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Overview on Behaviour Decision and Motion Control Technology of Unmanned Express Transport Vehicles

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ABSTRACT: Unmanned logistics transportation is the development trend of transportation express industry, this paper summarizes and introduces the algorithms of environment perception technology and path planning technology in the control part of unmanned express transporter, analyses the application of environment perception sensors of unmanned express transporter and the working principle of environment perception algorithms corresponding to it with the current status of research, and introduces the principle of intelligent bionic algorithms commonly used in the path planning with the current status of research. Through the introduction of the achievements of researchers in recent years, the main research contents and directions in the field of behavioural decision-making and motion control technology of unmanned express delivery vehicles are analysed, and the outlook of the field of behavioural decision-making and motion control technology of unmanned express delivery vehicles are reasonably made.

KEYWORDS: Unmanned transportation, environment perception, path planning, algorithms.

I. INTRODUCTION

In recent years, with the rapid development of the e-commerce industry, logistics and express delivery gradually into the rural cities of thousands of households. Although the logistics industry in most countries has been very developed, but for the logistics industry exists "last kilometres" is still no good solution. The traditional transportation method is through the courier delivery of goods or let consumers take the initiative to pick up the courier centralized, this artificial delivery method can certainly solve the logistics "last kilometres" problem, but there are certain drawbacks[1].With the transformation of the national economic structure and demographic structure, the rise in labour costs is an irreversible trend, coupled with the further growth of online shopping scale, if the traditional mode of transportation is still used, will inevitably lead to a continuous rise in the cost of express delivery, which increases the burden on consumers, while picking up the consumer experience is also made to further reduce the consumer experience[2].

Considering this, unmanned urban courier transports have been created. Amazon is the earliest enterprise to enter the field of unmanned delivery, but the main field of its research is the logistics and distribution of drones, but because of the many restrictions on the flight of drones, only some special areas to meet the flight of drones for delivery [3]. For unmanned courier transporters with a wider range of uses and adaptations, the U.S. company Starship Technologies (Starship Technologies) designed and developed a unique small electric unmanned vehicle in 2015, with a range of about 5 kilometres, which allows users to check the location in real time and open the door to pick up the goods after arriving at the designated location through the cell phone application APP[4]. In 2018, UDELV and Nuro in the United States launched their own company independently developed and designed fully automated unmanned delivery vehicles.UDELV company designed a self-driving transport van is mainly applied to longer distances on empty unmanned roads, and the first run started from San Mateo County, California, and routed through dozens of kilometres of highway to distribute the goods to various Customers, the vehicle can be 40 km / h driving at a constant speed, the range of up to 100 highway, is a typical representative of the longer distance transportation. Nuro company designed unmanned delivery truck at the beginning of the design is to be able to be closed parks in low-speed drivingbut taking into account some of the needs of its transportation in the city road, or to increase its normal driving in all kinds of urban roads[5]. And its design also uses new lightweight materials, reducing the weight of the vehicle, and transportation efficiency is higher.

Currently in the city unmanned car research organizations mainly to major e-commerce companies and universities, its purpose is also to solve the logistics courier transport process of the "last kilometres" problem, so compared to other driverless electric vehicles and traditional fuel cars, urban unmanned express delivery vehicle has unique characteristics. First of all, at present, its application is mainly in colleges and universities and some independent industrial parks, the main feature of the scene is that the traffic situation is not complex, the main conflict traffic flow is the flow of people; Secondly, the scene for the range requirements are not demanding, on the market at present in terms of business vehicles, electric car range is still a big problem, the essence of the development of battery technology is still imperfect, therefore, electric vehicles want to Completely replace the fuel car is still immature[6]. However, for the urban unmanned express delivery vehicle, there is no such deficiency, the reason is that most of the urban unmanned express delivery vehicle transport radius is within a circle of ten kilometres, the current battery range can fully meet the driving requirements of unmanned express delivery vehicle. Furthermore, due to the transportation distance for short-range transportation, and the arrival time is not harsh, and at the same time, for the consideration of unmanned control and safe driving, the speed requirement of unmanned express delivery vehicle is generally around 30 km / h. Therefore, compared with the traditional unmanned car and fuel car, its braking system and the steering system requirements are much smaller, so that the focus of the research and development and the difficulty is mainly concentrated in the control, the research and development costs is also much lower compared to driverless cars.

