Research on Multi-AGV Management System of Autonomous Navigation AGVs for Manufacturing Environment

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Yang Yang, Yanming Quan* and Yiming He

School of Mechanical and Automation Engineering, South China University of Technology, Guangzhou, China
Email: meymquan@scut.edu.cn

Abstract. This paper serves intelligent AGVs which can autonomous positioning, autonomous navigation and autonomous movement. And build a multi-AGV management system for manufacturing environment applications, which is relatively complete functions and good interaction between users and AGVs. In order to meet the requirements, the system development process highlights the functional design of the AGV management system and optimizes the data processing capabilities. Complete the construction of the interface and database on the Qt and MySQL software. The test was conducted after importing into the test database. The results showed that the built system operated smoothly and the data processing was correct and timely.
Keywords. Autonomous Navigation AGV, Multi-AGV management system, Database, ROS.

1. Introduction

Automated guided vehicles began to flourish in the middle of the last century, and now they have been widely used in many fields, especially in the industrial supply chain. The extensive application of AGV in the manufacturing environment requires the support of a robust management system. In recent years, many scholars and enterprises have conducted many researches and practices for this purpose. For example, the system developed by V. Jaiganesh et al. (2014) implements the scheduling of automatic guided vehicles in the material processing link and the release of mobile orders [1]. Another system developed by Meisu Zhong et al. (2020) solves the path planning of two types of AGVs in automated terminals and scheduling [2]. Guilherme t et al. (2019) discussed the successful factors of sustainable implementation of AGV in supply chain management, and adopted structural equation modeling (SEM) to improve the operation efficiency of AGV in the warehouse industry [3]. However, the existing management system emphasizes the task scheduling capability of the AGV, yet the system function is relatively simple, which weakens the user's ability to manage data information or the interface design is defective, resulting in too much information intake for the user.

In addition, the existing successfully-applied management system mainly manages traditional AGV groups that run along fixed paths or are guided by preset paths, whose management system functions are mainly for real-time monitoring, traffic coordination, task scheduling and path planning for AGVs. With the rise of intelligent manufacturing, intelligent AGVs capable of autonomous positioning, autonomous navigation and autonomous mobility are gradually entering the enterprise supply chain. For example, the Yunnan Baoshan Tobacco Leaf Re-roasting Plant began to introduce Toyota AGV forklifts in 2018. Equipped with a BT laser sensing system, it automatically responds to deceleration, detour, and stop in time according to the settings, which not only improves safety but also reduces labor. Also, AGV and the factory WMS system are connected, which can realize the information

synchronization and timely task deployment with each logistics link [4]. For the application of AGV in smart factories via 5G communication technology, ZTE Corporation uses multiple cloud-based intelligent AGVs to form a flexible production and handling system, and uses image information of unmarked scenes to fuse sensor data from inertial measurement units for global positioning and map construction technology (SLAM or VIO) to realize the autonomous movement of the AGV in the factory and the immediate task release. This 5G cloud-based AGV has been successfully piloted in the production line of the Changsha R&D and production base in 2019 [5]. However, the AGV management system required for intelligent manufacturing is still very rare and is still in the research and trial stage.

Aiming at the above-mentioned problems, this paper takes intelligent AGVs that can realize autonomous positioning, autonomous navigation and autonomous movement as the service objects, and a multi-AGV management system for manufacturing environment applications was built, which possesses relatively complete functions and good interaction between users and AGVs. The management system studied in this paper is different from the traditional multi-AGV management system. The path planning at the user end can be performed by the AGV itself, which reduces the complexity of the system. But more emphasis is placed on the real-time nature of AGV monitoring, the task scheduling capability of multiple AGVs and system data processing capabilities. Therefore, this paper highlights the function design in the AGV management system and optimizes the data processing capability in depth.

2. Application Basics

2.1. Autonomous Navigation AGV

The AGV served by this system is an omnidirectional intelligent cargo truck with a Mecanum wheel chassis or differential wheel chassis, which is equipped with sensors such as an embedded controller, wheeled odometry, IMU and lidar. It can effectively perceive the environmental information and its own status information, and realizing autonomous navigation without any external marking preset guidance.

