

**FORM 2**

THE PATENTS ACT, 1970

(39 of 1970)

&

5

THE PATENTS RULES, 2003

**COMPLETE SPECIFICATION**

**(See Section 10; rule 13)**

10

**SELF-DRIVING ELECTRIC VEHICLES**

**APPLICANT(S)**

APPLICANT	NATIONALITY	ADDRESS
Nandhini Venkataraman	Indian	SRM Institute of Science and Technology, Ramapuram Campus, Chennai, India
Vasupratha Manivannan	Indian	SRM Institute of Science and Technology, Ramapuram Campus, Chennai, India
Pramikha Kannan	Indian	SRM Institute of Science and Technology, Ramapuram Campus, Chennai, India
Habib Ghanbarpourasl	Türkiye	Turkish Aeronautical Association University, Ankara, Türkiye

		Bahçekapı, Okul Sk. No:11, 06790 Etimesgut/Ankara
Mithileysh Sathiyarayanan	British	MIT Square Services Private Limited 128 Kemp House, City Road, London, Great Britain, UK - EC1V 2NX

The following specification particularly describes the invention and how it is to be performed.

## **FIELD OF THE INVENTION**

The present invention relates to the field of automotive technology, more specifically to electric vehicles (EVs). It further pertains to autonomous driving technologies and battery management systems, focusing on enhancing the efficiency and range of electric vehicles

5 through swappable battery packs.

## **BACKGROUND OF THE INVENTION**

Electric vehicles have gained popularity due to their environmental benefits and lower operating costs compared to traditional internal combustion engine vehicles. However, widespread adoption faces hurdles such as range anxiety and long charging times.

Although

10 autonomous or self-driving technologies have advanced, and integrating these technologies with electric vehicles introduces additional challenges, including energy management and ensuring consistent performance over long distances.

Another prior art **US10513247B2** discloses “Battery swapping system and techniques” which shows a battery pack lift system includes: a frame having nonrunners mounted

15 thereon according to a battery pack fastener pattern for a vehicle; a lift configured to raise and lower the frame with regard to the vehicle; a first air bearing positioned between the frame and the lift, the first air bearing configured to allow relative movement between the frame and the lift; and a second air bearing positioned on the frame, the second air bearing configured to allow relative movement between a battery pack and the frame.

20 Prior art **US8517132B2** discloses “Electric vehicle battery system” which shows the electric vehicle includes a battery pack that can be exchanged at a battery exchange station. At the battery exchange station, an at least partially spent battery pack is exchanged for an at least partially charged battery pack. A battery bay is configured to be disposed of at the underside of the electric vehicle. The battery bay includes a frame that defines a cavity.

25 The cavity is configured to at least partially receive the battery pack therein. The battery bay comprises at least one latch rotatable pivoted about an axis substantially parallel with a plane formed by the underside of the vehicle. The latch is configured to lift, and retain the battery pack at least partially within the cavity.

Contrary to the prior art, the present invention provides a seamless, efficient, and eco-friendly solution to the challenges of electric vehicle range and autonomy.

## **OBJECTS OF THE INVENTION**

5 The principal object of the present invention is to provide a self-driving electric vehicle equipped with swappable battery packs to facilitate long-distance travel without the concern of range anxiety.

Another object of the present invention is to reduce the total charging time required for electric vehicles during long journeys.

10 Another object of the present invention is to enhance the autonomy of electric vehicles by integrating advanced navigation and battery management systems.

Another object of the present invention is to improve the overall efficiency and reliability of electric vehicles for long-distance travel.

The foregoing and other objects, features, and advantages of the present invention will 15 become readily apparent upon further review of the following detailed description of the preferred embodiment as illustrated in the accompanying drawings.

