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Research on AGV Guided by Real-time Locating System (RTLS) for Material Distribution

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Abstract

In discrete manufacturing workshop, traditional manual material distribution method lacks of unified scheduling and supervision due to a bottleneck of capturing real-time information. Considering these problems, this paper raises the concept "R-AGV (RTLS-based Auto Guided Vehicle)" and proposes the framework of R-AGV-based material distribution scheme on the basis of RTLS platform and workshop electronic map. Then under the principle of shortest transport distance (STD), we put forward the path planning algorithm including global path planning algorithm for designing route of R-AGV and local multi-sensors fusion algorithm for avoiding obstacle. Considering experimental purpose, we develop a simplified 8-workstation prototype system capturing the main characteristics of the real discrete manufacturing workshop. Our analysis and experiment results show that the R-AGV-based material distribution system provides new levels of process visibility and efficiency comparing to traditional AGV-based distributing systems.

Keywords: *Real-time locating system, Auto guided vehicle, Material distribution, Discrete manufacturing workshop*

1. Introduction

With the development of modern manufacturing industry, those real-time traceability and visibility, enabled at the upstream, are important for increasing the efficiency and improving quality of manufacturing operations [1, 2]. As an important part of manufacturing procedure, the material distribution process has a stronger demand for real-time locating on the purpose of visualization. At present, traditional auto-guided vehicle (AGV) has more extensive application in informationalized workshop. Although, AGV is more suitable for the manufacturing mode with high assembly line [3, 4]. It is not suitable for the feature of product distribution in discrete manufacturing workshop because traditional AGV moves along with fixed routes and lacks flexibility [5].

Nowadays, Real-time locating system (RTLS) has become an important component in many existing ubiquitous location aware systems. Moreover, indoor RTLS shows a great application prospect in every field, especially in supply chain, manufacturing, business processes and warehouse operations [6]. The widest application of RTLS is the industrial field and the related researches have been operated for a couple of years. Bin Ding proposes a new RTLS system model based on the technology of Radio Frequency Identification (RFID) and Wi-Fi to realize materials tracking [7]. Frederic Thiesse investigates the value of RTLS information on the locations of physical objects in a production system to the problem of efficient job scheduling with a RFID-based RTLS implementation in a semiconductor lab [8]. Although RTLS have been widely utilized in manufacturing industry, they are merely confined to the monitor of manufacturing process and objects (*e.g.*, person, material and vehicle) and seldom utilized to control guided vehicle to realize efficient and flexible material distribution.

Thus, we consider taking indoor RTLS into the navigation and visualization of distribution vehicles with the real-time coordinates provided by RTLS platform. In order to

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distinguish from the usual AGV, it is named "RTLS-based Auto Guided Vehicle (R-AGV)".

This paper is organized as follows. Section 2 sketches the structure of material distribution system (MDS) utilizing R-AGV based on RTLS and then introduces the RTLS platform and workshop electronic map, respectively. After that, we propose the path planning algorithm in Section 3, including global path planning algorithm and local multi-sensors fusion algorithm. In Section 4, the prototype system is developed to evaluate the performance of R-AGV-based MDS. Finally, the overhead of the whole paper is raised with a conclusion.

2. System Design of R-AGV

Considering the requirements of discrete manufacturing workshop and the application situation of traditional AGV, we put forward the novel R-AGV applied for material distribution. It should be emphasized that R-AGV is controlled and guided by real time information, which is quite different from traditional AGV or manual forklift. Consequently, R-AGV shows more flexibility and maneuverability. Due to the feature of real time and ubiquity, R-AGV is able to move along any direction, which saves much transporting time. Also, the workshop map provides direct real-time monitoring of the manufacturing conditions in real workshop, which benefits the timely response for the emergency situation. In the next section, we will describe the detailed design solution.

