. GPS offers a macro-level position reference, complementing the detailed data from other sensors.

[00054] Sensor fusion is the next step, that involves the integration of data from LiDAR, radar, cameras, and GPS. The technique enhances the reliability and accuracy of environmental perception by compensating for the limitations of individual sensors. For instance, LiDAR and radar data can supplement camera images in low-visibility conditions.

[00055] In yet another embodiment, the integrated sensor data is then compared with information from high-definition maps. Said maps contain detailed information about the road network, including lane markers, road geometry, traffic signals, and other relevant infrastructure data. The comparison is crucial for contextualizing sensor data within a known framework, enhancing the accuracy of the vehicle's localization.

[00056] Localization algorithms are employed to calculate the vehicle's precise position based on the sensor data and map comparison. Said algorithms may include techniques like particle filters or Kalman filters, which estimate the vehicle's position and movement by considering the uncertainties and inaccuracies inherent in sensor data.

[00057] In yet another embodiment, the high-definition maps are updated based on real-time data collected from the vehicle's sensors. The maps remain updated and reflect changes in the environment, such as new road configurations, obstacles, or temporary road signs. The sensor fusion technique incorporates filtering and weighting of different sensor

inputs to improve data integration accuracy. Said filtering and weighting of different sensor inputs might involve prioritizing data from certain sensors under specific conditions, like favoring radar and LiDAR in poor visibility, or relying more on camera data in well-lit, clear conditions.

[00058] In yet another embodiment, the localization process is dynamically adjusted based on changing environmental conditions and real-time traffic data. The adaptability is vital for ensuring the vehicle's localization remains accurate in various scenarios, such as weather changes, traffic congestion, or road closures.

[00059] In yet another embodiment, the vehicle’s precise location is wirelessly transmitted to an external traffic management system. The transmission allows for enhanced traffic monitoring and management, contributing to overall road safety and efficiency. The transmission also enables a broader communication network among autonomous vehicles and infrastructure.

[00060] In yet another embodiment, the integration of said steps results in a robust and dynamic system crucial for the autonomous operation of the vehicle. Accurate localization ensures the vehicle can navigate safely, adhering to traffic rules, and responding appropriately to the environment. The system forms the backbone of autonomous vehicle navigation, enabling said vehicles to operate seamlessly in complex and ever-changing urban environments.

[00061] Referring to one or more preceding embodiments, the interplay of advanced sensors, sophisticated algorithms, and real-time data processing highlights the complexity and research in the field of autonomous vehicle technology. Each component, from collecting sensor data to wirelessly transmitting the vehicle's location, plays a crucial role in ensuring the vehicle's safe and efficient navigation. The efficiency of the method 200 lies in the ability to

accurately interpret and respond to the dynamic world, marking a significant milestone in the journey towards fully autonomous transportation.

[00062] The system tackles the challenge of developing a high-precision localization system for autonomous vehicles, crucial for navigating complex and dynamic real-world traffic scenarios. As autonomous driving progresses toward full automation, the precision of vehicle localization becomes fundamental. Localization is the vehicle's ability to ascertain the exact position and orientation, crucial for safely manoeuvring through intersections, traffic, and interactions with pedestrians.

[00063] The system's technical advantages include centimetre-level precision, ensuring safety and navigational accuracy. The system’s robustness is proven through performance in adverse conditions like heavy rain and areas with weak GPS signals, such as urban canyons. The system's seamless map integration, combining sensor data with high-definition maps, offers enhanced situational awareness. An unreal-based simulator allows for realistic scenario testing, ensuring the system's effectiveness in actual traffic conditions. The modular design of the system provides adaptability across different vehicle models and sensors, facilitating broader applicability. The adaptability accelerates the development timeline for autonomous vehicle deployment, offering a competitive edge.

[00064] Testing the high-precision localization system within an unreal-based simulator has yielded key insights. The system showcases remarkable precision, with deviations from the true position within centimeters, essential for safe navigation in urban environments. The robustness is displayed by maintaining accurate localization even without GPS signals, combining sensor fusion and high-definition maps. The system effectively handles real-world traffic scenarios simulated within the Unreal-based environment, indicating readiness for urban and suburban deployment. The adaptability to various vehicle models and sensors suggests the system's potential for widespread integration.

[00065] The system’s objectives are geared toward creating a realistic simulation scenario using the Unreal Engine-Based Simulator in the Autonomous Driving Toolkit. The scenario can feature an ego-vehicle with advanced sensors to accurately replicate driving conditions. Algorithms will be designed for processing and leveraging sensor data for precise vehicle localization. The study aims to implement camera sensors with potential SLAM capabilities and, optionally, integrate high-definition map data to enhance localization accuracy. Additionally, decision logic for recognizing traffic lights and interacting with other vehicles will be integrated, essential for real-time navigation and adherence to traffic laws.

