Smart Logistics and Distribution System Based on Laser and Vision Fused SLAM Algorithm

Like Zong
School of Management, Hefei University of Technology, Hefei 230009, Anhui, China
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Abstract: In the context of rapid increase of the intelligence and information level in the field of industrial economy, China's logistics industry has ushered in a stage of rapid development. Logistics and distribution services, a key sector in commodity circulation, play a significant role in the manufacturing industry and the national economy. However, there are still some problems in logistics and distribution services, as the traditional manual logistics mode still prevails, with the efficiency and information security compromised. In response to existing problems, this program aims to create an environmental protecting unmanned intelligent logistics distribution system. This system applies AGV trolley, the core product of this program, to intelligent navigation and transportation logistics. Based on the shared storage distribution path optimization model of the two-way service of supply and demand, the unmanned distribution trolley and distribution path are reasonably arranged as required by the user to deliver a great variety of raw materials and goods in information-based packaging boxes and unit cabinets to the destination on time. On the one hand, accurate logistics information becomes available as a result, which is beneficial for optimization and scheduling, so that the problem of parcel loss in logistics can be solved in general. On the other hand, users can trace the detailed logistics process in a precise manner. Furthermore, this design unit supports a highly efficient automated logistics approach, as goods of different sizes can be matched with design units with corresponding sizes, so that storage utilization is maximized, and the logistics loading and unloading process is simplified. In addition to its role in packaging, this design unit is also subject to recycling, as it protects the environment by reducing disposable packaging while protecting user privacy and optimizing user experience.
Keywords: natural navigation, intelligent logistics, unmanned distribution

1. Research context and significance

In 2020, the total amount of social logistics of China is up to RMB 300.1 trillion yuan, with an increase of 3.5% year-on-year, and the total social logistics costs accounted for 14.7% of GDP. In the context of adjustment of the industrial structure and transformation of the development mode, with the market size continuing to expand, China's logistics industry has entered a key period of strategic opportunity, glowing more vitality and vigor, while its basic and strategic position in the national economy is becoming increasingly significant. It is mentioned in the "Guidelines on Developing Comprehensive Transport Network" released by the Central Committee of the Communist Party of China and the State Council in 2021 that the transportation industry shows trends of digitalization, networking, intellectualization, and greenization, and that logistics operations should follow the direction of "optimized logistics of goods", namely, to be efficient, economical and reliable.

The rapid development of the logistics industry has also put tremendous pressure on the service quality of the express delivery industry. In terms of logistics efficiency, there are more and more negative news about the low degree of networking, the lack of scientific logistics control, the increase in labor costs, damage of goods, and not-in-time of delivery. Due to outdated logistics facilities and low degree of automation, in a lots of regions, the speed of express delivery is far from being desired. In addition, as far as the problems in environmental protection and resource waste caused by disposable express packaging as concerned, consumers have higher expectations for privacy protection and environmental-protecting packaging. The intelligent logistics AGV distribution system proposed by the author and the team members is expected to do a good job in solving these problems. To be specific, the SLAM-based AGV will be applied to intelligent sorting and unmanned transportation at night, with the help from automation of informationized packaging boxes and unit cabinets with a high efficiency, so as to improve distribution efficiency, simplify the sorting process, improve user satisfaction, the quality and efficiency of logistics services, and facilitate the development of China's intelligent logistics!

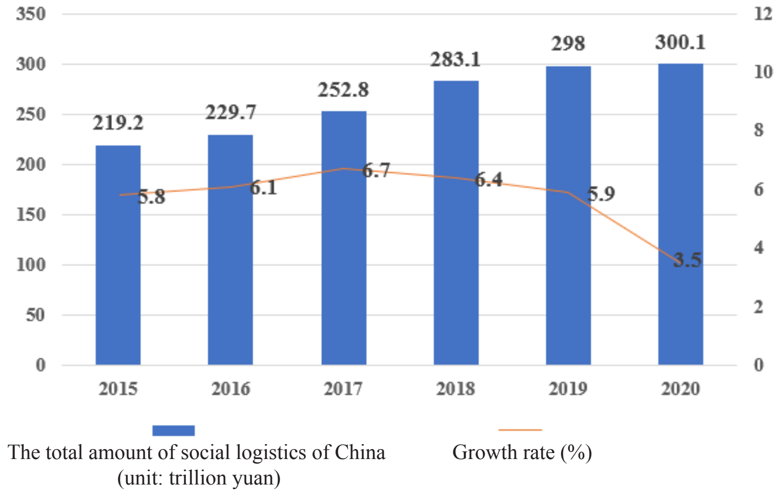

Figure 1. Statistics of the total amount and growth of social logistics of China

2. Overall design of AGV

2.1 Overall structure design

The trolley, whose whole outer frame is constructed of aluminum profiles, with a connection of connecting keys, is convenient to assemble, and has sufficient structural strength to be used as the overall frame of a transport mechanism. This equipment supports automatic lifting and stable transportation of goods. The interior of the entire trolley is composed of three layers. For the uppermost moving layer, the outer frame is of an opening and closing mechanism connected by hinges, and the lifting platform is driven by a lifter lifted by a push-rod motor at the bottom; for the the middle layer, a controller and a power storage room are embedded in; at the bottom, six Mecanum wheels driven by DC gear motors are set in a horizontal and longitudinal movement layout.

