ISSN 2616-5767 Vol.7, Issue 3: 110-115, DOI: 10.25236/AJETS.2024.070316

# Design of Unmanned Trolley Target Search and Adaptive Charging System Based on Multimodal Perception

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***Abstract:*** *This paper aims to design an unmanned trolley target search and adaptive charging system based on multimodal perception, so as to improve the autonomous navigation, target positioning and search ability of unmanned trolley in complex environment, and realize the autonomous management and supplement of energy. The paper first summarizes the principle of multimodal perception technology and its application in unmanned car, including various data fusion methods, such as vision, radar and acoustics. Subsequently, the target search system of the unmanned car is designed, through the feature extraction, identification algorithm and path planning strategy, to realize the efficient search and positioning of the target. At the same time, an adaptive charging system is built, which realizes the autonomous charging function of unmanned cars through energy state monitoring, identification and positioning of charging facilities, and the strategy of autonomous navigation and charging docking. In the experimental verification stage, this paper builds the hardware platform of unmanned car and designs the corresponding software system. The effectiveness and reliability of target search and adaptive charging system are verified through the indoor and outdoor environment. The experimental results show that the system can accurately identify the target, plan the reasonable path, and independently find the charging facility for charging when the energy is insufficient. This study not only enriches the research results in the field of unmanned vehicle technology, but also provides strong support for the application of unmanned vehicle in a complex environment. In the future, it will further optimize the system performance, expand the application field, and promote the sustainable development of unmanned car technology.*

***Keywords:*** *Multimodal Perception, Unmanned Car, Target Search, Adaptive Charging, Data Fusion, Feature Extraction*

## 1. Introduction

With the continuous progress of science and technology, the unmanned car, as an intelligent mobile platform, has shown broad application prospects in many fields. Among them, the target search and adaptive charging technology are the key to realize the long-term independent operation of the unmanned car. Multi-modal sensing technology, through the fusion of various sensor information, improves the sensing ability of the unmanned car in a complex environment. Therefore, it is of great theoretical value and practical significance to study the unmanned vehicle target search and adaptive charging system based on multimodal perception. This paper aims to design a target search and adaptive charging system based on multimodal sensing, improve the target search capability of the unmanned vehicle in complex environment, and realize the long-term stable operation with the adaptive charging technology. The development of this study will not only help to promote the development of unmanned vehicle technology, but also can provide technical support and solutions for practical applications in related fields.

### *1.1 Research Background and Significance of Unmanned Trolley*

With the rapid development of science and technology, unmanned car, as a new mobile device integrating automation and intelligence, has attracted increasing attention from all walks of life. With its unique mobility and flexibility, the unmanned car has shown great application potential in logistics, transportation, environmental monitoring, military reconnaissance and other fields. In the field of logistics, unmanned car can handle and distribution of goods, improve logistics efficiency and reduce

ISSN 2616-5767 Vol.7, Issue 3: 110-115, DOI: 10.25236/AJETS.2024.070316

labor cost; in the field of environmental monitoring, unmanned car can conduct data collection and sample analysis in inaccessible areas and provide valuable data for scientific research; in the military field, unmanned trolley can perform reconnaissance and patrol tasks, reduce personnel risk and improve operational effectiveness. Therefore, the research of unmanned car technology is of great significance to promote the development of related industries, improve social production efficiency and enhance national defense strength.

### *1.2 The Development Status of Multimodal Sensing Technology*

Multi-modal sensing technology is the core means for unmanned cars to realize intelligent sensing. Through the fusion of various sensor information, it realizes the comprehensive and accurate perception of the surrounding environment [1]. Currently, significant progress has been made in multimodal sensing technology. In terms of visual perception, the application of deep learning algorithm enables unmanned trolley to identify complex image information and realize the functions of target tracking and scene understanding. In radar perception, millimeter-wave radar and laser radar improves the obstacle detection and positioning accuracy of unmanned trolley in complex environment; acoustic perception and infrared perception have been widely used in unmanned trolley. However, multimodal sensing technologies still face some challenges, such as information fusion problems between different sensors, sensing data processing and analysis problems, etc. Therefore, continued in-depth research and optimization of multimodal sensing technology is crucial to improve the perception performance and intelligence level of unmanned cars.

### *1.3 Research Status of Unmanned Trolley Target Search and Adaptive Charging System*

The research on target search and adaptive charging is gradually becoming a hot spot. The target search system and the adaptive charging system can find the charging facilities to ensure the long-term stable operation of the unmanned vehicle. At present, some research teams have made preliminary results in target search and adaptive charging of unmanned vehicles, but there are still some problems, such as optimization of target search algorithm, identification and positioning accuracy of charging facilities, etc. Therefore, this study aims to propose a more efficient and reliable unmanned trolley target search and adaptive charging system through deep research and innovation.