2.2. AGV Communication

The AGV of this system uses the Robot Operating System (ROS) to communicate with the upper and lower computers, and uses the communication methods such as "node", "message", "topic" and "service" in ROS to form a communication method. In this system, related data is analyzed and processed by creating "nodes". Through the creation of nodes, nodes create topics, other nodes subscribe to topics to realize the communication of messages between nodes. In this way, the central controller on the AGV platform processes and analyzes sensor information. At the same time, the central controller can realize the control of the actuator and data communication with the host computer through the wireless communication device.

3. Management System

3.1. Development Process

In the development of the system, first analyze the basis of the application of the system is analyzed at first. Through the feedback in the actual use process, the functional requirements of the management system are analyzed, and the execution and purpose of the function are designed during the analysis process. The overall design is preliminary, and the model used is a data flow diagram. Then, the data types in the system are analyzed, the model used is the E-R model, the entities in the system and the data attributes on the entities are analyzed to obtain the data types that can support the operation of the system and then the system on the database management software database is built. Finally, the interface design is modularized, the function is divided into several modules, and the placement of controls on the interface within the module and the display of related information follow the principles

of user interface design.

3.2. System Design

3.2.1. Function Design. In the actual operation and use of the AGV process and the analysis of user needs, it is obtained that there are three core functions of the multi-AGV management system:

(1) Information management function. The management system faces not only users and AGVs, but also manages various types of data in the background of the system.

(2) Real-time monitoring function, AGV feeds back its data information to the system, and the system displays it in real time through the interface. Through the real-time monitoring function, users can easily understand the task execution status and AGV running status, and can provide data support for related decisions.

(3) Task scheduling function, select AGV and task type, and release scheduling information or task information to the specified AGV.

Establish a database in the system, read and write operations to the databases, and realize the information management function of the system [6]. Develop database operation and login functions of the system. The login function is aimed at solving the problems of multiple users. The login function can confirm the user's individual information and mark the individual user operations on the system, which can implement the operation information backtracking and enhance the system security. The database operation function is aimed at the query of data information and can export the database information at the same time, which is convenient for users.

As an expression tool of structured system analysis method, data flow graph can express the logic function of the system and the logic transformation and flow process of data in a graphical way from the perspective of data processing and transmission [7]. The data flow diagram of this system is shown in figure 1 below.

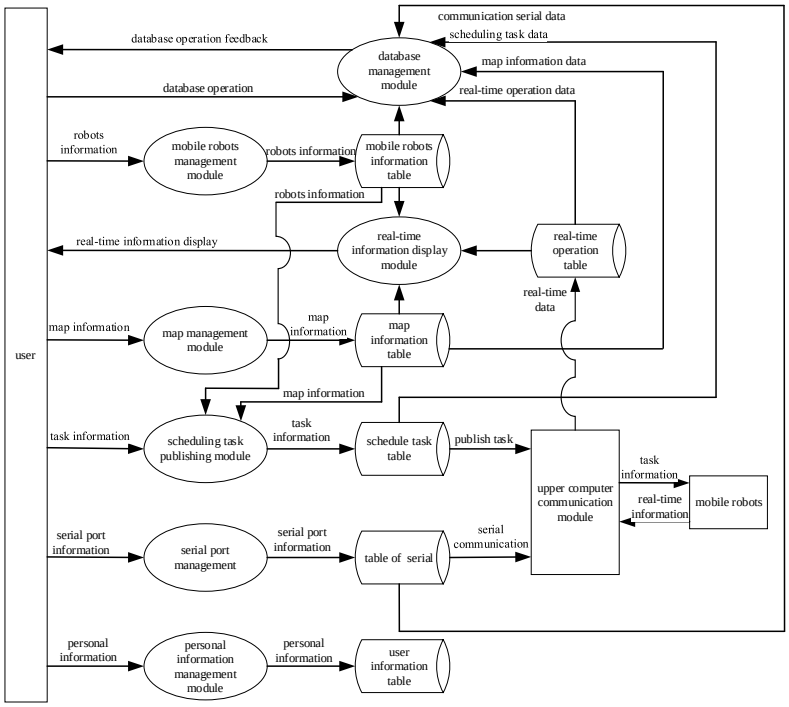

Figure 1. Data flow diagram of the system.