II. ENVIRONMENT PERCEPTION TECHNOLOGY

The main components of environmental perception technology are environmental perception sensors and corresponding environmental perception algorithms, common perception system sensors (based on LiDAR) can be divided into two categories: radar and visual sensors[7]. Radar sensors are based on their different operating principles, such as LiDAR, millimetre-wave radar, etc., and the most common sensors for visual sensors are camera Perception velocity.

Various types of sensors have their own advantages and disadvantages, their application of the scene and the application of the location of the car is also very different, the advantages and disadvantages of the three commonly used radar is summarized and summarized, its advantages and disadvantages are shown in the table below.

NAME	VANTAGE	DISADVANTAGES
LIDAR	Less interference from the environment, with the advantages of high measurement accuracy and high resolution	High cost, highly affected by climate, unable to recognize patterned text
MILLIMETER-WAVE RADAR	Relative speed and velocity can be accurately obtained Strong anti-interference ability, high resolution	Unable to provide obstacle height information, weak perception of stationary objects
CAMERA PERCEPTION	Low cost, can capture color signals, high accuracy of close-range identification	Disadvantages such as poor stability of zoom lens and inaccurate recognition of distant objects

Environmental perception technology is the basis of unmanned control vehicles, the more accurate and real-time raw data obtained from the outside world, the more secure and intelligent the control of unmanned express transportation vehicles. Based on the different sensors, the external sensing technology is divided into LiDAR, millimeter-wave radar and camera Perception technology, and the following will summarize the recent achievements of these three sensing technologies one by one.

2.1 LiDAR technology

LiDAR is the most effective in obstacle detection, but due to the high price, it is not much used in low-cost unmanned logistics and transportation vehicles at present. Although there are not many applications at present, but its accurate detection effect still makes it has a lot of research space, for the two-dimensional and three-dimensional classification of LiDAR, many colleges and universities have carried out different algorithm research respectively.

Zeng Fan[8]according to 2D LiDAR scanning road point cloud characteristics, using the nearest neighbor algorithm, provides a new passable area detection algorithm, this method first remove the road surface and then through the inverted "L" type point cloud to extract the corner points in the use of least squares to further determine the road boundary. In terms of obstacle recognition, the adaptive threshold clustering method and the improved DBSCAN clustering algorithm can effectively recognize and avoid obstacle targets at low speeds.

Duan Jianmin et al.[9]proposed a multi-layer LiDAR scanning technology, the core content of which is the establishment of different levels of scanning layer coordinates, i.e., the establishment of the coordinate system of the car and the sensor respectively, and then for the same level of the coordinate system for the individual processing, and finally the information obtained will be fused and analyzed to obtain the final data and then determine the obstacles and some of the positional relationship of the surrounding roadside.

Wang Jun[10]proposed a 3D LiDAR obstacle detection algorithm based on four-dimensional spatial filtering, which solves the shortcomings of traditional raster map-based algorithms that are prone to failing to recognize obstacles correctly due to improper segmentation. Yin Zhang et al.[11]designed a new obstacle detection method using 3D LiDAR and 3D point cloud technology. In the peripheral data collection using three-dimensional LiDAR to obtain intelligent unmanned vehicles point cloud original data, on this basis through the deep learning algorithm training its speed and accuracy of obstacle recognition, after the real vehicle test proved that the efficiency and accuracy of the algorithm compared with the traditional recognition algorithm has a greater improvement.