Contrary to the prior art, the present invention provides a seamless, efficient, and eco-friendly solution to the challenges of electric vehicle range and autonomy. By integrating Bayesian uncertainty estimation into the DDPG framework (Bayesian Reinforcement Learning), the algorithm enhances the decision-making process of self-driving cars, particularly in scenarios requiring swift maneuvers to avoid obstacles. The Bayesian methods enable the agent to model and distinguish between epistemic and aleatoric uncertainty, allowing for more informed decision-making. The algorithm supports online adaptation by continuously updating the actor and critic networks based on new observations, enabling the autonomous vehicle to adapt to changing environments and unforeseen obstacles in real-time. Bayesian DDPG prioritizes safety-critical decision-making by considering uncertainty estimates in action selection, mitigating risks associated with uncertain situations. The algorithm balances exploration and exploitation

by incorporating exploration noise and updating the policy based on sampled experiences and uncertainty estimates, facilitating efficient learning of optimal policies for obstacle avoidance. By providing a principled framework for uncertainty-aware decision-making, Bayesian DDPG enhances the obstacle avoidance capabilities of self-driving cars. The integration of Bayesian methods with DDPG allows the self-driving car to accurately predict the movements of obstacles, such as other vehicles or pedestrians, and make swift, accurate decisions. The algorithm enables the self-driving car to learn quickly how to handle unpredictable situations, improving its ability to navigate and make decisions in real-world scenarios.

#### **Bayesian DDPG Algorithm (Bayesian Reinforcement Learning )**

1. Initialize actor network weights:  $\theta_{\text{actor}}$ , critic network weights:  $\theta_{\text{critic}}$
2. Initialize target networks weights:  $\theta_{\text{actor\_target}} = \theta_{\text{actor}}$ ,  $\theta_{\text{critic\_target}} = \theta_{\text{critic}}$
3. Initialize replay buffer D
4. Initialize prior distributions  $P(\theta_{\text{actor}})$ ,  $P(\theta_{\text{critic}})$
5. while not converged do:
  6. Sample a batch of experiences from D
  7. Update posterior distributions  $P(\theta_{\text{actor}}|D)$ ,  $P(\theta_{\text{critic}}|D)$  using Bayes' theorem
  8. Sample  $\theta_{\text{actor}} \sim P(\theta_{\text{actor}}|D)$ ,  $\theta_{\text{critic}} \sim P(\theta_{\text{critic}}|D)$
  9. for each step in the episode do:
    10. Add exploration noise to the action:  $a_t = \mu_{\text{actor}}(s_t, \theta_{\text{actor}}) + \varepsilon$ , where  $\varepsilon \sim N(0, \sigma)$
    11. Execute action  $a_t$  in the environment
    12. Observe next state  $s_{t+1}$  and reward  $r_t$
    13. Store transition  $(s_t, a_t, r_t, s_{t+1})$  in D
    14. Sample a mini-batch of experiences from D
    15. Compute target Q-value:  $y_t = r_t + \gamma * Q_{\text{critic\_target}}(s_{t+1}, \mu_{\text{actor\_target}}(s_{t+1}, \theta_{\text{actor\_target}}), \theta_{\text{critic\_target}})$
    16. Update critic network weights by minimizing the TD error:  $L = (Q_{\text{critic}}(s_t, a_t, \theta_{\text{critic}}) - y_t)^2$
    17. Update actor network weights using the sampled experiences and critic's gradient:  

$$\nabla_{\theta_{\text{actor}}} J \approx \nabla_a Q_{\text{critic}}(s, a, \theta_{\text{critic}})|_{\{s=s_t, a=\mu_{\text{actor}}(s_t, \theta_{\text{actor}})\}} * \nabla_{\theta_{\text{actor}}} \mu_{\text{actor}}(s, \theta_{\text{actor}})$$
    18. Update target networks towards current networks:  $\theta_{\text{actor\_target}} = \tau * \theta_{\text{actor}} + (1 - \tau) * \theta_{\text{actor\_target}}$ ,  $\theta_{\text{critic\_target}} = \tau * \theta_{\text{critic}} + (1 - \tau) * \theta_{\text{critic\_target}}$
    19. end for
  20. end while

#### **SUMMARY OF THE INVENTION**

The present invention relates to a self-driving electric vehicle equipped with an innovative swappable battery pack system. The present invention is designed to autonomously

20 navigate the vehicles to the swapping stations, where depleted battery packs can be quickly exchanged for fully charged ones, significantly reducing downtime associated with recharging batteries. The present system includes a software program for route

optimization, battery management, and autonomous driving functionalities, ensuring optimal performance and safety.