3.2.2. Database Design. The data design of the multi-AGV management system is the key to the system information processing capability and the normal operation of the system. First, the E-R diagram is used to obtain the data types required in the above functional design. E-R diagram is called entity relationship diagram. Its basic elements are entity, attribute and relation. It is a conceptual model used to describe the real world [8]. The E-R diagram is shown in figure 2:

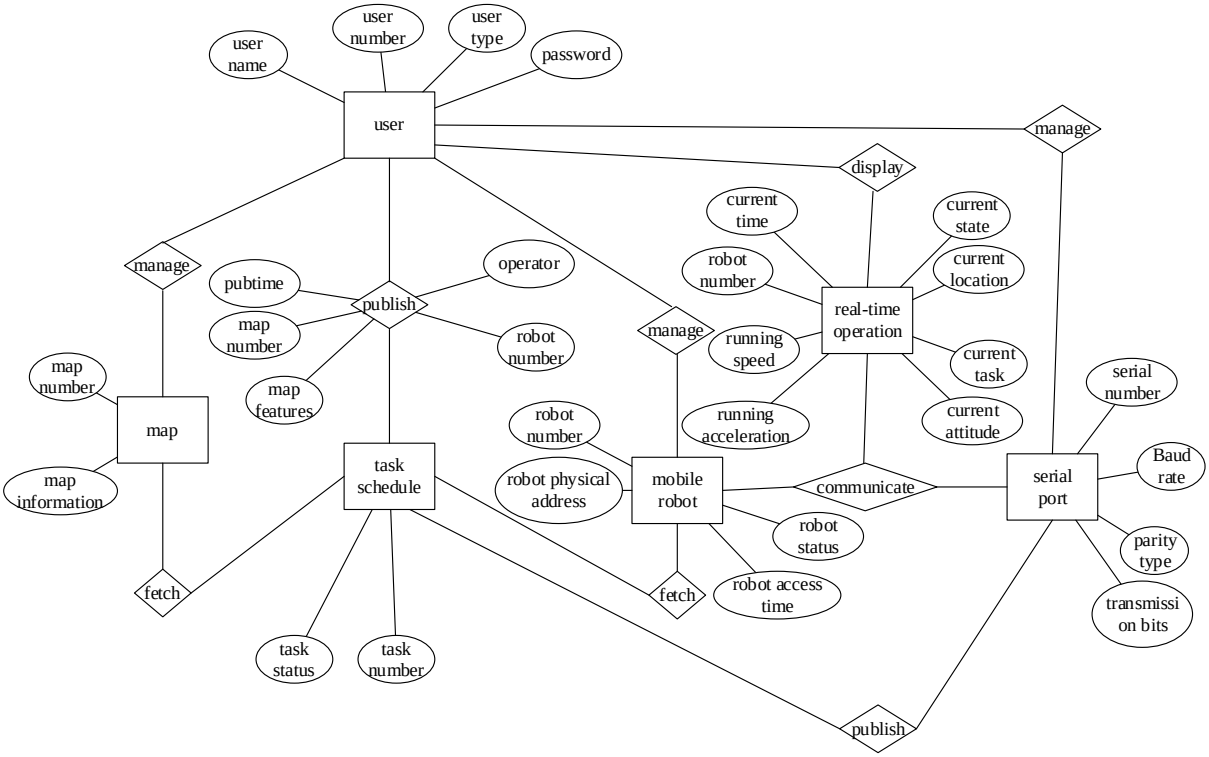

Figure 2. E-R diagram of the system.