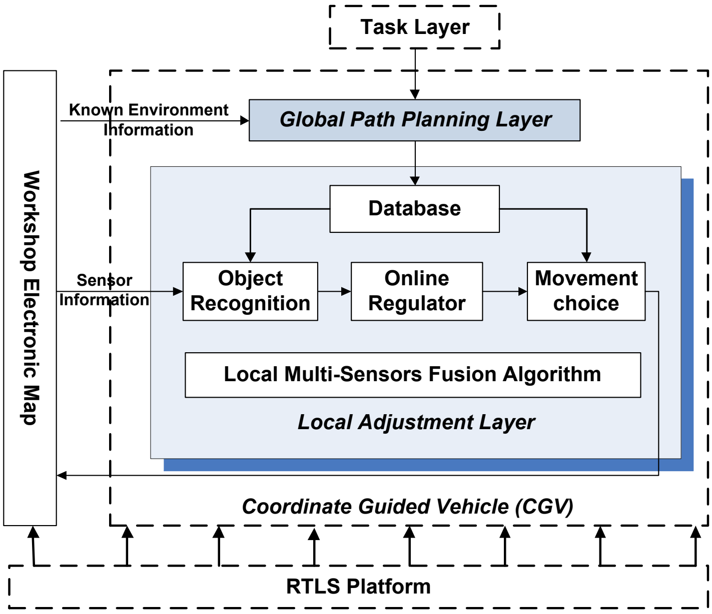


Figure 1. The System Structure of R-AGV-based Distribution System

2.1. Structure of R-AGV-Based Material Distribution System

In this section, we propose an overall functional framework for the designing and realizing of R-AGV-based material distribution system. The system structure is described in Figure 1.

As we can see from the system structure, the process of R-AGV-based material distribution system is as following: the upper task layer firstly assigns material distributing missions to R-AGV according to production management system, then combining workshop electronic map, R-AGV develops distribution route based on different categories, e.g. first in first out (FIFO), shortest processing time (SPT), earliest due date (EDD). The underlying RTLS platform supplies the real-time information to the management platform database for guiding and monitoring R-AGV.

Based on workshop electronic map, the function design of R-AGV includes two layers: global path planning layer and local adjustment layer. The global path planning layer is for setting out global distribution routes according to the mission from task layer. And local adjustment layer is responsible for avoiding obstacles with local multi-sensors fusion algorithm to realize dynamic optimization in the process of distribution.

2.2. RTLS Platform

So far, a number of RTLS technologies have been utilized to solve indoor tracking problems, such as bluetooth, infrared ray, ultrasonic wave and RFID (radio frequency identification devices) [9, 10]. Especially, RFID is widely used in practical applications, *e.g.*, logistics transportation, warehouse management and manufacturing workshop owing to its characteristics of non-contact, wide-coverage and low-cost [11]. Ultra-Wideband (UWB) radio seems to be a good choice for achieving such high location precision. The extremely large bandwidth offered by UWB systems allows a fine time resolution of the multipath components of the received signal [12]. In the UWB-based locating systems, Ubisense is the relatively extensive commercial RTLS platform.

The differences of various locating techniques in RTLS are apparent. Considering their characteristics, we adopt the strategy that combining accurate positioning (Ubisense system) with area positioning (RFID technology) in our RTLS platform. Although Ubisense can provide high-accuracy location, it has high power consumption and price with active tags. And the 15cm-locating-precision of Ubisense is able to meet the demand of R-AGV localization. Even so, the Ubisense is only utilized to locate R-AGV and the positions of other objects (*e.g.*, person, material, tool, machines) are sensed through RFID technology, because these objects just need area location rather than high-accuracy location in our system.

2.3. Workshop Electronic Map

Workshop electronic map is the simulative display of actual workshop in two-dimensional or two-dimensional structure. The various manufacturing elements showed in the workshop electronic map in accordance with the real layout in the workshop by RTLS platform. It is good for administrative staff to visually monitor the manufacturing situation in workshop, which can effectively improve the response for emergency accidents. To some extent, the workshop electronic map can be considered as the visual database of manufacturing elements.

In workshop electronic map, the manufacturing elements are divided into three categories: dynamic manufacturing elements, static manufacturing elements, and environment elements. The dynamic elements contain staff, R-AGV, material. Similarly, the static elements cover workshop shape, workstations and machine tools. The environment elements indicate the influence factors in workshop environment (*e.g.* temperature, humidity, smoke degree), which can be sensed through Wireless Sensor Network (WSN) [13]. During the process of designing workshop electronic map, the static manufacturing elements can be fixed in advance while the dynamic manufacturing elements should refresh in real time according to RTLS platform.

3. Proposed Path Planning Algorithm for R-AGV

When R-AGV receives the distribution task from task layer, it needs to design the distribution route according to the special task. So we propose the path planning algorithm for R-AGV designing the optimal route based on the workshop electronic map. The path planning algorithm of R-AGV scheduling is divided into two modules: global path planning algorithm and local multi-sensors fusion algorithm.

3.1. Global Path Planning Algorithm

Global path planning algorithm is mainly designed for generating a dispatching path based on shortest transport distance (STD) according to the distribution tasks from management system, combining with the status of manufacturing elements in workshop electronic map.