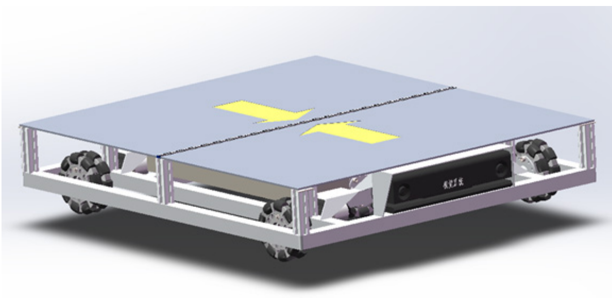

Figure 2.1 Omnibearing goods transport platform

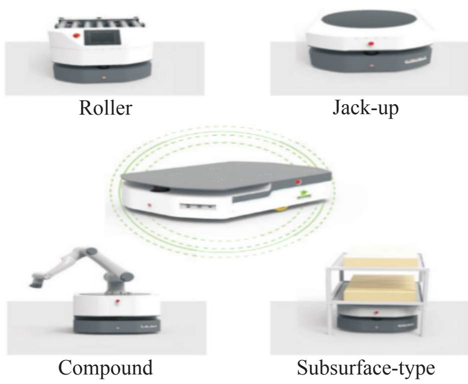

Figure 2.2 Expanding AGV structure

The AGV trolley adopts omnidirectional motion control, using a DC motor with encoder to implement closed-loop control of the moving speed, making the system more stable and reliable; in the meanwhile, Bezier curve control is adopted to make the system more robust.

2.2 Control system

The AGV control system is composed of a wireless communication module, a perception recognition module, a power supply module, a driver module, an automatic loading and unloading module, and a safety protection module. The hardware part of the trolley is mainly composed of the upper data command processing host ARM and the lower chassis controller STM32. The upper ARM mainly adopts the vision module and the LIDAR module to collect data for navigation and positioning, while the wireless module is connected for communication with the upper management system. The chassis controller is mainly used to receive instructions from the upper layer and do corresponding actions, with the drive chip integrated on driving the motor to rotate directly; meanwhile, it also collects information such as the speed and mileage of the motor to feed back to the upper ARM. Its structure is shown in Figure 2.3.

The AGV power supply system consists of the wireless charging device and the internal power supply device. The wireless charging device, which is based on wireless power transmission technology, is used to realize non-connected power transmission. If the AGV prompts low battery during performing tasks, it will move to the designated charging point automatically for wireless charging. At the same time, the AGV on this system also has a long endurance.