- 25 According to an embodiment of the present invention, a self-driving electric vehicle system comprising: an autonomous navigation subsystem equipped with an array of sensors for real-time data acquisition and processing to enable autonomous driving; a modular battery pack

designed for quick swapping, said battery pack being electrically connectable with the vehicle's power system; an automated battery swapping station system for exchanging depleted battery packs with charged ones, wherein said station is equipped with automated mechanisms for removing and replacing the battery pack in the vehicle; a battery management system (BMS) configured to monitor the state of charge and health of the battery pack and to communicate with the autonomous navigation subsystem to plan routes that include stops at battery swapping stations based on the vehicle's energy requirements; and wherein the autonomous navigation subsystem, modular battery pack, automated battery swapping station system, and BMS are operatively connected to enable long-distance travel without requiring prolonged stops for battery recharging.

According to another embodiment of the present invention, a method for facilitating long-distance travel in an electric vehicle, comprising the steps of utilizing an array of sensors to autonomously navigate a vehicle along a route; monitoring the state of charge of a modular battery pack within the vehicle through a battery management system; identifying a need

for a battery swap based on the monitored state of charge and locating a nearby battery swapping station using the autonomous navigation subsystem; autonomously guiding the vehicle to the located battery swapping station; automatically swapping the depleted battery pack with a charged battery pack through an automated mechanism at the station; and wherein the method enables continuous long-distance travel by minimizing downtime associated with recharging the battery pack.

According to an aspect of embodiment of the present invention, the plurality of sensors includes light detection and ranging (LIDAR), radar, cameras, and ultrasonic sensors.

According to another aspect of an embodiment of the present invention, further comprising a global positioning system (GPS) and mapping technology integrated with the autonomous navigation subsystems for route optimization including real-time traffic conditions.

According to another aspect of an embodiment of the present invention, the automated battery swapping station system uses renewable energy sources for charging the battery packs.

According to another aspect of embodiment of the present invention, the BMS is further configured to adjust the vehicle's energy consumption based on the current state of charge

30 and the estimated distance to the next swapping station.

According to another aspect of embodiment of the present invention, the step of utilizing an array of sensors includes processing data through a machine learning model for enhanced object detection and path planning.

According to another aspect of embodiment of the present invention, further comprising  
5 the step of dynamically updating the vehicle's route in response to changes in traffic conditions and station availability as detected by the autonomous navigation subsystem.

According to another aspect of embodiment of the present invention, the automated swapping includes a verification process to ensure the newly installed battery pack is fully operational and securely connected before the vehicle resumes travel.

10 According to another aspect of embodiment of the present invention, the modular battery pack includes a cooling system to maintain optimal operating temperatures during use and charging.

Various objects, features, aspects, and advantages of the inventive subject matter will become more apparent from the following detailed description of preferred embodiments,  
15 along with the accompanying drawing figures in which the same numerals represent like components

## **BRIEF DESCRIPTION OF THE DRAWINGS**

These and other features, aspects, and advantages of the present invention will become better understood through the following description, appended claims, and accompanying  
20 drawings:

**FIG. 1** illustrates a flowchart that outlines the steps involved in self-driving electric vehicles with swappable battery packs according to various embodiments.

## **DETAILED DESCRIPTION OF THE INVENTION**

The present invention has been particularly shown and described concerning certain  
25 preferred embodiment, and specific features thereof. The embodiments set forth hereinbelow are to be taken as illustrative rather than limiting.

The following description includes the preferred best mode of one embodiment of the present invention. It will be clear from this description of the invention that the invention is not limited to these illustrated embodiments but that the invention also includes a variety of modifications and embodiments thereto. Therefore, the present description should be seen  
5 as illustrative and not limiting.

While the invention is susceptible to various modifications and alternative constructions, it should be understood, that there is no intention to limit the invention to the specific form disclosed, but, on the contrary, the invention is to cover all modifications, alternative constructions, and equivalents falling within the spirit and scope of the invention as defined  
10 in the claims.