The biggest distinction between R-AGV and traditional AGV is that R-AGV can travel along any route. As we all known, the shortest way between two points is the straight line. It has a great advantage for large-space discrete manufacturing workshop to shorten the delivery path.

In order to facilitate path planning, every workstation area is bound by a unique coordinate point, which corresponds to the entrance of the area. So, we only need to focus on the point. Then, considering 2D space, workstation i can be described:

$$ws_i = (x_i, y_i) \quad i = N^+ \tag{1}$$

Thus, for example, the dispatching task j is expressed as the coordinate series:

$$task_j = [WS_1 \quad WS_2 \quad WS_3 \quad \cdots \quad WS_n] \quad j, n = N^+ \tag{2}$$

Where n indicates the distribution workstations that the task j contains. It should be emphasized that the subscript of WS means the sequence of workstations that R-AGV needs to go through in order, while it doesn't correspond to the name of workstation. And (2) needs to satisfy constraint conditions:

$$\begin{cases} WS_n = ws_i \\ WS_k \neq WS_{k-1} \text{且} WS_k \neq WS_{k+1} \end{cases} \quad k \in N^+ \tag{3}$$

Then, the total delivery distance TDD of task j is described as:

$$TDD_j = \sum_{k=1}^{n} \left\| WS_{k+1} - WS_k \right\| + \left\| WS_1 - WS_0 \right\| \quad k \in N \tag{4}$$

Where n is the quantity of total distribution workstations that the task contains and $\left\| WS_{k+1} - WS_k \right\|$ is the delivery distance from kth distribution workstation to $(k+1)$th distribution workstation. And WS_0 is the coordinate of starting position of R-AGV. It should be emphasized that the starting position does not agree with the origin coordinate. It is the current position of R-AGV.

If the distribution task has strict requirements of priorities for workstations, R-AGV only needs to follow the order of distribution task to carry out the material distribution. Otherwise, if the order of distribution workstations is adjustable, we need to calculate the shortest delivery distance and make R-AGV delivery route.

Assuming the task j need to go through n workstations, it has $n(n+1)/2$ possible distribution paths.

$$TASK_j = \left\{ task_j^{(1)}, \quad task_j^{(2)}, \quad task_j^{(3)}, \quad \cdots, \quad task_j^{(m)} \right\} \qquad m = n(n+1)/2 \tag{5}$$

According to STD, we need to find the scheme with shortest distribution path, in other words, we need to find $Task_j^{(m_0)}$ such that:

$$TDD_j^{(m_0)} = \min_{l \in [1,m] \& l \in N^+} \left(\sum_{k=1}^{n} \left\| WS_{k+1}^{(l)} - WS_k^{(l)} \right\| + \left\| WS_1^{(l)} - WS_0^{(l)} \right\| \right) \tag{6}$$

So,
$$task_j = task_j^{(m_0)} \tag{7}$$

It should be emphasized that finishing the distribution task means the R-AGV arrives at the last workstation. The distance that R-AGV comes back to the starting position from the last workstation is not taken into consideration. After finding out the shortest distribution path, R-AGV can distribute the materials according to global shortest path.

3.2. Local Multi-Sensors Fusion Algorithm

After global path planning, the local obstacle avoidance algorithm is necessary for R-AGV to avoid obstacles because some unexpected obstacles are inevitable when distributing materials. Accordingly, we propose the local multi-sensors fusion algorithm, which integrates several kinds of sensor information to deal with the obstacle problem. The flowchart of local multi-sensors fusion algorithm is shown in Figure 2. Meanwhile, anti-collision method is taken into consideration to suspend R-AGV in an urgent emergency.

