The application and impact of delivery robots

Haolin Tan[1*]

[1]Staten Island Academy, New York City, 10310, United state of America

Abstract. With the rise of social media and the accelerated pace of life, the food delivery industry has taken off. As more people have embraced ordering food, numerous problems have emerged within the food delivery industry and society. As the number of food delivery orders has grown, delivery times have become increasingly stringent. This has led to a rise in traffic accidents involving delivery drivers. According to statistics, 70% of respondents are very concerned about traffic safety, but 80% say they frequently violate traffic rules simply to avoid being deducted money and receiving negative customer reviews for overdue delivery times. In addition to traffic safety risks, delivery drivers often run into conflicts with community security and customers. Many communities prohibit delivery drivers from entering to protect residents, leading to conflicts and even fights between delivery drivers and security. Furthermore, many delivery drivers face verbal abuse and negative reviews from customers when they exceed their delivery deadlines. Their social status and safety are undermined. This article will introduce the applications and principles of food delivery robots, analyze the challenges facing the food delivery industry and society, and explore how delivery robots can address these issues.

1 Introduction

Analysis shows that food delivery robots will reduce the industry's operating costs, improve efficiency, and bring intelligence to the industry. In recent years, with the rapid development of the internet, the web has gradually permeated every aspect of social life. With the rapid spread of information and intensified competition across all industries, people are increasingly seeking ways to save time, leading to the emergence of the food delivery industry. Data shows that the majority number of food delivery customers are university students, attracted by its convenience and affordability. Reports indicate that over 70% of students order food delivery weekly. Furthermore, urban office workers, faced with busy schedules, also choose convenient food delivery to save time. According to data from the China Internet Network Information Center and the Food Delivery Committee of the China Hotel Association, there are 545 million online food delivery users in China, with a market size of approximately 1.2 trillion yuan. The average daily spending on food delivery is nearly 3.3 billion yuan. China's online food delivery market is projected to grow from 301.294 billion yuan in 2017 to 1.6357 trillion yuan in 2024, a compound annual growth rate of 27.34%. Demand for food delivery continues to grow.

* Corresponding author: t20080802@gmail.com

As the food delivery industry continues to expand, numerous issues have emerged. Delivery drivers face social ostracism and a lack of social and professional security due to the nature of their work. Furthermore, due to China's high traffic volume, safety incidents involving delivery drivers are on the rise. Fig. 1 shows Unpleasant experiences encountered by food delivery workers at work.

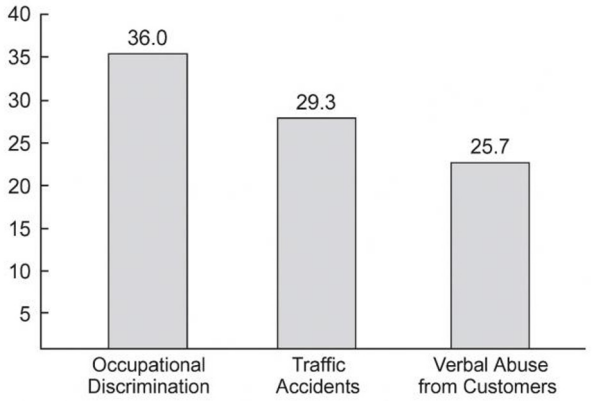

Fig. 1. Day life unpleasant experience statics of delivery person 1.

The main purpose of food delivery robots is to solve the problem of delivery personnel in the "last mile". This is also the time when delivery personnel suffer the most social discrimination and conflicts with customers.

