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A Study of AGV Collaboration with Internet of Things Concept for Collision Avoidance at Warehouse Intersection

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Abstract

With advance of technology, automated guided vehicle (AGV) will become common daily vehicles, which means collaboration between AGVs are more and more important. This paper suggests that how to make AGV avoid collisions with other AGVs is a practical problem, and it is a common need and should be solved if there are two or more AGVs interacting with others. Therefore, a better system design should be developed and implemented. This paper used a three-layer structure of internet of things (IoT) to design an AGV collaboration system, to avoid collisions with other AGVs in this system, and to decrease path deviation. The concept of IoT was applied for AGV communicating with other AGVs through sending AGV position messages. In such a case, AGV would know other AGV positions and decide which actions to take. This paper used Robot Operating System (ROS) to design an AGV collaboration system, and conducted an experiment to verify the feasibility of this system. The experiment simulated the intersection of warehouse in the real world. According to the results, two AGVs can avoid collisions by knowing positions of each other in every path scenario. When two AGV both followed straight paths, the deviation was the smallest. When one AGV turned left and another turned right, it might have largest deviation.

Keywords: *Automated Guided Vehicle, Collision Avoidance, Internet of Things, Robot Operating System*

INTRODUCTION

AGVs have been widely used for material handling in manufacturing and supply chain environments [1]. It is frequently used to improve efficiency and operation in various sectors of modern industry [2]. The utilization of AGVs for material handling in intelligent or autonomous warehouses has the potential to increase warehouse efficiency and company competitiveness [3]. AGVs has been used in the warehouse business to increase flexibility and reduce operating costs [4].

Industry 4.0 has a major impact on several elements of business, particularly those involving warehousing. The Internet of Things (IoT) has been used in warehouse management systems to track product information in material handling [5]. The AGV was critical equipment that utilized IoT technology to eliminate human resources and reduce delays throughout the production process [6]. Robot Operating System (ROS) provides a layer between the hardware and application layers as a middleware framework [7]. The ROS technology provides a message exchange using publish-subscribe architecture to develop communication [8]. It helps to manage the communication between AGVs when performing work. Therefore, the design of communication system with ROS and proper responses of AGVs through IoT architecture is the primary motivation of this study.

This paper aims to integrate the IoT concept with AGV motion control to prevent collision at the intersection. And at this stage AGV makes motion decisions based on locations of two AGVs accordingly. AGVs expect to interact and collaborate to complete assigned activities automatically and increase the agility of their movements. The objectives of this research are design a collaboration system between two AGVs through the wireless communication environment using IoT concept to perform tasks. It is assumed that an AGV collaboratively performs a task with another AGV in a warehouse. The ROS system is used with IoT three-layer architecture to develop a communication network for validating the proposed design.

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LITERATURE REVIEW

First, basic concepts of IOT and ROS are discussed in this section. A commonly accepted definition for IoT is *a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'Things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network* [9]. Based on the previous definition, three-layer architecture was widely used to illustrate the IoT applications. The bottom layer is the physical layer which includes sensors, actuators and embedded devices. The middle layer is the network layer which may include Wi-Fi, Bluetooth, ZigBee, etc. The upper layer is the application layer which considers this layer as the host of any specific IoT applications. In this research, the physical layer is for the AGVs, the network layer is for the Wi-Fi communication, and the application layer is for the AGV motion tasks.

Robot Operating Systems (ROS) is an open-source middleware framework for the development of complex robotic systems and applications [10]. The Ubuntu and ROS combination is an ideal choice for programming robots because an operating system based on Linux can provide great flexibility to interact and provide provision to customize the operating system according to robot application [11]. The ROS Master is much like a DNS server, associating unique names and IDs to ROS elements active in the system. The ROS Master provides naming and registration services to the rest of the nodes in the ROS system. It tracks publishers and subscribers to topics as well as services. The role of the Master is to enable individual ROS nodes to locate one another. Once these nodes have located each other they communicate with each other peer-to-peer.

One kind of AGV is proposed to implement the designed AGV collaboration system, and NeuronBot is selected and shown in Fig. 1. The NeuronBot is a miniature and autonomous robotic development platform with an integrated computational unit, several sensors, and motion capability. It is suitable for enabling a wide range of research, training, and educational activities [12]. It was developed by ADLINK Technology, Inc. as a corporate entity and has the copyright on it. The NeuronBot using Neuron Software Development Kit, Ubuntu 18.04 as an environment, and ROS 1/ ROS 2 Intel® OpenVINO™ as a middleware.