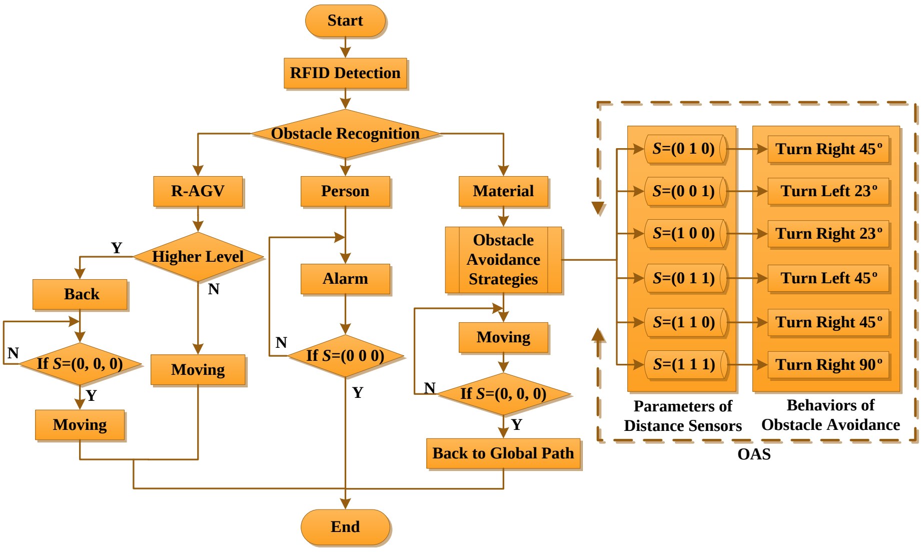


Figure 2. The Flowchart of Local Multi-Sensors Fusion Algorithm

The multi-sensors include infrared distance sensors (IDS), collision sensors (CS) and RFID reader. The infrared distance sensors are responsible for obstacle detection while the collision is mainly for avoiding hitting something. In the traditional robot-obstacle-avoidance method, only distance sensors (*e.g.*, infrared ray, ultrasonic wave, picture processing) are utilized to keep away from obstacles. But these kinds of method are in the lack of flexibility because the robot does not know what the obstacle is. As a sequence, RFID reader is put into use for obstacle recognition. Then, the R-AGV can choose different obstacle avoidance strategies according to specific obstacles category. It should be emphasized that each object is attached with a RFID tag in our RTLS platform.

In the design of R-AGV, we lay out three infrared distance sensors, eight collision sensors and one RFID reader. As shown in Figure 3, three infrared distance sensors are used to sense the obstacle from front-left, front and front-right (corresponding to IDS1, IDS2 and IDS3), between which the angle is 45 degrees. And eight collision sensors distribute around the R-AGV. When infrared distance sensors detect obstacle, it will generate an electrical signal, where the safe distance is adjustable according to the size of R-AGV.

$$R_{IDS} = L_2,\ R_{CS} = D \tag{8}$$

Where L_2 is the length of R-AGV and D is the safe distance setting manually.

The single signal of IDS can be expressed:

$$S_{IDSi} = \begin{cases} 0 & clear \\ 1 & obstacle \end{cases} \quad i = 1,2,3 \tag{9}$$

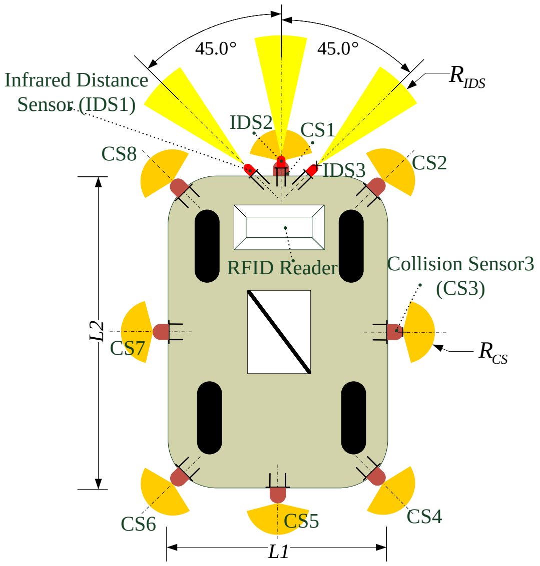


Figure 3. The Structure Diagram of Sensors Layout in R-AGV

Then, the multi-sensors fusion (we put three infrared distance sensors) can be described:

$$S = (S_{IDS1} \quad S_{IDS2} \quad S_{IDS3}) \tag{10}$$

Table 1 shows that the different behaviors of obstacle avoidance in accordance with different information fusion of three infrared distance sensors $(S_{IDS1}, S_{IDS2}, S_{IDS2})$.