China's first delivery robots appeared in Jinan in 2010. At the time, these robots were not intelligent, relying solely on magnetic navigation technology to move along fixed magnetic tracks, unable to reverse or avoid obstacles. It wasn't until 2015 that domestic robots began incorporating SLAM systems, marking the true beginning of the development of delivery robots. In 2016, Microsoft and Intel collaborated on the development of autonomous driving, leveraging radar, visual computing, GPS, and artificial intelligence systems to automatically control vehicles. That same year, Pudu Technology began applying autonomous driving technology to its robots. Since then, SLAM, which builds omnidirectional maps, and lidar, GPS, and IMUs, which ensure high-precision obstacle avoidance and positioning, have enabled delivery robots to operate efficiently in small, complex environments like restaurants and karaoke bars.

Currently, food delivery robots are limited to operating in specific areas. However, through continuous technological refinement and improvement, enhancing their adaptability and interactive capabilities, their scope of operation can be gradually expanded to include urban blocks, ultimately achieving a city-wide delivery coverage. This can also effectively address labor shortages caused by issues such as an aging society, while effectively reducing labor costs and improving service quality.

2 Theme

2.1 Design concept

The primary design concept of this product is to assist the entire food delivery process through intelligent and fully automated delivery, solving the "last mile" delivery challenge [1].

2.1.1 Improve efficiency

The food delivery robot can memorize the environment and route maps of residential areas, thus preventing food delivery drivers from getting lost in residential areas due to unfamiliarity with road conditions, thereby extending delivery time. In addition, food delivery robots can help deliverymen avoid contact with security guards, avoiding the extra time caused by security guards refusing deliverymen from entering the community for delivery or confirming with customers due to their job responsibilities.

2.1.2 Service quality

The food delivery robot can also reduce direct contact between delivery drivers and community security guards and customers. The delivery robot can effectively avoid conflicts arising from the nature of their work or personal reasons, thereby improving overall service quality.

2.2 External components

2.2.1 Obstacle Avoidance

Obstacles are identified using a laser radar. The radar outputs the distance to the nearest obstacle and instructs the system to brake or slow down, precisely locating obstacles. The radar is mounted on top of the robot to ensure that its detection range covers the entire front and oblique sides of the robot. A 3D array solid-state laser radar is used for obstacle avoidance [2]. It emits an elliptical conical light beam to detect obstacles within a fixed line of sight and instructs the system to brake or slow down. The advantages of this obstacle avoidance method are high resolution, the ability to accurately identify obstacle locations, a 20Hz initial detection frequency, a more agile obstacle avoidance response speed, and no echo interference or false alarms due to uneven ground surfaces.

2.2.2 Signal reception

This device receives signals and commands via an infrared signal receiver, enabling the delivery robot to operate an elevator equipped with a dedicated infrared signaling device, allowing the robot to enter and exit the elevator. The delivery robot's charging station is also equipped with this device to guide the delivery robot during charging. Upon reaching the elevator lobby, the robot sends a command to the elevator control system server to summon the elevator to its floor. The elevator control system server then sends a command to the elevator controller to directly illuminate the elevator's up or down buttons. Once the elevator reaches the robot's floor, the floor detection module sends elevator status information to the elevator control system server, which instructs the robot to enter the elevator. Once inside, the robot sends a destination floor command to the elevator control system server, which instructs the elevator controller to directly illuminate the destination floor button. Upon reaching the destination floor, the floor detection module sends elevator status information to the system server, which instructs the robot to exit the elevator [3].

Stereo cameras help expand recognition range and accuracy. Like a robot's eyes, they assist with identification, positioning, detection, and measurement. Binocular stereo vision is based on triangulation. Using an imaging device, two images of the object are captured from different locations. By calculating the positional deviation between corresponding points in the images, the object's three-dimensional geometry is obtained, and its resolution can be

very high. Stereo cameras ensure delivery drivers can more accurately and quickly avoid obstacles and perform precise image recognition.