### *1.4 Research Purpose, Content and Innovation Points*

This study aims to design a vehicle target search and adaptive charging system to solve the problem of target search and energy supply in complex environment. The research contents mainly include the fusion and optimization of multi-modal sensing technology, the design and implementation of target search algorithm, and the formulation and implementation of adaptive charging strategy. In terms of innovation, this study will propose a new multi-modal sensing data fusion method to improve the accuracy and stability of the unmanned vehicle on the surrounding environment. At the same time, this study proposed a deep learning-based target search algorithm to achieve rapid and accurate identification and positioning of unmanned vehicles. In this paper, an adaptive charging strategy is proposed based on the energy state and environmental information of unmanned vehicles. Through the implementation of the above research content and innovation points, this research aims to provide new ideas and solutions for the development and application of unmanned car technology, and promote the progress and development of related industries.

## 2. Principle of Multimodal Sensing Technology and Its Application in Unmanned Cars

The principle of multimodal perception technology is to integrate the information obtained by different sensors, such as vision, hearing, touch, etc., to achieve a more comprehensive and accurate perception of the environment. In the unmanned car, the technology captures camera images, radar detection distance, speed, sonar recognition sound, etc., and integrates various data analysis, so that the car can more accurately identify road conditions, obstacles and pedestrians. This not only improves the safety and stability of the unmanned car, but also enhances its autonomous navigation and decision-making capabilities, enabling it to drive more freely in complex environments.

### *2.1 Overview of Multi-Modal Sensing Techniques*

Multi-modal perception technology, in short, is to combine a variety of different modes of sensor

ISSN 2616-5767 Vol.7, Issue 3: 110-115, DOI: 10.25236/AJETS.2024.070316

information, to carry out the comprehensive and multi-angle perception of the surrounding environment [2]. This technology can make full use of the advantages of different sensors in the perception ability, make up for the lack of perception range and accuracy of a single sensor, so as to improve the acquisition ability and processing efficiency of unmanned car to environmental information. In unmanned cars, multi-modal perception technology mainly relies on various technical means such as visual perception, radar perception and acoustic perception. These technical means each have their own characteristics, complement each other, and together constitute the core of the unmanned car perception system.

### *2.2 Application of Multimodal Sensing Technology in Unmanned Trolley*

Visual perception technology mainly relies on the camera and other image acquisition equipment, through image processing and analysis, the realization of the recognition and understanding of the surrounding environment. In unmanned cars, visual perception technology is widely used in road sign identification, obstacle detection, pedestrian recognition and other scenarios. Through deep learning and computer vision algorithms, the driverless car can accurately identify various elements on the road to make the right decisions and actions. Radar sensing technology uses radar equipment to transmit electromagnetic waves and receive the reflected back signals to realize the ranging and speed measurement of the surrounding environment. In unmanned vehicles, radar sensing technology is mainly used to detect obstacles ahead, measure distance and speed and other information. Through the fusion with other sensor data, the unmanned car can more accurately judge the position and speed of obstacles, so as to make timely obstacle avoidance actions. Acoustic perception technology mainly relies on sound sensors and other equipment, through the acquisition and analysis of sound signals, to realize the perception of the surrounding environment. In unmanned cars, acoustic sensing technology is mainly used to detect the sound information around the vehicle, such as the horn sound of other vehicles and the speech sound of pedestrians. These information is of great significance for the safe driving of unmanned cars in complex environments.

### *2.3 Multimodal Perceptual Data Fusion Method*

Multimodal perception data fusion is the core link of multimodal perception technology. Because different sensors differ in perception principle, accuracy and range, their data is fused to get more comprehensive and accurate environmental information. Data fusion methods usually include steps such as data preprocessing, feature extraction, data association, and decision fusion. First, the raw data from different sensors is pre-processed to eliminate noise and interference; then, the characteristic information of each sensor data is extracted; then, the data of different sensors are matched and related by data association algorithm; and finally, the decision results use the decision fusion algorithm to obtain the final perceptual result. Through multi-modal perception data fusion, the unmanned car can make full use of the advantages of various sensors to improve the perception ability and processing efficiency of environmental information. This not only helps to improve the safety and stability of the unmanned car, but also provides strong support for it to realize autonomous navigation and intelligent decision-making in a complex environment. Multi-modal sensing technology provides the unmanned car with a strong sensing ability, which makes it perform well in navigation, positioning and obstacle avoidance. With the continuous progress of technology and the continuous expansion of application scenarios, multimodal sensing technology will play a more important role in the field of unmanned cars.

