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Design and Development of Automated Guided Vehicle (AGV) System for Industries Based on Radio Frequency Identification (RFID) Technology

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***Abstract*— Automated guided vehicles (AGVs) are known for their routing flexibility advantage, hence they are frequently applied in automated warehouses, airports, Automated storage(AS) /Retrieval System(RS) to optimize the transportation tasks and, consequently, to reduce costs. Automated guided vehicle (AGV) is used widely in many industrial applications to transport materials. A short-travel material transport system is designed and controlled in this paper for a unit load AGV to transfer the material from Pick-up station rack to the Placing of material to finished goods rack aisle and back, including a both-side pick-and-place-material transfer mechanism and a programmable logic controller (PLC). AGV follows the path as per program in microprocessor and on-board sensors on the AGV, and locates itself according to the RFID tags beside the pick-up station. The RFID module detects the pick-up position of finished goods for the gripper and the placing the same in designated storage racks, and controls the horizontal and vertical movement of the load-transfer mechanism by using a geared motor and a chain and sprocket mechanism for 180 degree rotation of finished goods on the other side. The finished goods transfer experiments of our AGV testify the performance of this material transport system.**

***Index Terms*—** AS/RS, gripper control, RFID, AGV, material transport, mechanism control

I. Introduction

Developing an AGV System is one of the major task in the field of mechatronics requiring a mechanical arrangement and control of the actuators. In most of the mechanism it is hard to maintain the path to be followed while carrying some goods on it, so taking into consideration all these things, the thought process gave us the way to design and develop a AGV machine which will detect the product automatically using RFID technology and carrying part to its predefined/designated Location in storage racks. RFID is the wireless use of electromagnetic fields to transfer data which are used for the purpose to identify and track automatically the tags which are attached to various parts. Information regarding the part is contained in these tags. This tag does not necessarily need to be within line of sight of the reader as compared with a barcode. The so-called smart parts based manufacturing system such as using CAD/CAM,CAPP, CMM and CAQC addresses these concerns well. The smart part carries operating instructions for the operating workers or automatic machines such as the AGV's. Uniquely identified individual parts can be processed according to their specific requirements based on individual customer preferences. Therefore, there is the need to correctly identify every part to ensure reliable process control in such a flexible and customer oriented manufacturing system. Radio frequency identification is a technology that has been in use for some time. It offers features that are well suited to be adapted for such flexible smart-parts manufacturing. As the use of this technology grows, it will come into the industrial mainstream just as it has already done in retail outlets where it is used for electronic surveillance, in hospitals, food, paper industries to name a few. The idea is to install a system with an Automated Guided Vehicle (AGV) to take care of this transportation and placing the parts at their designated racks. The purpose of this project is to present which demands there are on the system and to find the best solution according to the demands. The conclusion was that the most suitable system for this application is a small unit load vehicle using system which will just identify the various obstacles coming in its path and then moving again as the obstacles are removed. Or if it goes off the track it will be incorporated with an inbuilt sensor system for bringing the AGV back on path.

The reason for this mandate was that we can improve the Store/warehouse operations and enhance profits by improving the product availability on store shelves, and by increasing the visibility in their supply chain. The major problem for the company to follow this mandate was that their facilities did not have a RFID infrastructure as this was a new and emerging technology. Therefore, it became difficult for them to comply with the mandate. The second biggest concern was the costs associated with RFID implementation. Since, being an emerging technology, the costs associated with the implementation were higher as compared with other similar techniques. Therefore, the profit margin of the suppliers was proposed to be reduced. Some problematic issues about the adoption of RFID in the plastic industry are then discussed. The scope of the topic is then narrowed down to provide a specific research area.