Table 1. The Fusion Obstacle Avoidance Algorithm of Infrared Distance Sensors

S_{IDS1}	S_{IDS2}	S_{IDS3}	S	*Obstacle Position*	*Obstacle Avoidance Behaviors*
0	0	1	(0 0 1)	right	Turn left 23°
0	1	0	(0 1 0)	front	Turn right 45°
1	0	0	(1 0 0)	left	Turn right 23°
0	1	1	(0 1 1)	front, right	Turn left 45°
1	1	0	(1 1 0)	front, left	Turn right 45°
1	1	1	(1 1 1)	left, front, right	Turn right 90°

For different obstacles, we may adopt different obstacle avoidance strategies. R-AGV recognizes the obstacle types with RFID reader after detecting the obstacle. On one hand, if the obstacle is person, R-AGV only needs to make an alarm and warn the person to give way. On the other hand, if the obstacle is some kind of material or other static object, R-AGV could call the multi-sensors fusion algorithm. The situation that two R-AGVs just run across, that is, the obstacle is another R-AGV, should be taken into consideration. We can classify the task into different levels of importance when the system assigns task for R-AGV. The levels of importance are divided into 10 ranks, bigger and more important. The lower-level R-AGV should give way for the higher-level R-AGV. It needs to be noted that once the R-AGV has finished its task, the importance level will be cleared to zero. The task level is expressed as:

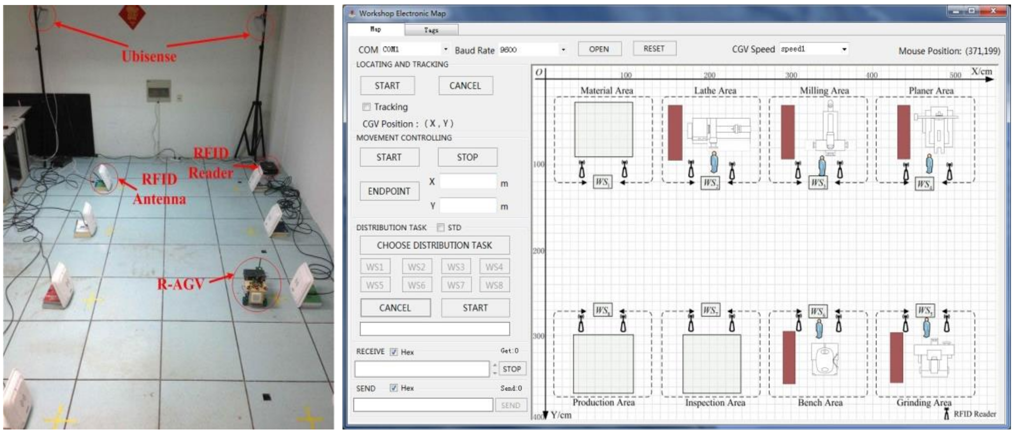
$$R_{Taskj} = \{0 \quad 1 \quad 2 \quad 3 \quad 4 \quad 5 \quad 6 \quad 7 \quad 8 \quad 9\} \qquad j \in N^{+} \tag{11}$$

4. Prototype System Development

Based on system architecture and path planning algorithm, we developed a prototype system to demonstrate the feasibility of R-AGV-based material distribution system and conduct further experiments. The prototype system includes workshop electronic map and R-AGV model. As mentioned in Section 2, we construct RTLS platform by combining the Ubisense with RFID technology. The R-AGV collects its real-time information mainly from Ubisense system. RFID technology realizes the area locating of other objects in workshop. Every workstation area is set up a RFID reader utilized to sense the object entering into this area.

4.1. Workshop Electronic Map Development

In the workshop layout, the basic 8-workstation environment is built as the research environment. The workshop electronic map and corresponding research environment is illustrated in Figure 4. There are 8 basic workstations in the map, material area (ws_1), lathe area (ws_2), milling area (ws_3), planer area (ws_4), grinding area (ws_5), bench area (ws_6), inspection area (ws_7) and production area (ws_8), respectively. Each workstation is simplified into a corresponding coordinate, which is the temporary storage position in the doorway of each region. The workstation area and corresponding coordinate is shown in Table 2.



COM COM1
Baud Rate 9600
CGV Speed speed1
Mouse Position: (371,199)

Figure 4. Research Environment and Corresponding Workshop Electronic Map

In the entrance of each area, we place one RFID reader to locate and monitor the objects incoming and outgoing in this area. Both the size of workshop and the position of workstations are pre-defined in the map according to the situation of real workshop environment. And the positions of other dynamic objects update in real-time with the data from RTLS platform.