2.3 Internal component

2.3.1 GPS

The GPS system, or Global Positioning System, is a satellite-based technology. GPS consists of 24 satellites orbiting at an altitude of 66,000 kilometers above the Earth's surface. Each satellite is equipped with a precise clock and positioning device, transmitting positioning signals [4]. When a receiver receives signals from multiple satellites, it can calculate its own position, velocity, and time. By resolving the time differences and distance relationships between these signals, the receiver can determine its own 3D spatial coordinates. However, it also has limitations, such as signal weakness, multipath interference, and satellite observation errors. GPS positioning may be affected in indoor environments or in areas with dense building obstructions. GPS enables real-time management and oversight of robots. The global positioning system can accurately locate food delivery robots, allowing the backend to monitor their position and velocity in real time and ensure their proper operation.

2.3.2 IMU

IMU (Inertial Measurement Unit) enables robot positioning and navigation and has become an important component of precise robot positioning. IMU integrates accelerometers, gyroscopes, and magnetometers, and by providing real-time responses, enables robots to accurately determine their orientation, position, and movement, allowing robots to navigate in dynamically changing environments. IMU is a miniature device composed of micro-electromechanical system components. These typically include three-axis accelerometers, three-axis gyroscopes, high-performance magnetometers, etc. It can help measure the robot's posture, angular velocity, and acceleration. IMU can provide high-fidelity position output, up to 200 Hz. The higher refresh rate significantly improves the system's reliability in quickly adapting to rapid changes in direction in dynamic environments, thereby facilitating rapid response [5].

2.4 software

2.4.1 SLAM

SLAM (Simultaneous localization and mapping) is applied to robots and is a key technology for robots to depict their unfamiliar surroundings. Since the imported map of residential areas cannot include individual floors or some unusual terrains, SLAM is needed to help robots depict and make decisions about their surroundings [6]. The front camera can extract information about terrain and obstacles, and the lidar can be used to identify objects and their features to draw a complete model in the 3D map.

2.4.2 YOLO

YOLO helps robots detect and identify the type and location of target objects. It divides the input image into fixed-size grids, with each grid responsible for detecting the object within it. Each grid has a bounding box containing its center coordinates, width, and height. Using

graphics, it analyzes the bounding box and classifies the target object. YOLO helps robots analyze and avoid multiple obstacles with varying appearances and behaviors [7].

3 Advantage and disadvantage

Currently, these delivery robots can solve the "last mile" delivery problem, ensuring efficient delivery in residential areas and significantly shortening delivery times. They can also effectively reduce the risks to delivery drivers and delivered goods, mitigate conflicts between delivery drivers and customers, and improve delivery and service quality. However, delivery robots are currently limited to operating in specific environments, such as residential communities, campuses, hotels, and other enclosed spaces. These robots require site managers to purchase them at a high price, and the location of the robot determines its price. Therefore, while delivery robots can effectively improve delivery quality, they also increase application costs, making them a poor choice for smaller, less complex locations.

4 Application

Uber Eats, a US-based online ride-hailing company, is collaborating with Japan's Mitsubishi Electric and US robotics startup Cartken to roll out autonomous delivery robots for its food delivery service, Uber Eats. These robots have already been deployed in numerous areas across the US. However, these robots are limited to short-range deliveries. While they can deliver on streets, they are limited to densely populated areas with narrow streets in US cities, such as New York and New Jersey. Therefore, Uber's robots are not well-suited to the vast urban areas of China.

5 Trend

Currently, food delivery robots can solve the "last mile" delivery problem, but as technology continues to improve, robots will be able to expand their delivery areas to streets and cities. Their high delivery efficiency can effectively reduce long-term operating costs and increase profits. Furthermore, given the severity of society's aging population, robots can perfectly address the labor shortage and provide excellent services to society [8].

6 Conclusion

Food delivery robots are a key component of smart city development, representing an improvement in urban development and services. Their role is not only to address food delivery issues, but also to address numerous societal challenges. In the short term, they require significant experience to refine and improve their technology. In the long term, however, food delivery robots can significantly develop both the food delivery and AI industries, representing a significant advancement in the application and innovation of robotics technology.

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