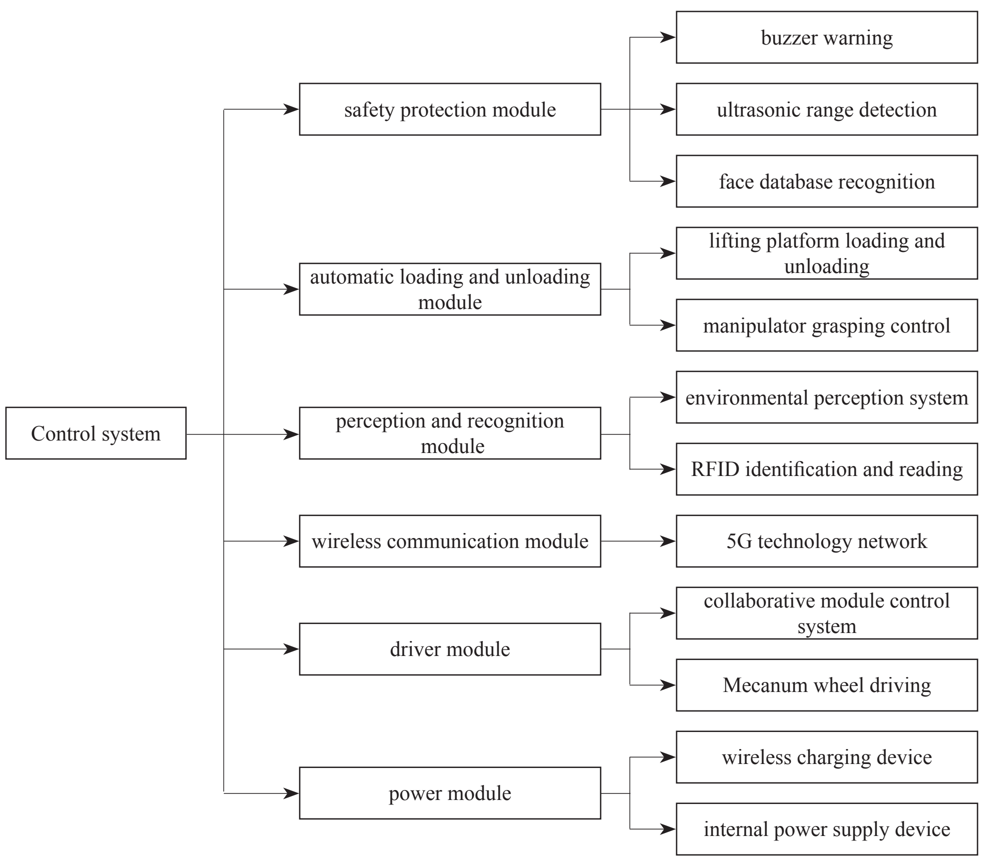

Figure 2.3 Structure of the control system

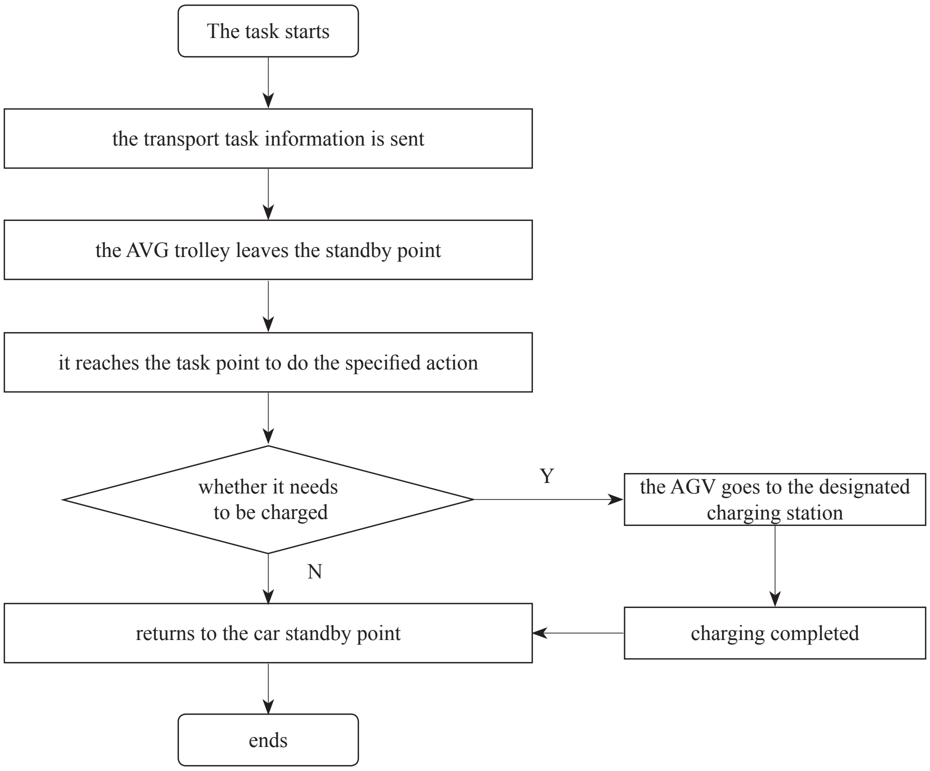

Figure 2.4 Charging flow chart

This project proposes an active perception scheme based on three-axis vibration sensors. According to the Bayesian probability perception, with active exploration behaviors, the interactive vibration information between AGV and the ground is used to explore and identify the environment, shifting to the highly recognizable movement state. In this way, AGV is allowed to independently determine the next action by virtue of vibration perception, and quickly extract more accurate information in outdoor recognition tasks.

In addition, the AGV is equipped with a variety of sensors, so it can measure the surrounding environment through the sensors while running and display the information on the screen. If needed, LIDAR can be used to model the surrounding environment, as shown in Figure 2.5.

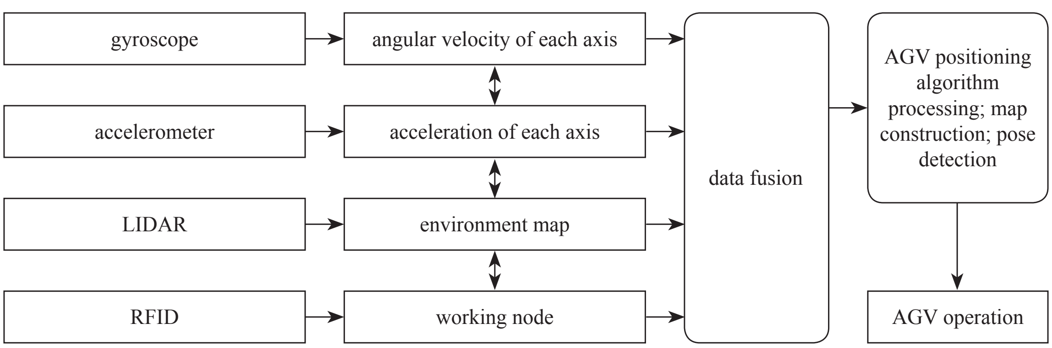

Figure 2.5 Multisensor AGV positioning system

2.3 Natural navigation (SLAM algorithm)

2.3.1 Laser and vision combined SLAM algorithm

The project adopts the SLAM algorithm that integrates laser and vision.

Vision SLAM can work in a variety of complex environments indoors and outdoors, but it has high requirements for ambient light, cannot extract feature points from untextured areas, and its monocular camera is subject to initialization failure, scaling drift and difficulty in determining when the distance is unknown.

Laser SLAM is featured by high accuracy and strong robustness, which is convenient for positioning and navigation, but the laser sensor can only scan one plane, and its performance in positioning in obstacle-hollow environment and dynamic environment is poor.

With the Bayesian method, we updated the result of combing the local laser grid map established with LIDAR using the Gmapping algorithm and the local visual grid map established with the RGB-D camera using the ORB-SLAM algorithm. The combination process framework is shown in Figure 2.6 and Figure 2.7 below.

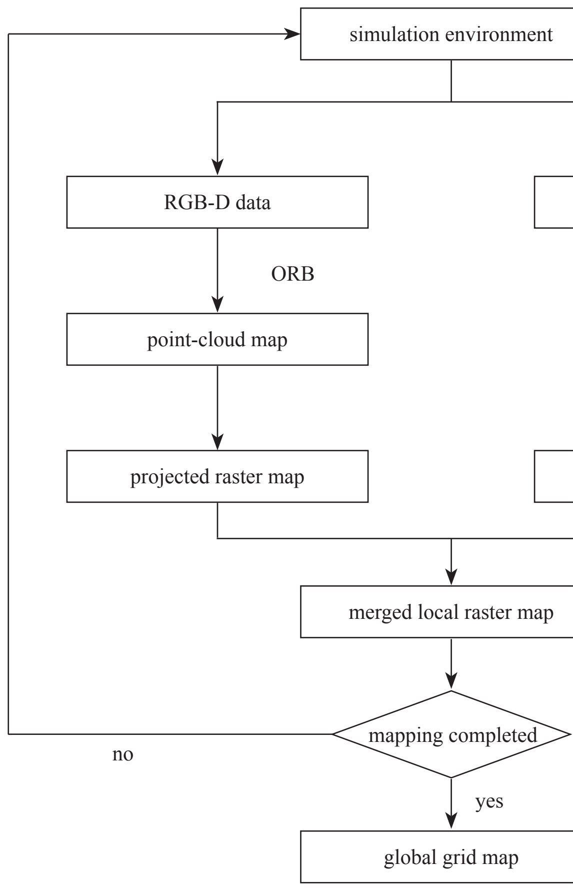

Figure 2.6 The process of combination in the simulation environment;