2.2 Millimeter-wave Radar

Zhou Xiaojun[12]simplified the traditional JPDA algorithm, and solved the problem of measurement noise when radar can cause leakage and operational interference by iterating and updating the state of the life cycle theory and Kalman filtering technique. At the same time, the algorithm is united with the traditional joint probability, and the experiment proves that the tracking algorithm can provide the target's motion state information for the intelligent driving system in real time.

Yoneda[13]uses interactive multi-model to transform the observation point coordinates to two-dimensional image coordinates, using the covariance matrix and integrating the corresponding region of the likelihood distribution, to calculate the change of the vehicle linear velocity and the swing angular velocity over time, and match it with the information of the millimeter-wave radar system, which is able to do the efficient and real-time updating of the vehicle position, laying a foundation for the system to judge the decision-making.

Gan Yaodong, et al.[14]addressed the problem of low accuracy and poor real-time performance of existing vehicle detection algorithms fusing millimeter-wave radar and traditional machine vision, designed a neural network algorithm based on adaptive Kalman filter tracking algorithm with SSD+MobileNetV2 for forward vehicle detection, to further improve the accuracy and speed of the fusion detection algorithm, and at the same time, established a framework for the fusion of millimeter-wave radar and deep vision information. At the same time, a millimeter-wave radar and deep vision information fusion framework is established, and experimental verification on complex road conditions shows that the algorithm effectively reduces the leakage rate of radar detection and tracking and improves the accuracy of the estimation of the target vehicle's position, motion state, and geometric parameters.

2.3 Camera Perception Technology

Camera as the representative of the early development of visual sensors, has become mature, the basic principle is through the camera captures the image processing, to calculate the parameters of the obstacle, such as the center of gravity, location, area, etc., and output data to the control center as a basis for judgment. Its advantage is that it can obtain enough raw image data and is cheap, although there are also problems such as short detection distance and the influence of light.

Cai[15]conducted systematic research on multimeric fusion perception for unmanned vehicles to solve the problem of the blind area of the field of view obtained by a single on-board camera. Through the reasonable layout of the cameras, it is possible to use the least number of multimeric cameras to cover the largest sensing area, and at the same time, the multimeric fusion algorithm is applied to integrate the individual cameras as a whole, so as to make them work as a system, and it is proved through experiments that the system can work properly in complex roads, such as icy and snowy roads, as well as in areas of low visibility, and can be recognized efficiently, and it basically achieves the system robustness and real-time performance. robustness and real-time performance of the system.

AL Khorshid[16]proposed a camera-based method for detecting lane markings, introducing a benchmark dataset obtained under different lighting conditions and combining a machine learning model and based on the Hough transform, the inverse perspective mapping method to detect the initial lane markings, combining the gradient magnitude of the edge image and the Kalman filter, and the information tracking of the next frame using the traceless Kalman filter. To compensate for the lack of the trace-free Kalman filter modeling, the inverse perspective mapping method and the Hough transform were used to detect the baseline model. Vehicle offsets relative to the left and right lane markings are modeled as a function of time and the future values of the offset parameters are predicted using the traceless Kalman filter based on the observations from the previous frame of the image.

2.4 Summary

For the LiDAR with better application prospects, researchers have carried out algorithm research and improvement of 2D and 3D LiDAR according to the classification of its different scanning space, which is mainly applied to the obstacle detection and road boundary detection in the environment sensing technology of unmanned logistics courier transporter, and many results have been achieved; for the millimeter wave radar which can accurately obtain the relative speed and velocity, it is applied to provide the target's motion The millimeter wave radar that can accurately obtain the relative speed and velocity is used to provide the target's motion and state information, so as to provide a basis for the system to judge the decision-making; and for the camera sensing technology with high accuracy in close-range recognition, it is optimized through the reasonable arrangement and establishment of fusion sensor algorithms, so that the camera sensing technology can take the strengths and make up for the weaknesses, and better satisfy the requirements of existing markets.