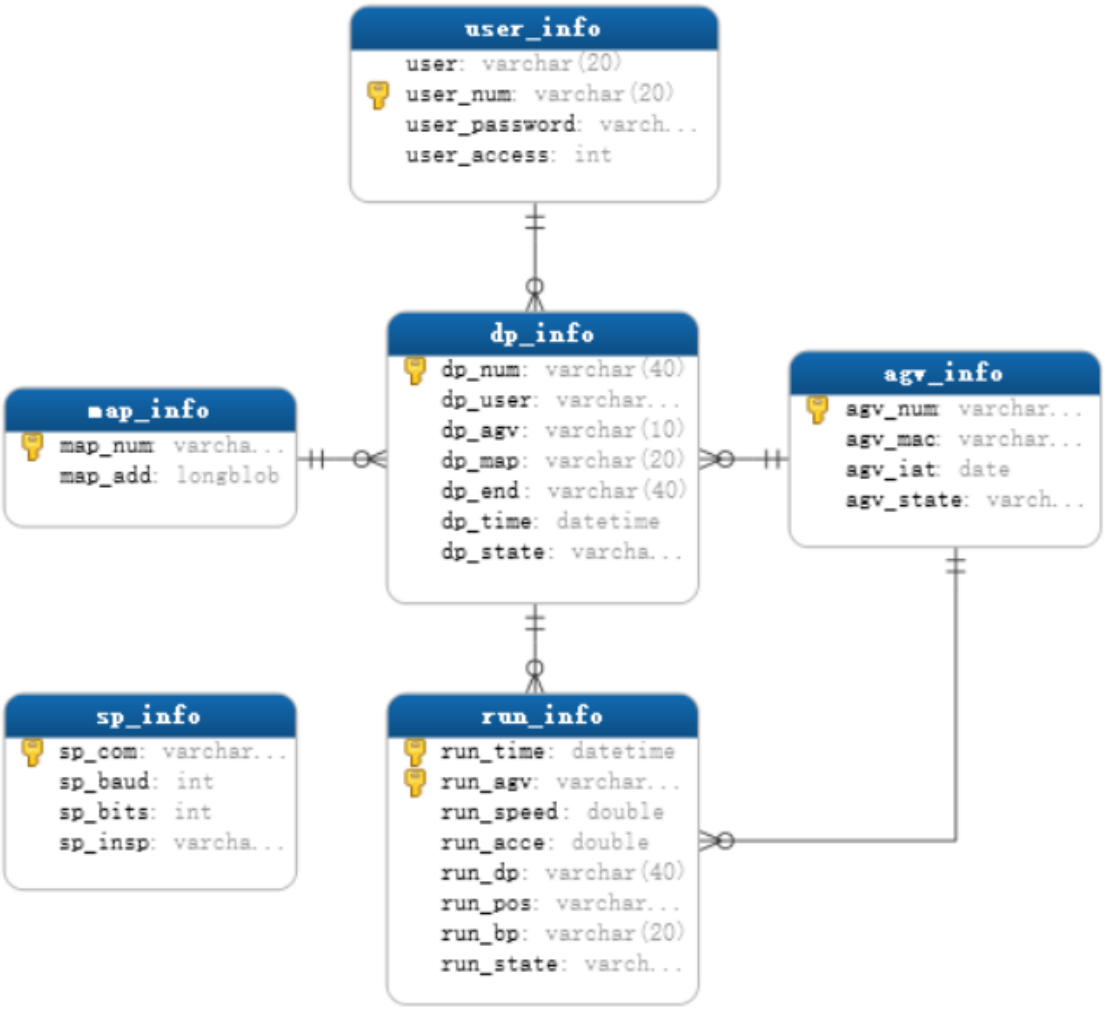

Figure 3. Database of the system.

When obtaining the data attributes of the entities in the system, the database is created in the MySQL database management system, and the data attributes in the tables contained in the database are defined. The primary key and the foreign key are defined according to the data attribute connection to finish the data design work.

When designing data tables, it is necessary to verify the normal form theory, which is the rule that must be followed in constructing database [9]. If the data table not conform to a certain paradigm, data redundancy, update exceptions, insertion exceptions, and deletion exceptions may occur.

Each column in the data table is an inseparable item that satisfies the first normal form requirement (1NF). Please refer to the figure 3. Satisfying the requirements of the first normal form to satisfy other data columns completely dependent on the primary key attribute is the second normal form (2NF). It is the third normal form (3NF) to satisfy other attributes except primary key without transitive dependencies. When the third paradigm is met in the design, it can ensure that the data in the management system is clear and stable, and there will be no abnormal data, which will meet the requirements of the system.

The six data tables in the system database were analyzed with standardized theory. The analysis results show that the six tables all meet the requirements of the third normal form (3NF), which

confirms the rigorous and reasonable design of the data tables in the system and can meet the operating requirements of the system.

3.3. System Experiment

The system interface and code development of this article are compiled on the Qt Creator platform using C++. The interface is connected with the background database to form a multi-AGV management system.

In the testing process, the data information in the manufacturing environment was imported and a test for publishing multiple task schedules was conducted. There is a screenshot of the system operation in figure 4.