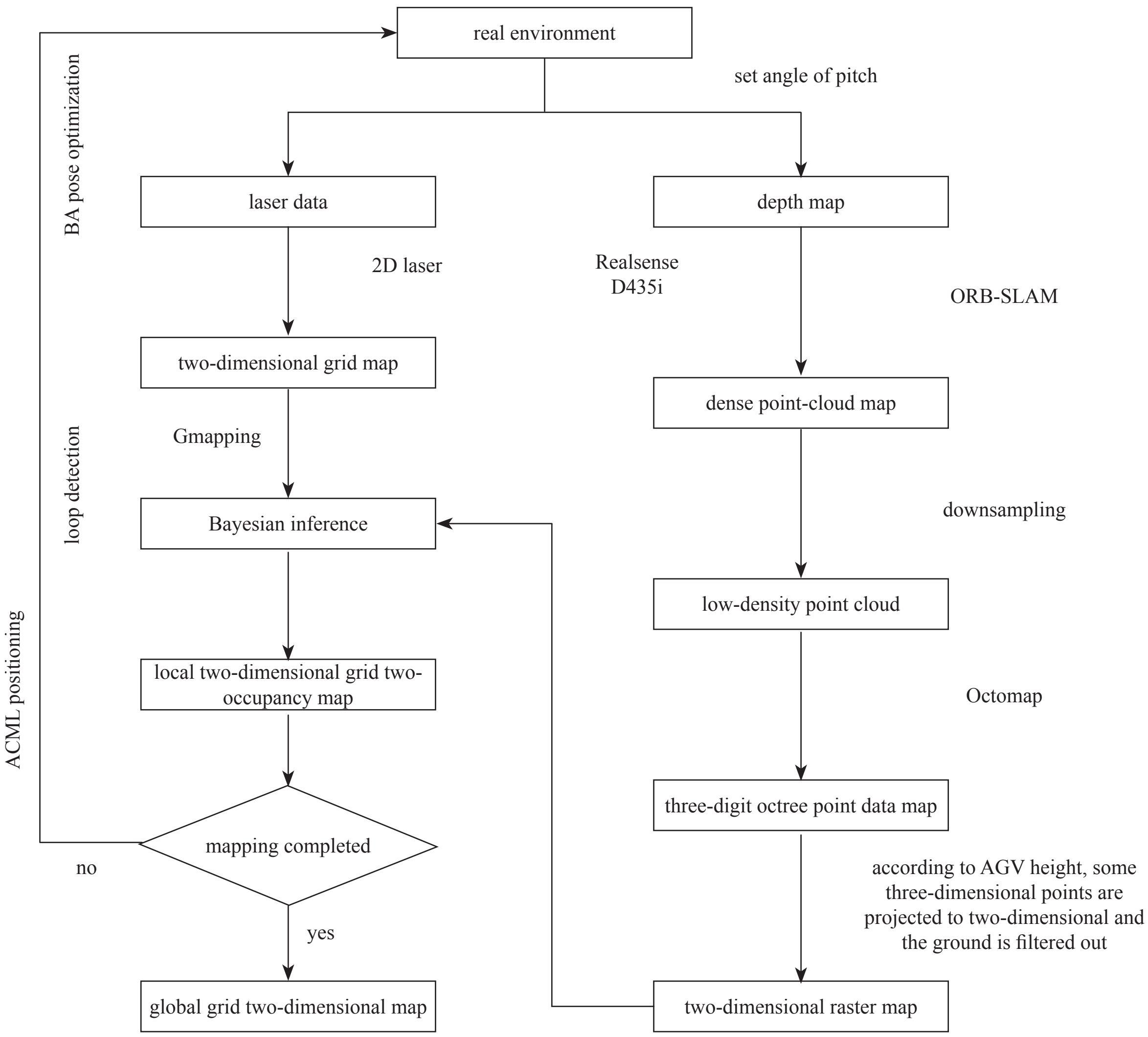

Figure 2.7 The process of combination in the real environment

2.3.2 Multi-AGV collaboration SLAM algorithm

This project adopts the SLAM mapping algorithm in multi-AGV collaboration large-scale scenarios. For the large-scale factory scene and the scene of multi-AGV simultaneous working, we use multiple AGVs to collect environmental data simultaneously, with the data aggregated and integrated.

In order to meet the needs of multiple AGVs working together in a factory environment, we built a multi-robot, multi-host integrated system, built an AGVS cooperation system, established a multi-AGV communication framework through the ROS system, associated the data of multiple AGVs, and then sent the ROS-pack through the TCP/IP protocol to corresponding topics, and built the relationship between sub-members by virtue of pose information and visual words. The system can reasonably allocate and dispatch the trolleys as required by different tasks, so as to reduce the work intensity of single trolleys, and greatly improve the production efficiency, as shown in Figure 2.8.