Figure 1 NeuronBot

RESEARCH METHODOLOGY

The proposed AGV collaboration system based on the IoT concept were described and depicted in Figure 2. The collaboration system architecture used the IoT model is composed of three layers as followings:

1. Perception layer.

It is the physical layer in the IoT architecture, which is responsible for obtaining data such as current position, obstacle range, direction, etc. from the AGV sensors and AGV actuators. In this layer AGV performs collaborative tasks in the local environment and makes decisions based on the related data received from the network layer.

2. Network layer.

This layer is responsible for passing the data from the perception layer to the application layer. The ROS architecture is used to build up the communication between AGVs and the computer. The same ROS master is applied to the AGVs and the system computer for exchanging information.

3. Application layer.

In this layer, the data processing is carried out. It will process the data to calculate the distance, current position, speed, etc. Users can set the destination of each AGV using the server, and the server will generate many ROS nodes based on the task content to give information about the AGV's position status through a network layer. The data from each AGV node will be sent to each other. So, the locations of all AGVs would be broadcast to the whole system. Then, AGV would respond directly after the node was updated by an application layer.

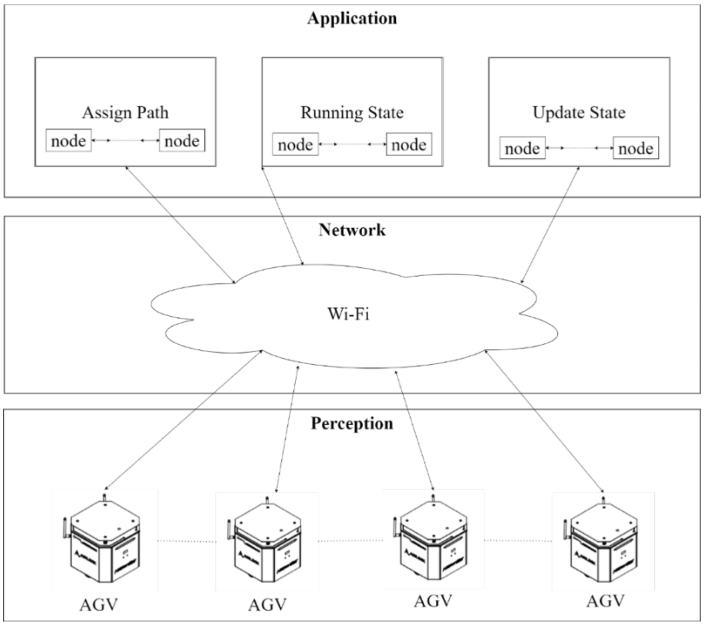

Figure 2 AGV Collaboration System Architecture

At this stage, two AGVs was applied to verify the proposed collaboration system, in general two ROS Masters are required as the middleware, however, this study only applied one ROS Master to do the job and it shown in Fig. 3 . The AGV can be moved or monitored by publishing and subscribing to these topics through a ROS Master, as shown in Figure 4. This study used ROS Launch to modify topic names and used group1 and group2 to distinguish similar topics. For example, the original topic is cmd_vel.

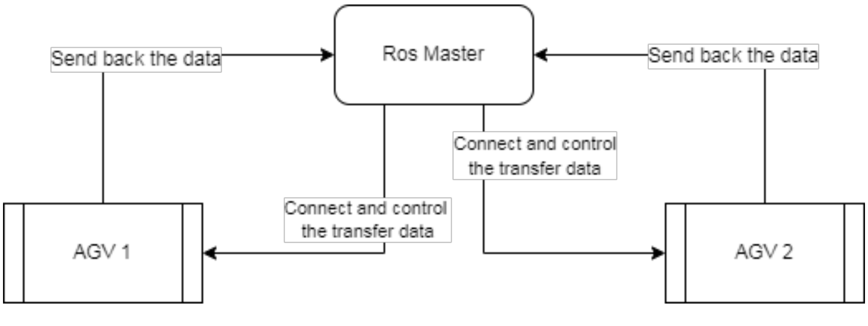

Figure 3. Wireless Communications with ROS [13]

The AGV 1 topic would be group1/cmd_vel and the AGV 2 topic would be group2/cmd_vel. It solved the problem of duplicating topic names for the same ROS Master. Therefore, even two AGVs only need one computer to control or monitor, as shown in Figure 4. Since the ROS Master is the same, each node can directly publish or subscribe to exchange the information. Regardless of how many AGVs are in the system, AGVs could be monitored with only one computer.