In any embodiment described herein, the open-ended terms "comprising," "comprises," and the like (which are synonymous with "including," "having" and "characterized by") may be replaced by the respective partially closed phrases "consisting essentially of," consists  
15 essentially of," and the like or the respective closed phrases "consisting of," "consists of, the like.

As used herein, the singular forms "a," "an," and "the" designate both the singular and the plural, unless expressly stated to designate the singular only.

The present invention relates to a self-driving electric vehicle equipped with an innovative swappable battery pack system. The present invention is designed to autonomously  
20 navigate the vehicles to the swapping stations, where depleted battery packs can be quickly exchanged for fully charged ones, significantly reducing downtime associated with recharging batteries. The present system includes a software program for route optimization, battery management, and autonomous driving functionalities, ensuring optimal performance and safety.

25 The key components of the present invention according to various embodiments are described below:

### **Autonomous driving system**

Sensors and perception: the array of sensors (LIDAR, radar, cameras, ultrasonic sensors) used for real-time data collection about the vehicle's surroundings; these sensors work together to create a 360-degree perception field, enabling the vehicle to detect and interpret objects, road conditions, traffic signals, and lane markings.

Software program: the software program processes sensor data to make driving decisions. This includes machine learning models for object detection and classification, models for path planning and decision-making, and systems for emergency response and anomaly detection. The updates and learning processes are managed continually to enhance system performance.

Navigation and route planning: the integration of GPS and mapping technologies with real-time traffic data to plan optimal routes. The vehicle autonomously adjusts its route based on traffic conditions, road closures, and the location of battery-swapping stations to ensure the most efficient path is taken.

Target Obstacle avoidance: The self-driving car easily avoids moving or stationary obstacles in the most unpredictable situations and this lies in its ability to effectively combine the strengths of Deep Deterministic Policy Gradient (DDPG) with Bayesian methods(Bayesian Reinforcement Learning) to solve obstacles for self-driving cars with a more durable, efficient, and adaptive autonomous driving system.

### **Battery pack design and swapping mechanism**

Modular battery packs: the design of the modular battery packs, including their capacity, dimensions, weight, and the materials used for enhanced energy density and safety; the cooling system that maintains optimal operating temperatures and the electrical architecture that allows for rapid charging and discharging.

Swapping mechanism: the automated system for battery swapping, including the mechanical structure with robotic arms, conveyors that remove depleted battery packs and replace them with charged ones, and the safety measures in place to ensure secure

attachment and detachment, as well as the electrical connection system that quickly integrates the new battery pack into the vehicle's power system.

Battery management system (BMS): the BMS monitors battery pack performance, including voltage, current, temperature, and state of charge and the BMS optimizes battery life through cell balancing and how it interfaces with the vehicle's central control unit to

adjust driving modes for energy efficiency.

### **Infrastructure for swappable battery stations**

Station design and location strategy: the design of the battery swapping stations, including their capacity, layout, and renewable energy sources (e.g., solar panels, wind turbines)

they utilize and the criteria for station placement, focusing on accessibility, proximity to major highways, and areas with high demand.

Operational logistics: the process for battery pack management within stations, including charging protocols, storage conditions, and inventory management and the system ensures

- 5 a sufficient supply of charged battery packs to meet demand, especially during peak travel times.

Integration with the electric grid and renewable energy: the stations' interface with the local electric grid, including energy storage solutions to mitigate demand spikes and the use of renewable energy sources to charge battery packs, emphasizing sustainability and reducing

- 10 the carbon footprint of electric vehicle travel.

### **User interface and experience**

Interaction with drivers: the vehicle's user interface and drivers can monitor the vehicle's status, and control settings, and communicate with the autonomous system, such as voice commands, touchscreen interfaces, and smartphone integration.

- 15 Reservation and payment system for battery swapping: the digital platform that allows drivers to reserve battery swaps in advance, check station availability, and manage payments and the system uses data analytics to predict demand and optimize station operations.