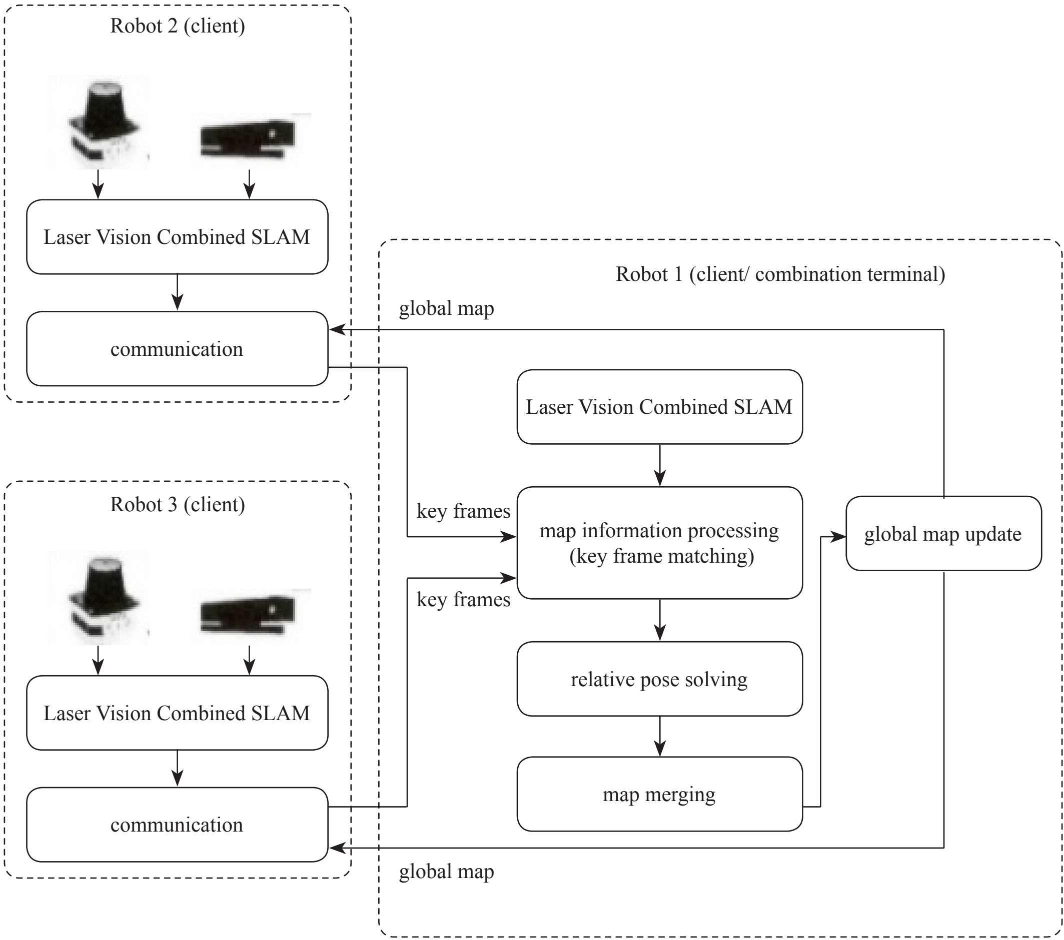

Figure 2.8 Multi-AGV communication framework

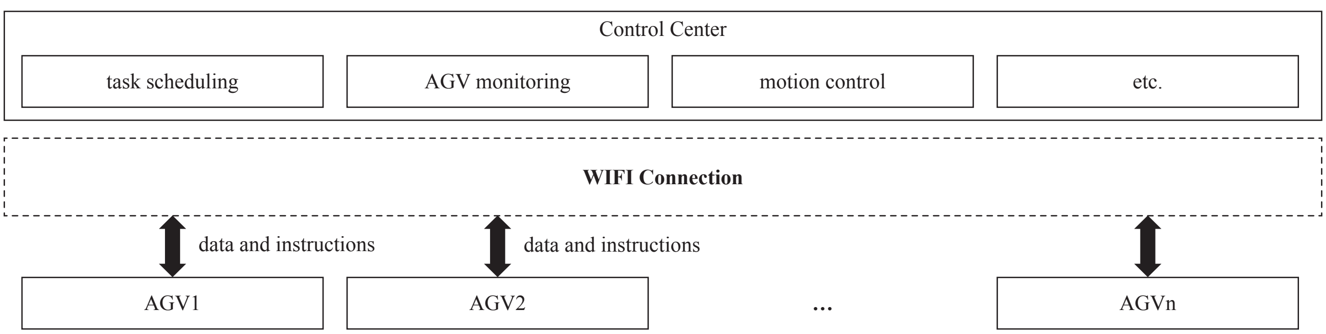

Figure 2.9 AGVS system diagram

3 Design of the intelligent logistics unmanned delivery scheme

3.1 Intelligent logistics framework design

As shown in Figure 3.1, the approach of intelligent logistics unmanned distribution is applied to a jurisdiction composed of several delivery terminals, several logistics centers, several client sites, one management platform, and several AGV trolleys. It also includes an intelligent means of delivery used in the unmanned distribution segment and automatic sorting segment in the intelligent logistics mode.