Table 2. The 8-workstation Areas and Corresponding Coordinates

Workstation	*Symbol*	*Coordinate(cm)*
Material Area	ws1	(70,125)
Lathe Area	ws2	(200,125)
Milling Area	ws3	(330,125)
Planner Area	ws4	(460,125)
Grinding Area	ws5	(460,265)
Bench Area	ws6	(330,265)
Inspection Area	ws7	(200,265)
Production Area	ws8	(70,265)

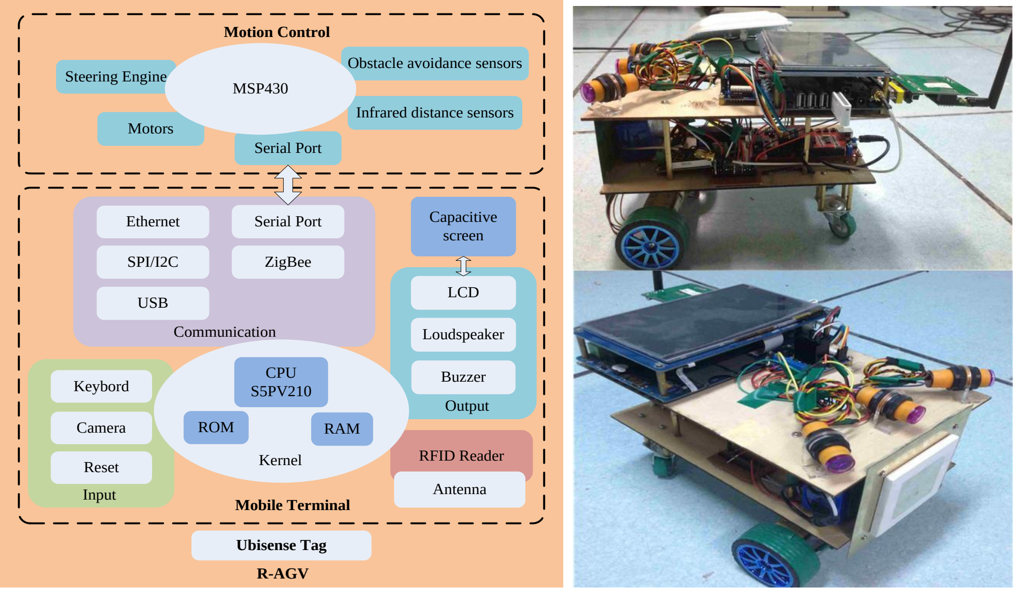


Figure 5. The Function Structure of R-AGV Model

4.2. R-AGV Model Development

In research environment, R-AGV model was designed in accordance with the basic requirement of real R-AGV for simulating the material distribution. The functional structure of R-AGV model is shown in Figure 5. It is composed of two parts: motion control module and mobile terminal module. Between these two parts, the serial port is utilized for data exchange. Specifically, the mobile terminal is implemented by ARM Cortex A8 controller which serves as shop floor controller. And it integrates several major wireless technologies: ZigBee, RFID and Ethernet. ZigBee is served as the communication mode of WSN to collect information of environment. Meanwhile, R-AGV gets access to the LAN through Ethernet interface to acquire the position information from RTLS platform. Then as we mentioned above, RFID is utilized to recognize obstacle. In motion control module, MSP430 is adopted to serve as Controller Chip, which is mainly responsible for motion.

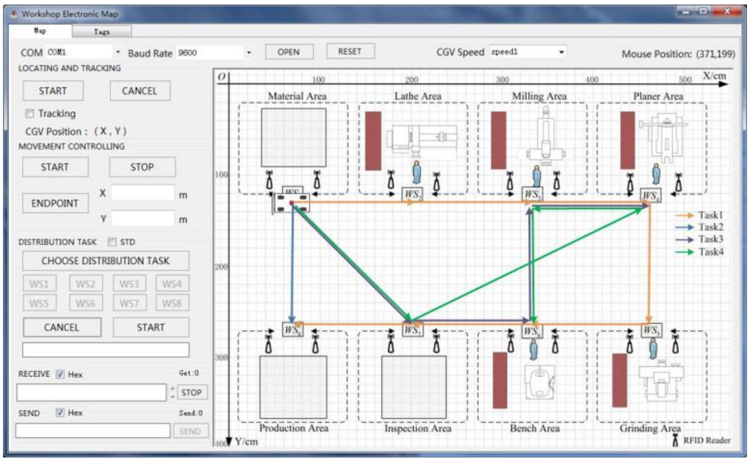
5. Performance Evaluation

5.1. Route Analysis of R-AGV

Due to the flexible and ubiquitous characteristic of RTLS, the distribution route of R-AGV is quite different from traditional AGV-based distribution method. R-AGV can move in any direction while AGV must drive along fixed orbits. In order to be convenient to compare with AGV-based distribution method, we set up a circular orbit with colored tape for guiding AGV in research environment, where the size of route is $520*110cm$ and the global length is $1260cm$. And the corresponding route defined in workshop electronic map is shown in Figure 6.