With the rapid development of the logistics industry, the complexity of the working environment of the unmanned logistics express transportation vehicle is also increasing, which makes a single radar detection technology has been unable to meet the existing social needs, in order to provide more accurate information on the external environmental data, while making the detection and processing of obstacle data more accurate, stable and real-time, according to different driving environments, a class or more types of radar equipment combined use, through the use of different radar equipment with different detection characteristics, the design of the corresponding fusion algorithms can greatly improve the identification of its accuracy.

In recent years, deep learning technology has received extensive attention from researchers because it can automatically learn the effective features of the target and ensure good detection without manual extraction of features[17]. Therefore, in the current research of unmanned logistics express transportation vehicle sensing technology, deep learning and machine learning technology with traditional algorithms has gradually become a popular research method and has a good application prospect for lane line detection, obstacle detection and road boundary detection in sensing technology.

III. PATH PLANNING TECHNOLOGY

3.1 Intelligent Bionic Algorithms

Path planning is the core technology for the intelligent operation of unmanned express delivery vehicles. Its degree of maturity determines the degree of intelligence of unmanned express transportation vehicles. At present, the commonly used path planning has the path planning based on intelligent bionic algorithm and the path planning algorithm based on dynamic environment.

The principle of intelligent bionic algorithm is more flexible and diverse, in line with the ecological characteristics of the natural world, and has a strong ability to adapt to problems, so it can be applied in the path decision-making of unmanned transportation vehicles. Intelligent bionic algorithms mainly include Particle Swarm Optimization Algorithm(PSO), Artificial Fish Swarm algorithm(AFSA), Genetic Algorithm(GA), Artificial Neural Network Algorithm(ANN) and so on. Their main advantages and disadvantages are as follows.

NAME OF ALGORITHM	VANTAGE	DISADVANTAGES
PSO	Fast early convergence; few setup parameters; simple operation	It is easy to fall into local optimization and not achieve satisfactory global optimization results
AFSA	Fast convergence; Good global search ability; Adaptive to search space	Slow convergence; easy to fall into local optimization; decrease in accuracy of optimal solution
ANN	Strong nonlinear mapping ability; self-learning and self-adaptive ability	Long training time; easy to fall into local minima; slow convergence speed
GA	Global optimization capability; Intrinsic parallelism	Slow convergence; easy to fall into local optimization

To better enable these algorithms to be used for unmanned transport vehicle path planning applications, many researchers have also continued to improve them, and some notable results have been achieved so far.

PSO was first introduced into unmanned transportation vehicle path planning by Yuanqing Qin et al[18]. However, due to its shortcomings of slow convergence in the later stage, easy to appear local optimization, and failing to reach the overall optimization, the application is not very convenient. To solve this problem Li et al.[19]considered multiple objectives to establish an objective function, and then introduced a new adaptive mechanism and applied a boundary violation processing scheme to limit the velocity and position of each particle, which avoids local convergence and makes it possible to achieve global convergence. While Tang et al.[20]added a tiny perturbation to the global optimal position of the particle swarm to enable it to search better, enhancing its ability to search and find the optimum globally.

AFSA are generally used for fault diagnosis as well as to deal with clustering problems. Due to its disadvantage of easily falling into local optimization, there are some cases that it is not applicable to intelligent vehicle path planning. To adapt it to the situation of unmanned logistics and transportation vehicles, Yi-Qing Huang[21]proposed an improved fish swarm algorithm, introduced a three-strategy hybrid mechanism, and tested the algorithm through the classical function optimization problem and TSP. Zhang Wenhui[22]came by introducing a direction operator to make the late convergence speed faster, and introduced the immune-memory property to solve the problem of easily falling into local optimization. Both improved algorithms effectively improve the characteristics of the fish swarm algorithm, making it more progressive in terms of computational time and computational accuracy.

ANN have also produced many research results in unmanned transportation vehicle path planning. For example, Singh et al.[23]proposed a method to optimize the path using a neural network controller and designed a 4-layer neural network so that it can effectively meet the requirements of obstacle avoidance and can navigate in real dynamic environments. Lv[24]searched for the optimal path by utilizing the feature of only local side connections between each neuron, which can be effectively adapted to dynamic environments as verified by simulation.