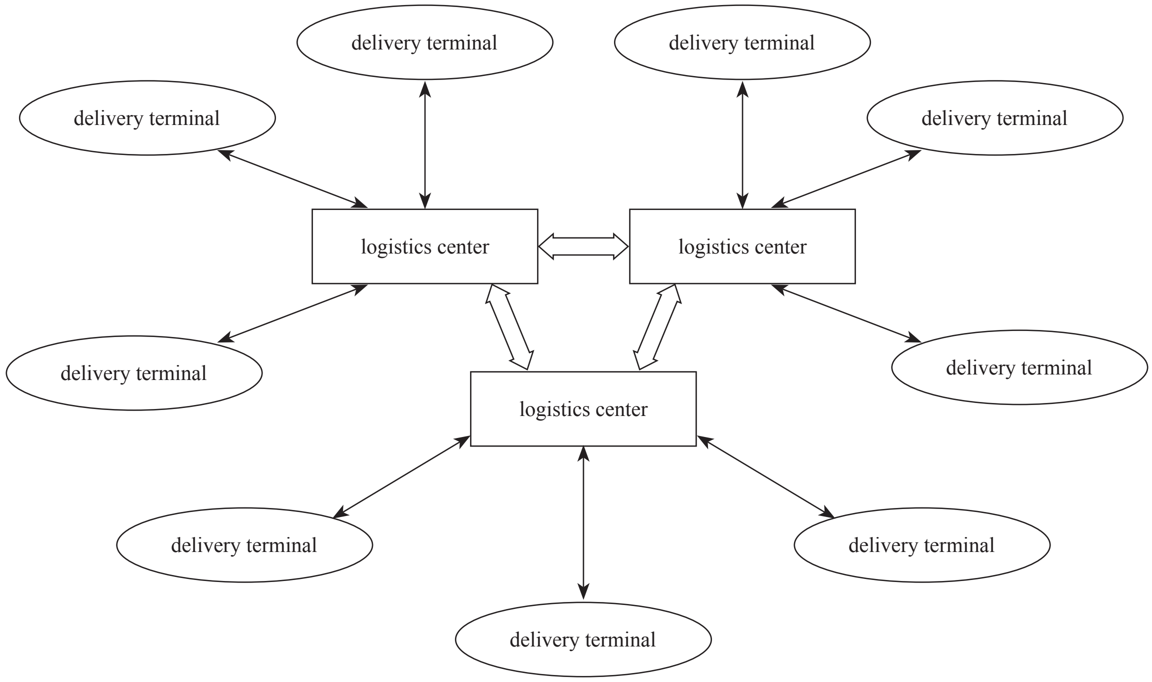

Figure 3.1 Products flow diagram

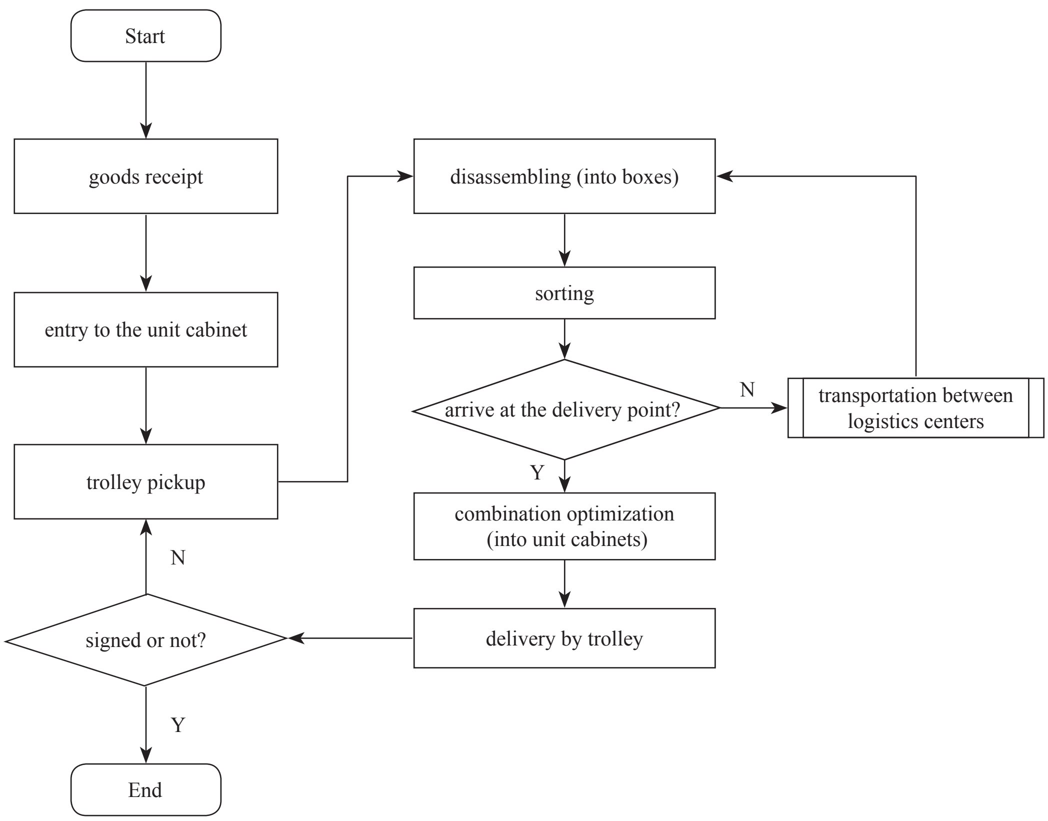

Figure 3.2 Flow chart of intelligent logistics unmanned distribution

3.2 Detailed procedures of intelligent logistics unmanned delivery

3.2.1 Pick-up and dissembling of unit cabinets

1) The management platform confirms the number and specifications of the unit cabinets to be picked up in each area under the jurisdiction of each logistics center, and conducts route planning.

2) According to the planned running path for the trolley, transport orders are generated with dispatching instructions issued to the AGV trolley.

3) The AGV trolley picks up the unit cabinets in the path one by one as planned by the system, and finally returns to the logistics center.

4) All unit cabinets are automatically dissembled into packaging boxes in the logistics center.

3.2.2 Smart sorting of the carrier

1) The intelligent packaging data module sorts the packaging boxes and returns and transports the sorting data according to the target distribution point and the jurisdiction of the logistics center prompted by the information collection&distribution module of the packaging boxes.

2) According to the results of the first sorting, the management platform plans the path for the first time and gives transportation instructions to the AGV trolley, which will send the sorted boxes to the logistics center in the corresponding jurisdiction.

3.2.3 Distribution of unit cabinets

1) The packaging boxes of each logistics center are sorted according to the target distribution site, and the packaging boxes with the same destination are optimized in combination.