COM COM1
Baud Rate 9600
CGV Speed speed1
Mouse Position: (371,199)
CGV Position : (X , Y)
RECEIVE ☑ Hex Get:0
SEND ☑ Hex Send:0

Figure 6. The Pre-defined Traditional AGV Route



COM COM1
Baud Rate 9600
CGV Speed speed1
Mouse Position: (371,199)
CGV Position : (X , Y)
RECEIVE ☑ Hex Get:0
SEND ☑ Hex Send:0

Figure 7. Different Theoretical Routes Corresponding to Different Tasks

Firstly, we take several pairs of theoretical route analysis to make the comparison of efficiency between R-AGV-based and AGV-based material distribution method (Figure 7). It is obvious that the time-consuming gap between AGV-based and R-AGV-based material distribution changes a lot depending on different tasks. If the distribution task is

$$task_1 = [ws_1 \quad ws_2 \quad ws_3 \quad ws_4 \quad ws_5 \quad ws_6 \quad ws_7 \quad ws_8] \tag{12}$$

Then the time-consuming of finishing task is similar between R-AGV and AGV, which is merely a limiting case. And the delivery path in theory is as shown in Figure 7.

And the reverse limiting case is that the task is

$$task_2 = [ws_1 \quad ws_8] \tag{13}$$

If we finish this task with R-AGV, the theoretical distribution distance is only

$$TDD_2^R = 110cm \tag{14}$$

While due to the one-way travel, the total distance with AGV is

$$TDD_2^A = 1020cm \tag{15}$$

Where the subscript A and R denote AGV and R-AGV, respectively.

From the distances under two limiting cases, we can find that R-AGV-based material distribution saves a lot of time on the case that R-AGV always travels along the shortest straight line between two workstations.

We selected a distribution task that contains workstations $\{ws_1, ws_3, ws_4, ws_6, ws_7\}$. If the task doesn't have the requirements of priorities, then under STD principle, the task can be described as:

$$task_3 = [ws_1 \quad ws_7 \quad ws_6 \quad ws_3 \quad ws_4] \tag{16}$$

Then, if the start position of vehicle is ws_1 , the total distance without priorities:

$$TDD_3^R = 540cm\ , TDD_3^A = 900cm \tag{17}$$

To the contrary, if the demand of certain workstation is urgent and the task needs to distribute material in chronological order, then we assume the distribution order for the task as following which contains the same workstations:

$$task_4 = [ws_1 \quad ws_7 \quad ws_4 \quad ws_3 \quad ws_6] \tag{18}$$

Assuming the start position is ws_1 as well, the distribution distance is

$$TDD_4^R = 692cm\ , TDD_3^A = 3270cm \tag{19}$$

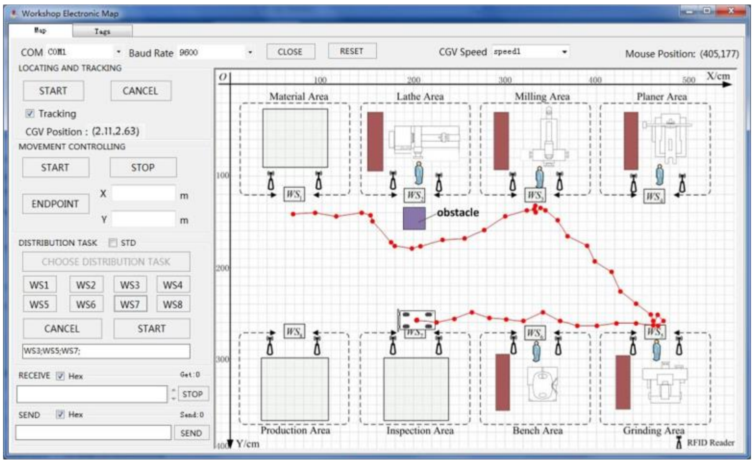
As it can be seen from the results, the moving distance with AGV is considerably larger than that with R-AGV benefiting from its free route.