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Time frames are proposed to be presented that show a predicted and actual weekly planning. Lastly, a pro-type model analysis is provided that serves as a backbone where this project was built upon. In recent years, because of its ubiquity, radio frequency identification (RFID) technology has becoming the hotspot in the field of object location. RFID systems use radio transmissions to send energy to a tag which, in return, emits a unique identification code back to a reader linked to an information management system. If the RFID tags with unique codes are embedded in objects, the identification of the objects can be greatly simplified. Furthermore, RFID has a lot of advantages, such as contactless communications, long lived, high data rate, non line-of-sight readability, and low cost [3,4,5]. For the above reasons, RFID technology has been often employed to recognize objects for navigation, manipulation, etc. Based on the above analyses, a kind of new RFID based AS/RSs is proposed in this paper in order to realize target recognition, automatic localization and AS/RS, which can not only improve the precision and speed of the automated warehouse, but also be suitable to the management of modern corporation.

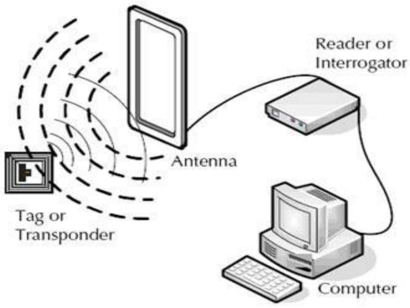

Figure 1:Radio frequency identification system

II. Load Transfer Methodology

Unit load AGV has many kinds of decks (e.g. bearings, Chain and sproicket, etc) to transport materials. In the consideration of the transfer requirements of automobile assembly production lines, we suggest a material transport control methodology to locate AGV beside the load stand accurately and retrieve and deposit the pallet automatically.

A. Docking

A load aisle is the fixed rack where the material is picked and placed from the AGV to the workstation and back. AGV movement near the load aisle is controlled differently to its movement on the path since both a higher accuracy and a different obstacle avoidance technique are needed. In the close proximity to the load aisle, AGV needs to navigate closer to obstacles and it must reach the designated placing point with greater precision. In order to achieve the accurate docking distance between AGV and the load stand, the real-time position of AGV needs to be updated continuously and AGV pose needs to be adjusted accurately.

Our AGV navigates on the specified paths by following the on board sensors, as shown in Figure 2. An on board guide sensor is mounted in the side of AGV body, and it can detect the lateral deviation between AGV and the desired paths. Path tracking control is used to eliminate this deviation and keep AGV on the path. When the load aisle is placed accurately beside the paths, the lateral position between AGV and the load aisle can be guaranteed by controlling the lateral deviation. On the other aspect, the longitudinal position from AGV to the load aisle is also very important to the docking process. It can be controlled by defining starting position of AGV. The RFID module sensor is installed in the head of AGV, which is designed as a semi-open structure in order to avoid the shielded metal environment that may block the RFID signals.

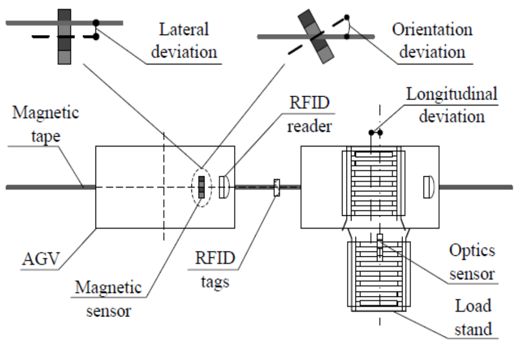

Figure 2. AGV docking process

B. Retrieving

Retrieving means AGV picks up the material from the station1. After AGV arrives at the accurate picking spot, it should check whether the material is at the designated position for the gripper to pick-up the same properly.

C. Depositing

Depositing means AGV puts down the material pallet to the load stand. AGV should contact the workstation and verify the load stand is free before the material delivery process starts. The pallet is pushed to the load stand from the side of AGV. It is a similar process of retrieving as following actions, shown in Figure 3.