There could be many kinds of functions in the AGV collaboration system. In this paper, the development of the AGV collision-avoidance system for two AGVs with wheel encoders is discussed. Several control rules and limitations of AGV activities are defined for this study, and motion planning is applied for the AGV to complete the moving task. Motion controls are developed and flow charts for the central computer and each AGV are shown as following.

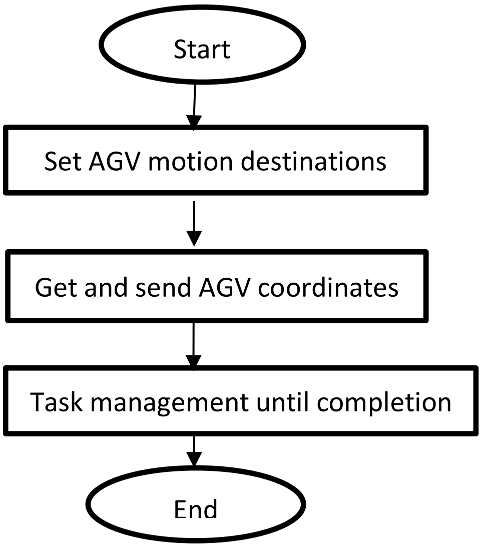

Figure 4. Control Flow Chart for Central Computer [13]

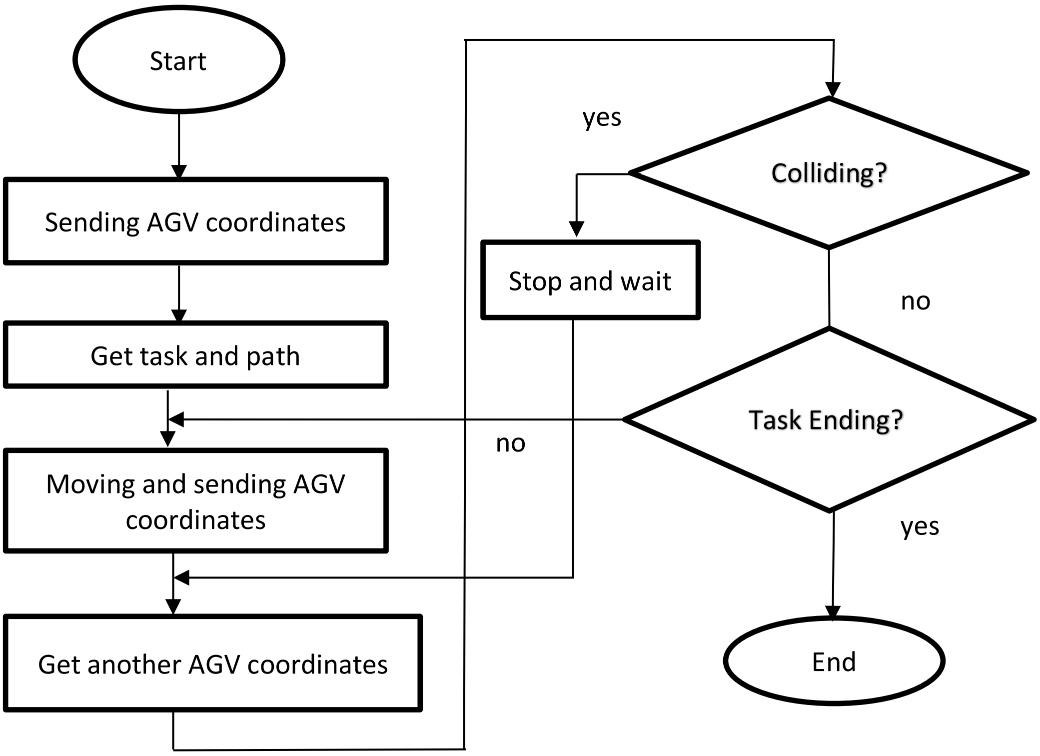

Figure 5. Control Flow Chart for AGV [13]

The central computer assigns the moving tasks to each AGV, and exchanges AGV coordinates for the AGVs until the task is completed. Each AGV gets the assigned task and starts moving, and it will decide whether to stop or move based on the location of other AGV or task status. Experiments will be performed to validate whether designed collaboration system for collision avoidance is feasible, and the experiments will be discussed in the next section.