2) The system arranges the transportation tasks for the unit cabinet according to the combination results and the order content.

3) The AGV trolley carrying the unit cabinet moves to the next logistics center or the distribution site as planned.

4) After the information collection&distribution module of the packaging box in the corresponding distribution unit cabinet receives the unpacking instruction, the user will be allowed to take out the item, and the status of the removed item's packaging box will be set as "to be stored", and then the distribution unit cabinet will be regarded as a new delivery unit cabinet.

3.3 Design of smart carrier for unmanned distribution

Smart carriers include "unit cabinet" and "packaging box", as shown in figure 3.3.

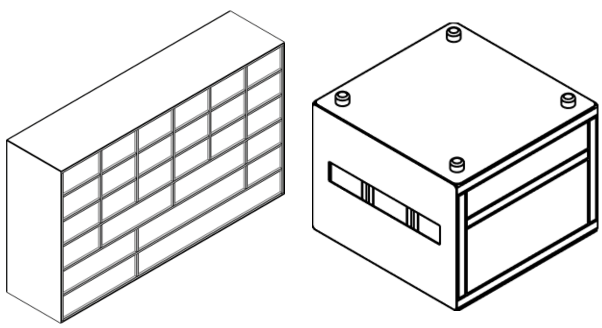

Figure 3.3 Smart carriers (unit cabinet and packaging box)

3.3.1 Design of appearance and structure

In order to ensure the strength and bearing capacity of the packaging box, beams and columns are welded to form the skeleton structure of the packaging box, so that the carriers can be stacked in multiple layers to protect the safety of the items in the packaging boxes and other equipment. In this way, the purpose of being put on the AGV automatic trolley can be reached.

The packaging boxes are of different sizes, and can be combined into unit cabinets of different sizes and scales. The packaging box is divided into the upper part, which is a closed space for storing the information storage module and the information collection&distribution module, and the lower part, which is a storage space.

Since the size of the packaging box is module-related and is designed in accordance with a unified standard, personal identification and automation of sorting can reach a higher extent. Compared with the prevailing traditional sorting method of "manual + conveyor belt + scanning order", this design can improve sorting efficiency and accuracy enormously, while reducing labor costs; moreover, as recycling of standardized design can be realized, the utilization rate of loading equipment is expected to increase with secondary packaging reduced in logistics.

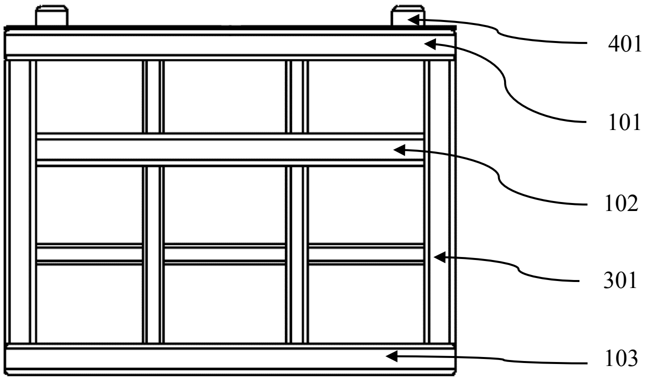

Figure 3.4 Front view of the packaging box skeleton

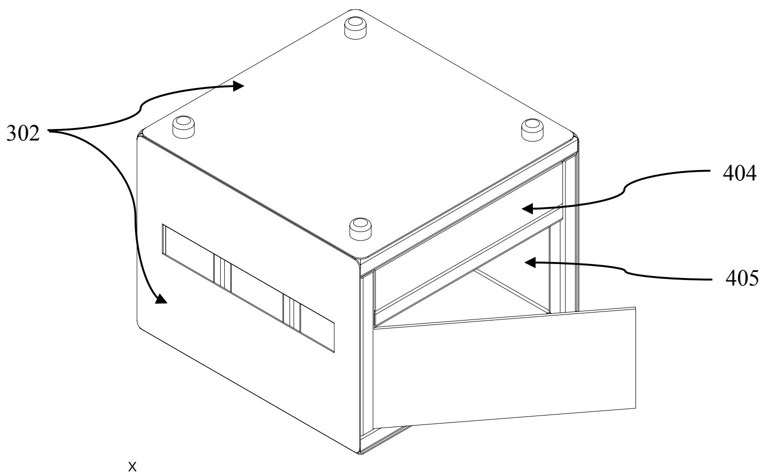

Figure 3.5 Axonometric drawing of the packaging box (opened)

3.3.2 Intelligent module design

In order to realize the information-based unmanned distribution and sorting throughout the whole process, the packaging box design also includes: information storage module, information collection&distribution module, security module, and packaging box power supply module. The layout of the information module allows direct interaction of the AGV trolley with the cargo information and sensor information, so as to improve the efficiency of distribution.

1) The information collection&distribution module sends the location information of the packaging box to the client and the management platform in real time during the transportation of the unit cabinet, and sends other information of the packaging box to the AGV trolley and the terminal management platform during the sorting and combination process;

2) The information storage module stores the respective information of the packaging boxes, covering position, size, cargo type and storage;

3) The security module can send alarm information to the management platform and raise the alarm through the information collection&distribution module when it detects that the packaging box is opened improperly or damaged; the security module is also equipped with a monitoring unit, which opens and closes the packaging box according to the operating instructions received by the information collection&distribution module of the packaging box, while monitoring the internal environmental temperature and humidity of the packaging box;

4) The power module of the packaging box contains spare small batteries, which can maintain the function for a while when the power supply of the packaging box fails.

User information and logistics information are only stored in the information-storage device and server database, avoiding the display of express orders and barcodes, thereby maximizing the protection of user privacy. Since the packaging box also has informative functions, the management terminal can receive information such as damage, loss, and abnormal transportation routes in time, so the the packaging box can be located for taking corresponding measures.