## 3. Design of the Unmanned Trolley Target Search System

In the development process of unmanned car technology, the target search system is a crucial link. This system integrates multiple sensing technologies to achieve precise search and positioning of specific targets. The overall architecture of the unmanned vehicle target search system, the extraction and identification algorithm of target features, and the target positioning method and path planning and target search strategy based on multimodal sensing will be described in detail below.

### *3.1 Overall Architecture of the Target Search System*

The overall architecture of the unmanned trolley target search system is a highly integrated system, which covers multiple levels such as perception, decision making and execution [3]. At the perception level, the system collects environmental information through multi-modal sensing devices such as

ISSN 2616-5767 Vol.7, Issue 3: 110-115, DOI: 10.25236/AJETS.2024.070316

high-definition cameras, lidar and sonar; at the decision-making level, the system uses advanced target feature extraction and identification algorithm to process and analyze the sensing data to identify and locate targets; at the execution level, the system plans the optimal path and controls the unmanned car to search for targets.

### *3.2 Target Feature Extraction and Identification Algorithm*

Target feature extraction and recognition algorithm is the core part of the unmanned target search system. These algorithms are based on deep learning and image processing techniques to extract the feature information of the target through the in-depth analysis of the perceptual data. For example, for visual perception data, the algorithm can identify the shape, color, texture and other features of the target; for radar perception data, the algorithm can analyze the dynamic information such as the distance and speed of the target. Through the extraction and matching of these features, the system can achieve the accurate identification of the targets. In the selection of recognition algorithm, we adopted advanced convolutional neural network (CNN) and support vector machine (SVM) and other technologies. These algorithms not only have high recognition accuracy, but also able to adapt to changes in different environments and target types. At the same time, we also constantly optimize the parameters and structure of the algorithm to improve the real-time and robustness of the algorithm to meet the needs of unmanned cars for target search in complex environments.

### *3.3 Target Targeting Method Based on Multimodal Sensing*

The target positioning method based on multimodal sensing is one of the key technologies of the target search system. This method enables precise positioning of targets by incorporating data from different sensing devices. Specifically, we first use the visual perception device to obtain the image information of the target, and extract the outline and location of the target through the image processing technology, then use the radar sensing device to obtain the distance and speed of the target, further determine the position of the target in the space; finally, we obtain the sound information of the target through the acoustic sensing device, so as to help verify the presence and location of the target. In the process of data fusion, we use the weighted average method, Kalman filter and other algorithms to fuse and optimize the data from different sensing devices. These algorithms are able to fully consider the complementarity and redundancy between different sensors to improve the accuracy and reliability of localization results. At the same time, we also use real-time calibration and update the sensor parameters and ensure the real-time and stability of the positioning results.

## 4. Design of Adaptive Charging System of Unmanned Car

With the increasing maturity of unmanned car technology, its endurance has become one of the key factors restricting its wide application. In order to solve this problem, we designed an adaptive charging system for the unmanned car to ensure that the unmanned car can independently find charging facilities and charge them when needed [4]. The following will introduce in detail the overall architecture of the adaptive charging system, energy state monitoring and evaluation methods, charging facility identification and positioning technology, and charging docking strategies for autonomous navigation and charging, and discuss relevant security and stability guarantee measures [5].

### *4.1 Overall Architecture of the Adaptive Energy Charging System*

The overall architecture of the adaptive charging system is a highly integrated system, which aims to realize the real-time monitoring of the energy state of the unmanned car, the identification and positioning of charging facilities, and the autonomous navigation and charging functions. The system is mainly composed of energy monitoring module, charging facility identification module, navigation planning module and execution control module. Through efficient data interaction and collaborative work among the modules, it ensures that the unmanned car can accurately judge its own energy state, find the charging facilities in time, and complete the charging process safely and efficiently.

### *4.2 Energy State Monitoring and Assessment Method*

The monitoring and evaluation of energy state is one of the core functions of the adaptive charging system [6]. Through the power sensor and battery management system integrated in the unmanned car, we obtain the power information of the unmanned car in real time. At the same time, combined with the

ISSN 2616-5767 Vol.7, Issue 3: 110-115, DOI: 10.25236/AJETS.2024.070316

driving speed, load, road conditions and other factors, the power consumption is predicted and evaluated. When the power level is lower than the preset threshold, the system will automatically trigger the charging request and start the charging facility identification and positioning process.

### *4.3 Charging Facility Identification and Positioning Technology*

Charging facility identification and positioning technology is one of the key technologies of adaptive charging system. We use the camera, lidar and other sensor equipment equipped by the unmanned car to perceive and analyze the surrounding environment. Through image recognition, machine learning and other technical means, identify the characteristic information of charging facilities, such as the shape, color, logo of charging pile. At the same time, the specific location of the charging facility is determined by combining the GPS positioning system and the map information. On this basis, the system can plan the optimal path for the unmanned car to reach the charging facilities.