### **Safety and regulatory compliance**

- 20 Safety features: the safety systems integrated into the vehicle, including collision avoidance, lane-keeping assistance, and advanced emergency braking and the redundancies built into the autonomous system to ensure reliability and safety.

Compliance with regulations: the present invention complies with current automotive and traffic safety regulations, including those specific to electric vehicles and autonomous

- 25 driving and the certification processes and the system is designed to adapt to evolving regulatory landscapes.

### **Process of operation of the present invention:**

The present invention relates to self-driving electric vehicles equipped with swappable battery packs and describes a transformative approach to overcome the traditional limitations of electric vehicle (EV) range and refueling time, thus facilitating long-distance travel. The present innovation is the seamless integration of autonomous driving technology with a

- 5 modular battery systems designed for quick and efficient swapping.

The present invention comprises an array of sensors, including LIDAR, radar, cameras, and ultrasonic detectors, to continuously gather data about the vehicle's surroundings. This information is processed in real-time by an advanced computer programme that enables the vehicle to navigate safely through traffic, adjust its speed according to road conditions, and  
10 make intelligent driving decisions. The autonomy of the vehicle is further enhanced by GPS and mapping technologies, which help in planning the most efficient routes, taking into account the need for battery swaps and real-time traffic conditions.

When it comes to powering the vehicle, the current invention provides a modular battery pack system and these battery packs can be easily swapped at designated stations,

- 15 eliminating the long wait times traditionally associated with recharging electric vehicles. The vehicle autonomously navigates to a swap station when it's time for a new battery, where automated systems quickly exchange the depleted battery for a fully charged one. This process is designed to be significantly quicker than traditional charging, ensuring minimal downtime for the vehicle.

- 20 The battery management system (BMS) continuously monitoring the health and charge level of the battery to determine the optimal time for a swap. It ensures the vehicle's energy efficiency is maximized, and the battery's lifespan is extended through careful management of charging cycles and temperatures.

- 25 The present invention provides the infrastructure of battery swapping stations. Strategically located to serve routes with high demand, these stations are equipped with a stock of charged batteries ready to be swapped in. They are designed to be compatible with a network of renewable energy sources, contributing to the sustainability of the system by reducing the carbon footprint associated with vehicle charging.

- 30 The present invention provides a significant leap forward in making electric vehicles a practical and appealing options for long-distance travel. By addressing the twin challenges

of autonomous navigation and electric vehicle range, it paves the way for a future where road travel is safer, more efficient, and environmentally friendly.

Although the field of the invention has been described herein with limited reference to specific embodiments, this description is not meant to be construed in a limiting sense.

- 5 Various modifications of the disclosed embodiments, as well as alternate embodiments of the invention, will become apparent to persons skilled in the art upon reference to the description of the invention.

10

15

20

**I/We Claim:**

1) A self-driving electric vehicle system comprising:

an autonomous navigation subsystem equipped with an array of sensors for real-time data acquisition and processing to enable autonomous driving;

5 a modular battery pack designed for quick swapping, said battery pack being electrically connectable with the vehicle's power system;

an automated battery swapping station system for exchanging depleted battery packs with charged ones, wherein said station is equipped with automated mechanisms for removing and replacing the battery pack in the vehicle;

10 a battery management system (BMS) configured to monitor the state of charge and health of the battery pack and to communicate with the autonomous navigation subsystem to plan routes that include stops at battery swapping stations based on the vehicle's energy requirements; and

wherein the autonomous navigation subsystem, modular battery pack, automated

15 battery swapping station systems and BMS are operatively connected to enable long-distance travel without requiring prolonged stops for battery recharging.

2) A method for facilitating long-distance travel in an electric vehicle, comprising the steps of:

utilizing an array of sensors to autonomously navigate a vehicle along a route;

20 monitoring the state of charge of a modular battery pack within the vehicle through a battery management system;

identifying a need for a battery swap based on the monitored state of charge and locating a nearby battery swapping station using the autonomous navigation subsystem;

autonomously guiding the vehicle to the located battery swapping station;

25 automatically swapping the depleted battery pack with a charged battery pack through an automated mechanism at the station; and

wherein the method enables continuous long-distance travel by minimizing downtime associated with recharging the battery pack.