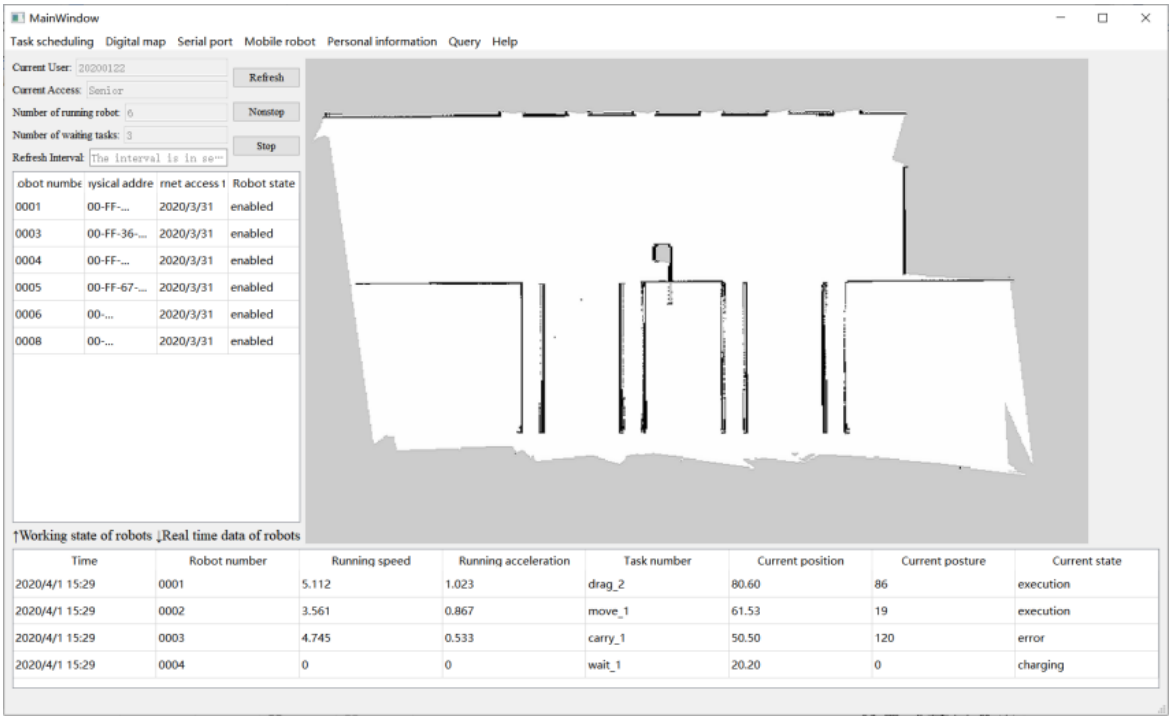

Figure 4. Screenshot of the system operation.

In the task scheduling function, the user enters the task scheduling information through the relevant interface of the system and publishes it, and the information is written into the database. In ROS, related information is read from the database of the system through subscription between nodes and the task information is sent to a specific AGV by means of a message to implement scheduling. The task information can be presented in the background database and the task scheduling function was realized. The management of AGV information and personnel information can be expressed in the corresponding data tables.

In the task scheduling function, the user enters the task scheduling information through the relevant interface of the system and publishes it, and the information is written into the database. In ROS, related information is read from the database of the system through subscription between nodes and the task information is sent to a specific AGV by means of a message to implement scheduling. In real-time display, background data can be displayed on the interface in real time, and users can intuitively and effectively ingest relevant information. When querying the database, the relevant information can be accurately queried, and the exported file is obtained in the folder during export. It is concluded that the management system can realize the management of data information, AGV task scheduling and real-time display of background data. It can operate well in database operations and

login functions. The system information processing ability run well and it can realize multi-AGV management in the manufacturing environment effectively.

4. Conclusion

In this paper, a multi-AGV management system of autonomous navigation for manufacturing environment is developed. The communication between the host and slave computers are realized through the ROS operating system. The system realizes communication, related data analysis and processing by the creation of "nodes" and subscription of topics. Data flow diagram is employed to ensure the smooth operation of the system functions and normal data logic. The physical connection of the system is analyzed by the E-R model, and the standardized analysis of the data is also performed to ensure the preciseness and rationality of the data. The interface and database were constructed on the Qt and MySQL platforms respectively, and the test was conducted after importing the test database. The results showed that the built system runs smoothly, and the data processing is correct and timely, which means that it can achieve the intended purpose of the design.

Acknowledgments

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