### *4.4 Autonomous Navigation and Charging Docking Strategy*

After determining the location of the charging facility, the unmanned car needs to independently navigate to the charging facility and complete the charging docking. We use advanced path planning algorithm and navigation control technology to ensure that the unmanned car can accurately and stably drive near the charging facility. In the process of charging docking, the system accurately controls the speed and position of the unmanned car to achieve accurate docking with the charging pile. At the same time, we also designed an intelligent charging management system, which automatically adjusts the charging current and voltage according to the power demand of the unmanned car and the charging power of the charging pile, so as to ensure the safety and efficiency of the charging process [7].

### *4.5 Safety and Stability Safeguard Measures*

In order to ensure the security and stability of the adaptive charging system, we take many safeguard measures. First, in terms of hardware design, we use highly reliable sensors and actuators to ensure that the system still works properly in harsh environments. Secondly, in terms of software algorithms, we constantly optimize the path planning and navigation control algorithms to improve the robustness and anti-interference ability of the system. We have also set up multiple safety protection mechanisms, such as too low power protection, over current and over voltage protection during the charging process, etc., to deal with possible abnormal situations.

## 5. System Implementation

### *5.1 Hardware Platform Construction of Unmanned Car*

The hardware platform of the unmanned car is the basis for realizing its functions. In the process of construction, the driving stability of the car, the sensor integration degree and the calculation performance of the car should be fully considered. First of all, we choose the high-performance motor and drive system to ensure that the car can drive smoothly and quickly respond to the control instructions. Second, we integrate multiple sensors, such as lidar, camera and IMU, to achieve all-round perception of the surrounding environment. These sensors are connected to the master control board through proper interfaces and circuit boards to ensure accurate transmission and processing of data. Finally, we choose a processor with powerful computing power to support complex algorithm operation and real-time decision making. During the construction of the hardware platform, we pay attention to detail and quality control to ensure the accuracy and reliability of each component. At the same time, we also fully consider the scalability and maintainability of the platform, in order to flexibly adjust and optimize in the subsequent development and debugging process.

### *5.2 Design and Implementation of the Software System*

Software system is the key to realize intelligent behavior. We adopt the modular design idea to divide the software system into perception module, decision module and execution module. The sensing module is responsible for processing the raw data from sensors and extracting useful environmental information; the decision module formulates the driving strategy according to the sensing information; the execution module is responsible for converting the decision instructions into specific control signals to drive the car.

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In the implementation of the software system, we focus on the optimization and real-time algorithm. We use advanced deep learning algorithms for target recognition and path planning to ensure that the car can accurately identify targets and plan the optimal path in a complex environment. At the same time, we also improve the real-time performance of the software system through multi-threaded and asynchronous processing technology, to ensure that the car can quickly respond to environmental changes and make corresponding adjustments. We also focus on the stability and reliability of the software system. Through the rigorous testing and verification process, we ensure that the software system can operate stably and achieve the desired results in various scenarios. At the same time, we also provide a friendly user interface and debugging tools to facilitate the follow-up development and maintenance work.

## 6. Conclusions and Prospects

Through the in-depth research and practice of the unmanned vehicle multimodal sensing technology and its application in the target search and adaptive charging system, we have achieved a series of satisfactory results. The integrated application of multi-modal sensing technology significantly improves the perception ability of the unmanned car in a complex environment, so that it can more accurately identify targets, locate itself, and plan the optimal driving path. At the same time, the design and implementation of the adaptive charging system provides a strong guarantee for the continuous operation of the unmanned car, and solves the key problem of endurance. In terms of hardware platform construction, we have successfully integrated the high-performance motor, drive system and sensors, to build a stable and reliable unmanned car platform. In the design and implementation of the software system, we adopted the modular design idea to realize the collaborative work of functions such as perception, decision-making and execution, and ensure the efficient operation of the software system through algorithm optimization and real-time processing. However, we are also aware that the development of unmanned car technology still faces many challenges. In the future, we will continue to study the fusion method of multimodal sensing technology to further improve the sensing accuracy and robustness of unmanned cars. At the same time, we will also focus on more efficient path planning algorithms and more intelligent charging docking strategies, in order to improve the operation efficiency and autonomy of unmanned cars. With the rapid development of artificial intelligence and Internet of Things technology, the application scenarios of unmanned cars will continue to expand. We expect that unmanned cars can play a greater role in logistics, inspection, rescue and other fields, and make more contributions to the development of human society. The development prospect of unmanned car technology is broad. We will continue to make efforts to promote the innovation and development in this field, and contribute to the construction of a more intelligent and more convenient future society.

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