5.2. Experiment Results

Based on the route analysis, we need to take the real experiments to show the performance of R-AGV. Firstly, we conduct the simple commissioning to demonstrate and check the performability of the prototype system with workshop electronic map and R-AGV model finished. We assigned the task for R-AGV model to simulate the process of material distribution. In addition, we put one obstacle in the moving route of R-AGV to verify the performance of fusion obstacle avoidance algorithm.

$$task_5 = [ws_1 \quad ws_3 \quad ws_5 \quad ws_7] \tag{20}$$

The time interval of auto-refresh was set to 2 s and the speed of R-AGV was set to 10cm/s. The red trajectory denoted the material distribution route of R-AGV. After R-AGV arriving at the workstations that the task contained, it will stay for several seconds representing the process of unloading the material, which is shown as close red points. The distribution track also showed that the time-consuming of task was 90 seconds. Then the running result of prototype system is shown in Figure 8. As we can see from the software inference, the R-AGV avoided the obstacle smoothly with the fusion obstacle avoidance algorithm. And because of locating error, the movement locus of R-AGV trends to fluctuate slightly.



COM COM1
Baud Rate 9600
CGV Speed speed1
Mouse Position: (405,177)
☑ Tracking
CGV Position : (2.11,2.63)
WS3;WS5;WS7;

Figure 8. The Running Result of Prototype System with task5

Then we conduct several series of experiments corresponding to analysis routes in Section 5.1 to compare the real performance with AGV-based distribution method. We assigned $task_1$, $task_2$, $task_3$, $task_4$ orderly to AGV-based method and R-AGV-based method, respectively. And we recorded the consuming time of each task to compare the performance. Meanwhile, we calculated the theoretical time of each task with different method to compare with corresponding research time. The results are shown in Table 3. It should be noted that the distribution time includes two parts: the moving time t_M and the total uploading time t_U . So the time of whole distribution process can be represented that

$$t = t_M + t_U \tag{21}$$

And

$$t_M = \frac{TDD}{v},\; t_U = n \times T_U \tag{22}$$

Where TDD is the total moving distance, v is the average speed of vehicle, n is the quantity of workstations that the task contains and T_U is the average uploading time. In our research, the speed v of R-AGV and AGV was set to 10cm/s. Besides, the R-AGV and AGV would stop for about 5 seconds after it arrives at the workstations for unloading material.

Table 3. Theoretical Time and Research Time of Traditional AGV and R-AGV with Different Tasks

		Traditional AGV		R-AGV	
	Quantity of Workstations	Theoretical time (s)	Research time (s)	Theoretical time (s)	Research time (s)
$task_1$	8	142	151.3	129	144.2
$task_2$	2	112	115.2	21	24.8
$task_3$	5	115	123.3	79	92.3
$task_4$	5	352	360.5	94.2	106.6

From the results, we can see that the general distribution time of R-AGV is evidently short than that of AGV due to the free moving. And there is also an obvious phenomenon that the gap between theoretical time and research time get bigger with the increasing of the quantity of workstations, which is due to more frequency stop and start. Besides, the gap of R-AGV between theoretical time and research time is larger than that of AGV. It is because R-AGV turns more frequently while AGV moves smoothly.

6. Conclusion

In this paper, aiming at the problems of traditional material distribution in discrete manufacturing, we discussed the importance of automatic collection of real-time data from manufacturing shop-floors using RTLS technology. Based on the analyses, a conceptual framework has been proposed as a roadmap for guiding the development of material distribution scheme utilizing RTLS-based auto guided vehicle (R-AGV). Meanwhile, RTLS platform and workshop electronic map were introduced as the basic platform technology for implementing the R-AGV -based material distribution system. Also, under the rules of the shortest transport distance (STD), the path planning algorithm of R-AGV, including global path planning algorithm and local multi-sensors fusion algorithm, was proposed for material distribution. Specifically, the prototype system including research environment, workshop electronic map and R-AGV model was developed for further experiments and demonstrating how the proposed R-AGV-based material distribution system can be instantiated. Furthermore, several pairs of experiments were conducted to show the advantage of R-AGV-based material distribution comparing against AGV method.

Although the superiority of R-AGV was proved with the development of prototype system, further research and development are necessary to realize in practical application. Firstly, we only discussed the one R-AGV situation in material distribution systems, multi R-AGV material distribution problem will be more complex and more difficult for developing to keep the system running smoothly and effectively. Another important issue is how to assign the distribution task with R-AGV considering the process sequence of specific parts, in other words, the integration between R-AGV-based material distribution system and upper management system is an intricate problem, *e.g.*, MES (Manufacturing Execution System), ERP (Enterprise Resource Planning), CAPP (Computer Aided Production Planning). So, we will concentrate on these problems in the next step research.

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