Design of AGV Control Strategy in a Processing System

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Abstract. A typical manufacturing system requiring a high degree of automation usually includes warehouse, AGV, CNC, assembly line and laser marking equipment. Among them, AGV plays an important role on the overall operating quality and operating efficiency. This paper studies AGV control strategy under the background of the typical manufacturing system. Firstly the two modes of AGV motion path are defined; the flow chart of AGV movement between any two points in the system is analyzed, and the AGV communication module in the minimum operation mode is designed; finally, control programs for several main scenarios are proposed based on PLC ladder diagram. The outcome helps the optimization of AGV control decision relating to a bottom operation layer of any manufacturing system.

1. Introduction

Generally a typical manufacturing system includes warehouse, AGV, CNC processing unit, assembly unit and laser processing unit. In fact, the bottom execution layer of manufacturing industry is formed on the basis of this kind of typical system[4].

A warehouse is a centralized storage facility for semi-finished products, finished products and empty bins. It mainly includes inward and outward conveyor belts, stacker, shelves and pallet; and stacker can move horizontally, vertically and in fore and aft way (figure 1)[3]. AGV is an automated handling equipment, which moves and transports goods between any two units of the typical manufacturing system[1]. A CNC unit is a piece of equipment for processing semi-finished parts. The function of an assembly unit is to assemble different parts or semi-finished products together. The laser processing unit is applied to mark an assembled product.

Figure 1. Three-dimensional diagram of a warehouse
AGV is a "link" connecting each unit or workstation of the manufacturing system, and the unmanned connection between each core workstation is completed via AGV. Generally AGV is the movable part of the typical manufacturing system, and hence AGV is crucial to the overall operating quality and operating efficiency of the manufacturing system[4]. This article studies AGV control strategy in the background of the typical manufacturing system.

2. Structure of the Control system

The control system of the typical manufacturing system is built as followed:

![Control system of the typical manufacturing system](image)

A control system includes upper computer, field bus, warehouse control unit, AGV control unit, assembly control unit and laser control unit etc.[2]. Upper computer is the core of the entire control system, which is responsible for the control and scheduling of the manufacturing system, and whose scheduling priority is the highest. Field bus is a kind of industrial data bus. It is a communication network in charge of the underlying field devices and data in the field of automation. It has the advantages of simplicity, reliability, economy and practicality. In this control system, field bus adopts the PROFINET automation bus standard. A warehouse control unit controls a stacker to transport goods in a three-dimensional space, that is, loading and unloading goods; and also monitors goods position and overall storage capacity in real time. AGV control unit regulates handling tasks between two stations of the system. This research aims at real-time industrial control task, so PLC is adopted as controller. Considering the scale and reserved capacity of the control problem, Siemens S7-1200 PLC is chosen[5].

3. Design of AGV Control Strategy

3.1 Motion paths of AGV

In the typical manufacturing system, there are two possibilities of AGV motion path, namely maximization and minimization mode. Maximum AGV motion path is described as the figure 3: AGV starts from the outbound conveyor belt of a three-dimensional warehouse and transports the workpiece (to be processed) to a CNC1 processing unit; after processing is completed, the workpiece is sent to the assembly unit for assembly; if the assembly is completed, AGV transports the workpiece to the laser unit for engraving; finally, AGV transports a finished product back to the warehouse or offline directly. Minimum AGV motion path is described as the figure 4: AGV starts from the outbound conveyor belt of the three-dimensional warehouse, and transports the workpiece (to be processed) to the assembly unit; after the assembly is completed, AGV transports the processed items to warehouse or go offline directly.
In order to reduce the complexity of the problems involved in this paper, AGV control strategy is studied in the minimum operating mode.

3.2 Flow chart of AGV movement
Flow chart of AGV movement between any two units of the system is described as figure 5. First, system activates AGV to prepare a running; after receiving the relevant control signal, AGV starts to move and then reaches a starting point; then a bin/pallet is placed on the AGV. During the second stage: system activates AGV to prepare an ending activity; then AGV starts to move and then reaches an end point; a bin/pallet is delivered to workstation; finally AGV stops. It is obvious that any whole path that AGV runs comprises one or more than one (such a) movement.
3.3 Communication framework of AGV
The framework of AGV communication program is shown in the figure below:

![Diagram of AGV Communication Framework](image)

Figure 6. Framework of AGV communication program (under minimized motion path mode)
In the minimum mode of motion path, AGV’s communication program frame is shown in the figure 6, including 6 program segments. The three main stages include: firstly, a random number is generated; then AGV and the controller of a downstream unit perform identity verification and then establish a link; in the fourth step, AGV and other controllers of system execute communication synchronization and status monitoring through a heartbeat signal.

3.4 Control programs of AGV
Some typical control programs of AGV are shown and described in the following parts.

![Diagram of Authentication Message](image)

Figure 7. Sending authentication message for a new connection
In this part, AGV starts and sends a character string (identity verification) to warehouse. After receiving the character string returned by warehouse controller, a new connection is set up.

![Diagram of Heartbeat Signal](image)

Figure 8. Heartbeat signal
When system is running, there is a heartbeat signal (figure 8) between AGV and the controller (of the next unit in an operating cycle). Namely, the heartbeat signal is a constantly changing signal like a heartbeat, which is generally used for communication status detection. Its function is to tell the controller whether the operation is normal. When the heartbeat signal is interrupted, controller can immediately detect the communication interruption of system and take corresponding measures.
After a workpiece is processed (figure 9), finished product goes back to warehouse. At this time, AGV carries the finished product to inbound conveyor belt of warehouse, and sends a feeding signal to warehouse unit controller; finally feeding in could be implemented.

Figure 10. Feeding ends
After finished product is successfully loading into warehouse (figure 10), due to safety considerations, after a delay of 5 seconds, a feeding completion signal is sent to warehouse unit controller, and AGV leaves warehouse then.

4. Conclusion
This paper focuses on the research of AGV control strategy for a typical manufacturing system. Firstly two kinds of motion path are analyzed, and the flow chart of the movement between any two points in the system is designed, and then the communication module in the minimum mode is put forward and last but not the least control programs of main scenarios based on PLC ladder diagram are coded. These results do support the optimization of AGV control strategy in this typical manufacturing system.

Future work includes: redesigning the communication module in the maximum mode, developing control programs in the maximum mode and so on.

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