[00066] Hence, the study represents a significant advancement in the field of autonomous driving, bringing the industry closer to realizing fully autonomous vehicles. The proposed system's accuracy, robustness, and adaptability in various scenarios are pivotal for ensuring the safety and reliability of self-driving cars on public roads.

[00067] According to a pictorial depiction made in FIG. 3, showcases a flowchart that outlines the localization process for an autonomous vehicle, describing about said process that integrates various data inputs to navigate through the environment. The process begins with a High-Definition (HD) Map, which may comprise detailed information about the road network, including lanes, traffic signs, and infrastructure.

[00068] Localization is the central process where the system determines the position relative to the HD map. The fed data from different sources. LiDAR Input Point Cloud represents the three-dimensional data about the surroundings collected by the LiDAR sensor. The point cloud is used to detect physical objects and their positions relative to the vehicle. Camera feeds are analyzed to identify visual features such as road markings, traffic signs, and signals. Camera feeds are likely used for understanding the vehicle’s environment in visual terms.

[00069] LiDAR data analysis of LiDAR data may involve identifying the distance and shape of nearby objects, contributing to the vehicle's understanding of the immediate physical environment. A separate branch stemming from the localization process is dedicated to traffic light control, which involves detecting traffic light positions. The system uses the sensors to detect the location of traffic lights in the vicinity. The system identifies whether the lights are red, yellow, or green, which is crucial for decision-making in traffic. Based on the state of the traffic lights, the vehicle (referred to as the 'ego vehicle') decides on the course of action, such as stopping, slowing down, or proceeding through an intersection.

[00070] Referring to FIG. 3 system continuously collects data from the environment, which feeds into the localization and navigation systems. Path Tracking Algorithm takes the localization data and plots a path to the vehicle's intended destination, likely using a form of path planning algorithm. There's a feedback loop where the performance of the path tracking algorithm is analysed, presumably to improve accuracy and reliability. Based on the path set by the algorithm and the data collected, the vehicle's control systems manage its steering, acceleration, and braking to follow the path. Navigation to waypoint is the end goal of the process, where the vehicle navigates to its intended waypoint or destination. The system adjusts the behavior based on traffic light states.

[00071] React to surrounding vehicles suggests that the system also reacts to the behavior of other vehicles in the vicinity, which is essential for safe navigation. The flowchart represents a system that combines sensor data, map data, and real-time reactions to navigate an autonomous vehicle safely through its environment. The flowchart highlights the complexity of autonomous systems, which must integrate vast amounts of data and continuously adjust to new information to operate safely.

[00072] According to a pictorial depiction made in FIG. 4, illustrates the processes involved in the implementation and analysis of camera and LiDAR data for an autonomous

vehicle system. Camera data analysis involves processing and interpreting the visual data captured by the vehicle's cameras. The output feeds into a "Deep Learning-based image object Detection module," suggesting the use of machine learning algorithms, particularly deep learning, to identify and classify objects within the camera's visual field.

[00073] LiDAR data, which provides depth information via laser scanning, is analyzed to understand the vehicle's surroundings in three dimensions. Similar to the camera data analysis, deep learning-based LiDAR object detection module uses deep learning algorithms but is tailored to the point cloud data that LiDAR sensors provide, detecting and classifying objects based on their shape and distance.

[00074] Occupancy grid-based cost map module likely generates a grid-based representation of the environment where each cell in the grid indicates whether the space is occupied, free, or unknown. Said module may also assign costs to traversing different areas, useful for path planning and navigation. Both the camera and LiDAR data are brought together in said step. Calibration aligns the data from both sensors so that they are in the same coordinate system, correcting for any positional or directional differences between the sensors. Reprojection is used to transform the data into a common viewpoint or representation that can be used for further analysis.

[00075] The combined and calibrated data from both the camera and LiDAR sensors is then analyzed together. Said analysis could involve further object detection, scene interpretation, and decision-making processes for the autonomous vehicle. The flowchart indicates that the system uses advanced machine learning techniques to interpret sensor data, which suggests a high level of autonomy. By integrating camera and LiDAR data, the system can leverage the strengths of both visual and depth perception to gain a more understanding of its environment, which is crucial for the safe operation of autonomous vehicles. The inclusion

of extrinsic calibration ensures that the data from both sensors align correctly, which is essential for accurate object detection and environmental mapping.