4. Innovation points

4.1 Laser and vision combined SLAM algorithm

With the Bayesian method, we updated the result of combing the local laser grid map established with LIDAR using the Gmapping algorithm and the local visual grid map established with the RGB-D camera using the ORB-SLAM algorithm, and created the raster map. According to our self-developed navigation and positioning algorithm, we used laser sensors to scan the surrounding environment and create maps in the system; moreover, while the AGV is moving, the laser sensor collects environmental information constantly, matches with the map data and locates, cooperates with the motion controller and follows the control algorithm to realize the automatic driving of AGV.

4.2 Multi-purpose integrated structure of AGV's multi-specification expandable platform

In the process of intellectualized transformation of traditional automobile material conveying production lines, it is necessary to purchase multiple types of AGV trolleys for matching at one time. The function of every type of AGV trolley has been determined previously and cannot be changed during the production process. In view of the demand for diversified production, AGVs with more functions are needed accordingly. Our AGV can switch different application modules according to actual application scenarios, thereby changing its function. Ultimately, the multifunctional AGV trolley would be applied to the material transportation system to expand its application scope.

4.3 Intelligent sorting system consisting of information-based packaging boxes and unit cabinets

This project supports a variety of intelligent and information-based operations represented by "intelligent optimization". According to the results of preliminary experiments, after optimization, the scheduling level can be increased by 25%, and the sorting speed can be increased by 50% on average. Information-based packaging boxes and unit cabinets lay a foundation for a number of intelligent scheduling operations such as intelligent assembly, vehicle scheduling, route optimization, and order distribution, etc. for intelligent logistics unmanned distribution; moreover, according to real-time traffic trends and big data of user information, the project makes the best solution available for every batch of orders.

4.4 Improvement of logistics efficiency

Goods of different sizes are provided with packaging boxes of different sizes, so that the storage utilization rate is improved to a great extent. In addition to the packaging role, packaging boxes also have carrying capacity. As a matter of fact, the loading and unloading step in the sorting center is removed from the logistics process, so that the sorting process is streamlined, and labor costs and the damage to goods are reduced.

4.5 Green and safe packaging

The packaging box proposed in this project is subject to recycling, so that disposable packaging is reduced greatly to protect the environment; at the same time, it protects user privacy, solving all kinds of problems related to information security, which are caused by attaching express orders containing user information to prevailing disposable packages.

5. Application prospect

As a major development direction of modern logistics, intelligent logistics is of great significance to cost reduction and efficiency increase of logistics, as well as high-quality development of logistics. According to market surveys, the overall market size of unmanned distribution is at least between 304 billion and 509 billion. With the rapid growth of E-commerce scale, moreover, the logistics industry will continue its growth. In addition to the broad market prospects, logistics can also generate considerable economic benefits for operators. In 2019, the express business volume reached 63.52 billion, and the daily average business volume reached 174 million. According to the market average, a courier's work efficiency is delivering 100 pieces per day, so the average number of couriers required per day is at least 1.74 million. Application of unmanned distribution system will reduce such labor costs enormously and standardize distribution service. The SLAM-based AGV trolleys work at night, so that the hidden dangers of distribution can be reduced and traffic pressure can be relieved. In terms of environmental protection, according to the current development trend of express delivery, the consumption of express packaging materials in China is expected to reach 41,270,500 tons in 2025, which will result in tremendous burden to resources and pressure to the natural environment. The packaging box designed by this team is recyclable, which can reduce disposable packaging while protecting user privacy.

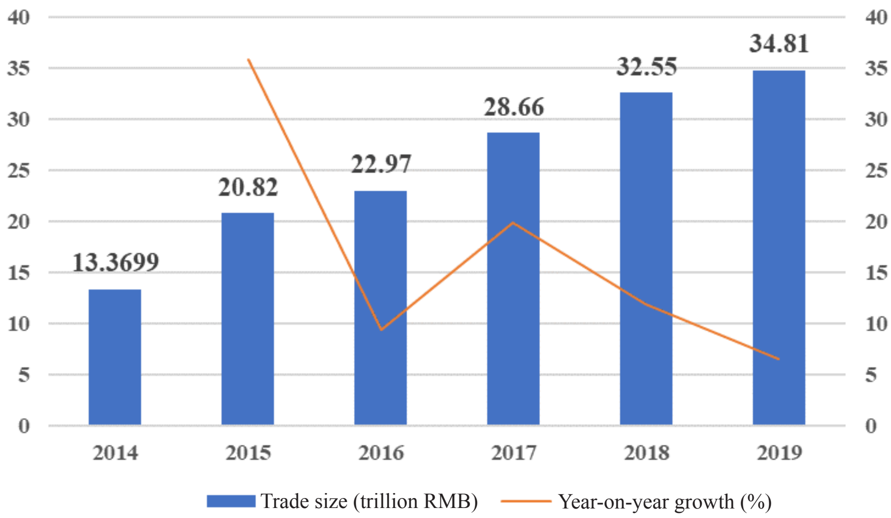

Figure 5. Statistics of China's e-commerce scale from 2014 to 2019

For consumers, the pick-up time will be flexible, the problem of parcel loss will be solved, their personal privacy will be protected, and the service experience will be improved; for logistics service provider, intelligent logistics AGV distribution will improve the utilization rate of warehousing, save labor costs, simplify the sorting process, and reduce the rate of damage to goods; at the same time, the logistics industry will be oriented to low emission, pollution-free, and recyclable development, boosting the industry upgrade on an environmental-friendly basis.

With broad application prospects, this project is expected to effectively solve the pain points of the traditional logistics industry, and enhance the intelligent and green level of logistics.

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