3) The system as claimed in claim 1, wherein the plurality of sensors includes light detection and ranging (LIDAR), radar, cameras, and ultrasonic sensors.

5 4) The system as claimed in claim 1, further comprises a global positioning system (GPS) and mapping technology integrated with the autonomous navigation subsystem for route optimization including real-time traffic conditions.

5) The system as claimed in claim 1, wherein the automated battery swapping station system uses renewable energy sources for charging the battery packs.

10 6) The system as claimed in claim 1, wherein the BMS is further configured to adjust the vehicle's energy consumption based on the current state of charge and the estimated distance to the next swapping station.

7) The method as claimed in claim 2, wherein the step of utilizing an array of sensors includes processing data through a machine learning model for enhanced object detection

15 and path planning.

8) The method as claimed in claim 2, further comprises the step of dynamically updating the vehicle's route in response to changes in traffic conditions and station availability as detected by the autonomous navigation subsystem.

9) The method as claimed in claim 2, wherein the automated swapping includes a

20 verification process to ensure the newly installed battery pack is fully operational and securely connected before the vehicle resumes travel.

10) The system as claimed in claim 1, wherein the modular battery pack includes a cooling system to maintain optimal operating temperatures during use and charging.

11- To enhance the vehicle's capabilities, the Bayesian Deep Deterministic Policy Gradient (DDPG) algorithm is employed for training autonomous vehicles to effectively avoid obstacles in dynamic environments. By integrating Bayesian uncertainty estimation into the DDPG framework, the algorithm enhances decision-making, particularly in scenarios requiring swift maneuvers to avoid obstacles. This supports online adaptation by continuously updating the actor and critic networks based on new observations, improving overall performance and robustness. The Bayesian DDPG prioritizes safety-critical decision-making by considering uncertainty estimates in action selection, ensuring the safety of the vehicle and its occupants.

## BAYESIAN DDPG ALGORITHM

Exploration Noise (Random actions)



Observe Actions and Get new state



Store Observations (Replay buffer)



Sample Observations (random samples)



Compute Target Q Value (Rewards + future rewards)