For the improvement of the GA, the genetic algorithm proposed by Wang Lei et al.[25]was designed with crossover and mutation probabilities, and the improved genetic algorithm can also be applied in the path planning of unmanned transportation vehicles by means of hybrid selection, as demonstrated by simulation experiments.

3.2 Algorithms for path planning in dynamic environments

The current research on static path planning has been very mature, but for the adaptability of the dynamic environment path planning algorithms, there is still a large space for development, because the dynamic environment has the characteristics of uncertainty, complexity, etc., it is required to do to meet the environmental changes, timely response to avoid obstacles or deal with emergencies and choose the optimal route to continue to move forward in this.

The dynamic environment planning algorithm designed by Peng Xiaoyan[26]is based on the discrete optimization of the local road. Combined with Gaussian convolution algorithm, and then use coordinate transformation to transform s-p to Cartesian coordinates. From the results of its simulation experiments the effect is good, can be to do effective obstacle avoidance, the overall operation trajectory is reasonable. The improved ACO algorithm of Ke Xing[27]. Designed two strategies to cope with the collision, the face of the collision will occur in the rolling prediction avoidance, not only solves the collision problem encountered or convergence speed has been improved.

3.3 Summary

From the current research, most of the researchers just applied a single algorithm for path planning, and the limitation of a single algorithm is very obvious, that is to say, if only one algorithm is used, even if it is improved, there will still be some shortcomings, that is, the speed of convergence and the accuracy cannot be guaranteed at the same time, and can only make a compromise choice. Therefore, combining the two intelligent bionic algorithms for application is a good choice, which is also a new idea for future unmanned transportation vehicle path planning algorithms, for more complex environments, i.e. Some path planning algorithms for dynamic environments, most of them are still in the two-dimensional plane, solving simple obstacle problems, which can be adapted to the current urban roads. However, if we want to extend it to more complex special environments and some severe environments, the research on path algorithms for dynamic environments is far from enough.

IV. CONCLUSION

For the environmental perception technology, its basic research direction in the obstacle detection and road boundary detection, due to the different environmental perception sensors, the corresponding algorithm design and improvement is also different, in the actual application should be designed according to the characteristics of the sensor used to achieve the required environmental perception and detection; at the same time, in the face of the more complex road conditions and the unmanned courier trucks of higher precision, response to the at the same time, in the face of more complex road conditions and the higher accuracy and response of unmanned express transportation vehicles, the algorithm of fusing multiple environmental sensing sensors can be used, including the fusion of the same type of sensors such as the multi-camera fusion algorithm, but also the fusion algorithms of a variety of different types of sensors, and according to the situation, appropriately join the depth of learning to carry on the training, in order to achieve better recognition effects.

In the field of path planning technology, intelligent bionic algorithms are more and more widely used because of some excellent characteristics unique to them. At the same time, the research on intelligent bionic algorithm is mainly reflected in two aspects, one is the optimization of a single algorithm, the introduction of different mechanisms for optimization, so that its own shortcomings can be corrected or continue to increase the advantages of the original algorithm itself; there is also a direction is through the fusion of a variety of intelligent bionic algorithms, through the fusion of the algorithms to solve the bottlenecks encountered in the path planning.

The current research is mostly the control algorithm of the unmanned express delivery vehicle, and there are fewer studies on the cluster algorithm, and the cluster transportation is more suitable for the future requirements of unmanned logistics in the city, because the cluster algorithm can achieve the improvement of the total transportation efficiency through the overall algorithm design, and effectively solve the problem of the "last kilometre of the city".

Although intelligent bionic applications in the field of path planning have a unique advantage, but in the face of more complex dynamic environment, still cannot be fully adapted, so the future in the strengthening of intelligent bionic algorithms in the three-dimensional environment of the optimization of the application of the path planning is a good prospect, but, again, this is also a very difficult challenge.

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