EXPERIMENT AND RESULT

An experiment was conducted to verify the designed AGV collaboration system, and the motion controls displayed in Figures 4 and 5 were implemented two NeuronBot. Two AGVs' motion was developed using global and local path planning, and both AGVs were working independently at first stage. In order to make two AGVs cooperate, a ROS Master using the IoT concept was applied to provide communication channel between them. The experiment was carried out on the building floor to simulate the warehouse operations in the corridor of the Industrial and Systems Engineering Building at Chung Yuan Christian University.

Two AGVs were set at two respective starting points and started to move. When one AGV reached a predefined point, it would cooperate with other AGV to pass the intersection without collision based on locations of two AGVs. There is no other sensors but wheel encoders to calculate the moving distance of AGVs. The global and local path planning were applied in this paper from the starting point of each AGV to the intersection point and the ending point (goal task). Figure 6 is the building floor layout for both AGVs and the unit is meter. The coordinate of the intersection point is (0,0), AGV will reduce speed when it reaches one meter away from the intersection point, and it will make decision to keep on moving or stop and wait based on which AGV is closer to the point.

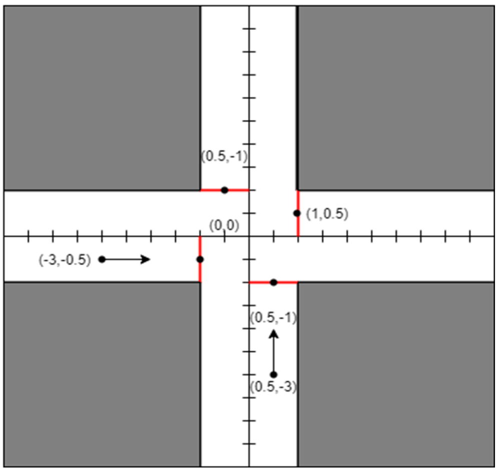

Figure 6 Global Map of the Intersection [13]

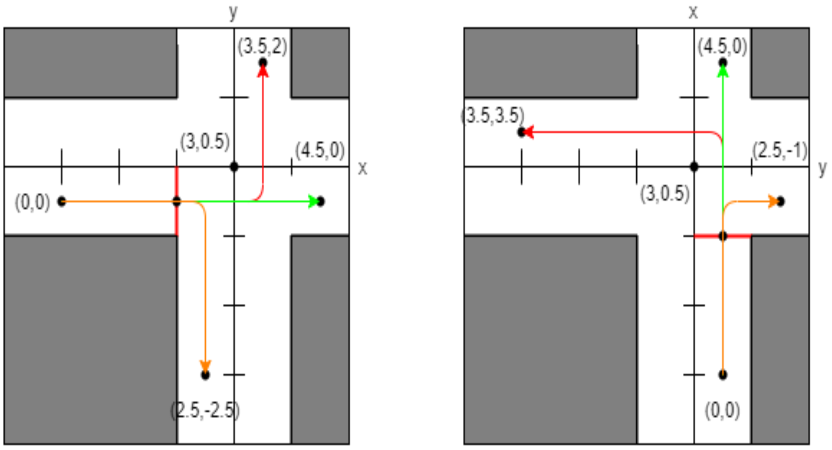

Figure 7 Local Maps and Path Planning of Two AGVs [13]

In order to have more thorough scenarios for this experiments, for each AGV there are three motions: straight, turn right or turn left. Therefore, there are nine scenarios for the combination of movement, and each scenario performed three trials to make sure the system performance is stable. The path planning of each AGV is shown in Figure 7. There were total 27 trials of this experiment and all have passed the test, and distance errors to the ending points were also collected for a statistical study. Here only conclusions were shown, and it was concluded that when two AGVs both follow straight paths, the error is the smallest. When one AGV turned left and another turned right, it might have the largest error.

CONCLUSION AND FURTHER RESEARCH

This paper aims to design an AGV collaboration system to avoid collisions at a warehouse intersection. The ROS technology and IoT concept were integrated to achieve real-time communication between two AGVs by exchanging location messages.

An experiment was designed to validate the AGV collaboration system. In this experiment, the AGV position was calculated form the odometer sensor data. The position data were applied to decide which AGV would pass first, which would stop and wait near the intersection point to prevent the collision.

AGV movement was designed by motion planning for assigned tasks. Nine scenarios with three trials each were developed to verify the feasibility of AGVs collaboration systems when AGV performing tasks. All trials have finished the tasks without any collision, and the results showed that when two AGVs both follow straight paths, the error is the smallest. Different scenarios may have different error valuses and this situation suggest better motion control methods be needed for further study.

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