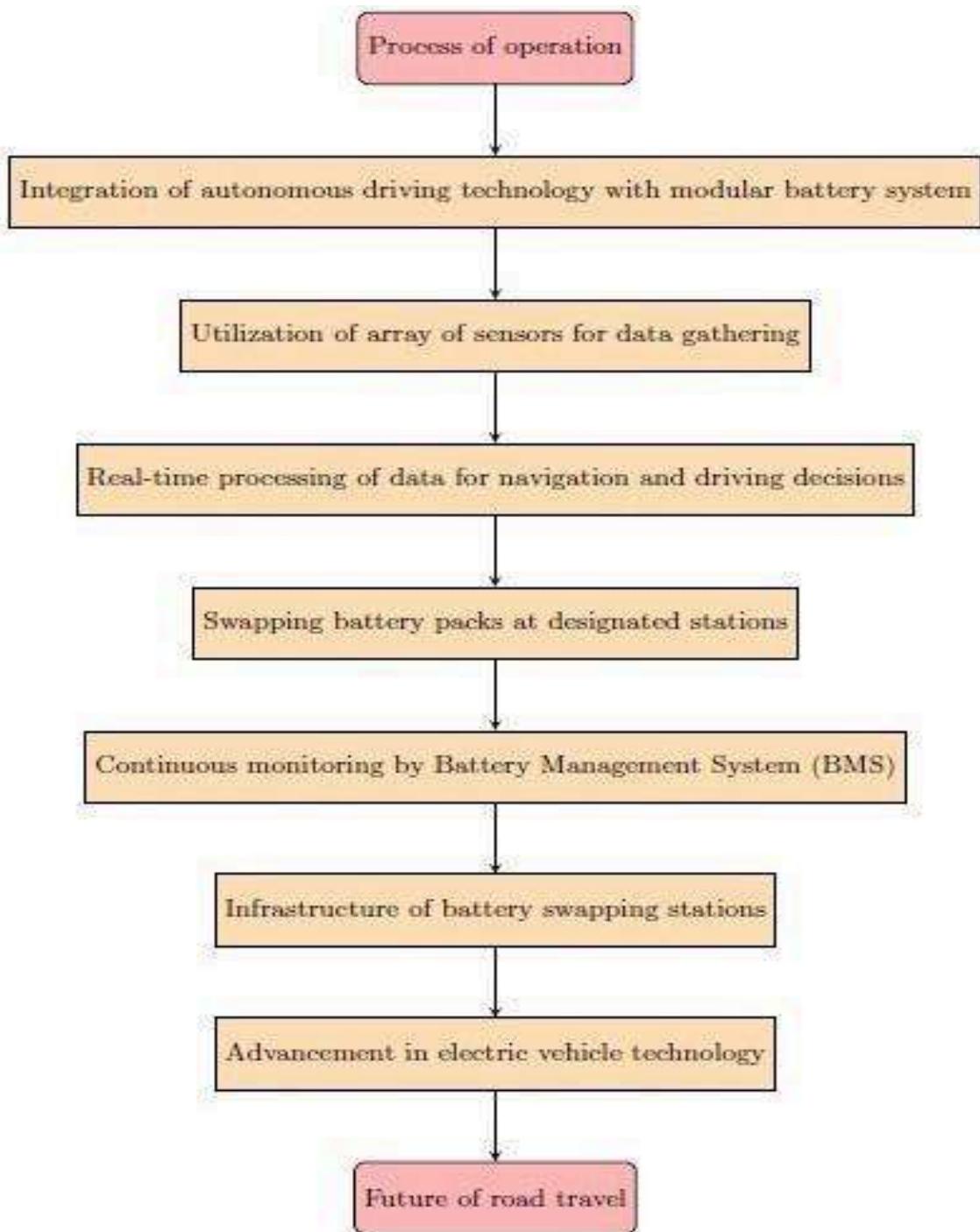
Update Critic Network (Minimize Q value error) and Update Actor Network



Improve decisions) and Update the Target Network



Check if Episode is Done (Continue or stop)





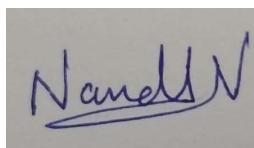
## **ABSTRACT**

### **SELF-DRIVING ELECTRIC VEHICLES**

The present invention relates to self-driving electric vehicles equipped with swappable battery packs, designed to facilitate long-distance travel without the limitations of conventional charging times. The present invention encompasses an autonomous navigation subsystem, employing an array of sensors including LIDAR, radar, cameras, and ultrasonic detectors for real-time environmental data processing. A modular battery pack, central to the vehicle's design, enables quick and efficient energy replenishment at automated battery swapping stations. These stations, integral to the ecosystem, support rapid exchange of depleted batteries for charged ones, underpinned by renewable energy sources for sustainability. A sophisticated battery management system (BMS) monitors battery health, optimizing energy usage and routing to include timely swaps, ensuring uninterrupted travel.

To enhance the vehicle's capabilities, the Bayesian Deep Deterministic Policy Gradient (DDPG) algorithm is employed for training autonomous vehicles to effectively avoid obstacles in dynamic environments. This algorithm supports online adaptation by continuously updating the actor and critic networks based on new observations, improving overall performance and robustness. By considering uncertainty estimates in action selection, the Bayesian DDPG prioritizes safety-critical decision-making, ensuring the safety of the vehicle and its occupants. Bayesian methods enable the agent to model and distinguish between epistemic and aleatoric uncertainty, allowing for more informed decision-making. Efficient exploration and policy improvement are facilitated by balancing exploration and exploitation, updating the policy based on both sampled experiences and uncertainty estimates, thus minimizing the impact of uncertainty on decision-making.

## **SIGNATURES:**



Nandhini Venkataraman -

Vasupratha

**Vasupratha Manivannan -**

Pramikha

**Pramikha Kannan -**