[00076] Example embodiments herein have been described above with reference to block diagrams and flowchart illustrations of methods and apparatuses. It will be understood that each block of the block diagrams and flowchart illustrations, and combinations of blocks in the block diagrams and flowchart illustrations, respectively, can be implemented by various means including hardware, software, firmware, and a combination thereof. For example, in one embodiment, each block of the block diagrams and flowchart illustrations, and combinations of blocks in the block diagrams and flowchart illustrations can be implemented by computer program instructions. These computer program instructions may be loaded onto a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions which execute on the computer or other programmable data processing apparatus create means for implementing the functions specified in the flowchart block or blocks.

[00077] Throughout the present disclosure, the term ‘processing means’ or ‘microprocessor’ or ‘processor’ or ‘processors’ includes, but is not limited to, a general purpose processor (such as, for example, a complex instruction set computing (CISC) microprocessor, a reduced instruction set computing (RISC) microprocessor, a very long instruction word (VLIW) microprocessor, a microprocessor implementing other types of instruction sets, or a microprocessor implementing a combination of types of instruction sets) or a specialized processor (such as, for example, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), a digital signal processor (DSP), or a network processor).

[00078] The term “non-transitory storage device” or “storage” or “memory,” as used herein relates to a random access memory, read only memory and variants thereof, in which a computer can store data or software for any duration.

[00079] Operations in accordance with a variety of aspects of the disclosure is described above would not have to be performed in the precise order described. Rather, various steps can be handled in reverse order or simultaneously or not at all.

[00080] While several implementations have been described and illustrated herein, a variety of other means and/or structures for performing the function and/or obtaining the results and/or one or more of the advantages described herein may be utilized, and each of such variations and/or modifications is deemed to be within the scope of the implementations described herein. More generally, all parameters, dimensions, materials, and configurations described herein are meant to be exemplary and that the actual parameters, dimensions, materials, and/or configurations will depend upon the specific application or applications for which the teachings is/are used. Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific implementations described herein. It is, therefore, to be understood that the foregoing implementations are presented by way of example only and that, within the scope of the appended claims and equivalents thereto, implementations may be practiced otherwise than as specifically described and claimed. Implementations of the present disclosure are directed to each individual feature, system, article, material, kit, and/or method described herein. In addition, any combination of two or more such features, systems, articles, materials, kits, and/or methods, if such features, systems, articles, materials, kits, and/or methods are not mutually inconsistent, is included within the scope of the present disclosure.

Claims

I/We Claim:

1. A high-precision localization system for an autonomous vehicle, comprising:

   an array of sensors including LiDAR, radar, cameras, and GPS, for collecting real-time environmental data;

   high-definition maps containing detailed road network information;

   a sensor fusion module configured to integrate data from the array of sensors; and

   localization algorithms to process integrated sensor data and map information to ascertain the vehicle's precise position.

2. The system of claim 1, wherein the sensor fusion module utilizes advanced computational techniques to enhance the accuracy of the data integration from multiple sensors.
3. The system of claim 1, further comprising a processing unit configured to execute the localization algorithms and continuously update the vehicle's position based on real-time sensor data and map information.
4. The system of claim 1, wherein the high-definition maps include dynamic elements such as real-time traffic conditions and environmental changes.
5. The system of claim 1, further comprising a communication module to receive updates for high-definition maps and transmit the vehicle's location to external systems.
6. A method for high-precision localization of an autonomous vehicle, comprising:

   collecting environmental data using an array of sensors including LiDAR, radar, cameras, and GPS;

integrating sensor data using a sensor fusion technique;

comparing the integrated sensor data with information from high-definition maps; and

calculating the vehicle's position using localization algorithms based on the comparison.

7. The method of claim 6, further including the step of updating high-definition maps based on real-time data collected from the vehicle's sensors.
8. The method of claim 6, wherein the sensor fusion technique includes filtering and weighting different sensor inputs to improve the accuracy of data integration.
9. The method of claim 6, including the step of dynamically adjusting the localization process based on changing environmental conditions and real-time traffic data.
10. The method of claim 6, further comprising the step of wirelessly transmitting the vehicle's precise location to an external traffic management system.



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High-precision localization system for autonomous vehicles

Abstract

The present disclosure relates to a high-precision localization system designed for autonomous vehicles. The system features an integrated array of advanced sensors, including LiDAR, radar, cameras, and GPS, which work in unison to gather real-time environmental data. The core of the system lies in the sophisticated sensor fusion module, which adeptly combines the diverse data streams from said sensors, creating a unified and enhanced environmental perception. Additionally, the system utilizes high-definition maps that provide detailed information about the road network, essential for precise navigation. Central to the system's functionality are advanced localization algorithms, which process the fused sensor data in conjunction with the map information to accurately determine the vehicle's position within its environment. The combination of sensor fusion and algorithmic processing ensures unparalleled accuracy and reliability in vehicle localization, importantfor the safe and efficient operation of autonomous vehicles.

Fig. 1



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