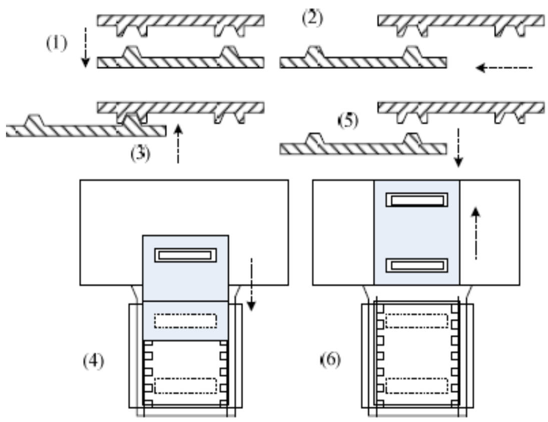

Figure 3. Load putdown approach

III. Gripper Mechanism Design

Two ways of constructing the part in the gripper as shown in Figure 4.

1. First is by physical constriction of the part within the fingers wherein the gripper fingers enclose the part to some extent, thereby constraining the motion of the part. Here the design of the contacting surfaces of the fingers is approximate shape of part geometry.
2. Second way of holding the part is by friction between the fingers and the workpart wherein the fingers must apply a force that is sufficient for friction to retain the part against gravity, acceleration, and any other force that might arise during the holding portion of the work cycle. So finger materials in such cases are relatively soft to increase the coefficient of friction between the part and the contacting finger surface.

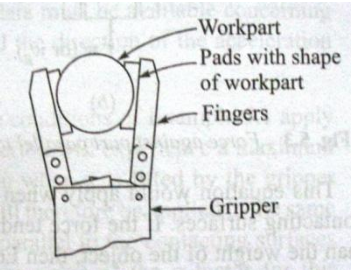

Figure 4. Single or Double type Gripper

Advantage of Friction method a) Less complicated, b) less expensive and c) readily adaptable to a greater variety of work parts.
Equation can be used to determine the required magnitude of the gripper force

$$\mu\, n_f F_g = \omega \qquad (1)$$

where μ = coefficient of friction of the finger contact surface against the part surface
n_f = number of contacting fingers
F_g = gripper force
ω = weight of the part or object being gripped

Eqn.(1) would apply when the force of gravity is directed parallel to the contacting surfaces. Eagleburger suggests that in a high-speed handling operation the acceleration (or deceleration) of the part could exert a force that is twice the weight of the part. He reduces the problem to the use of a g factor in a revised version of eqn.(1) as follows:

$$\mu\, n_f F_g = \omega\, g \qquad (2)$$

where g = g factor, supposed to take into account of the combined effect of gravity and acceleration.
g value = 3.0 if the acceleration force is applied in same direction as the gravity force.
g value = 1.0 if the acceleration force is applied in opposite direction as the gravity force.
g value = 2.0 if the acceleration force is applied in a horizontal direction.

A. Work piece Data

Weight of Insuboard with Al. sheet on both sides= ¼ kg.
Weight of Insubox with Insushield, Insuboard = 1/7.5 kg.
Insuboard held in a gripper using friction against two opposing fingers.
Coefficient of friction between the finger contacting surfaces and the Insuboard surface μ = 0.25.
Insuboard orientation is such that the weight of the Insuboard is directed parallel to the finger surfaces.
Fast work cycle anticipated, g factor = 3.0 should be applied.
Solving and using eqn.2 as $\mu\, n_f F_g = \omega\, g$

$$(0.25)\,(2)\,F_g = (1/4)\,(3)$$
$$F_g = 3/2 = \mathbf{1.5}\ \text{kg}$$

Similarly for Insubox,(0.25) (2) F_g = (1/7.5) (3)

$$F_g = 3/3.75 = \mathbf{0.8}\ \text{kg}$$

Gripper must cause a force of 1.5kg (for Insuboard) and 0.8kg (for Insubox) to be exerted by the fingers against the Insuboard and Insubox surface.
Robot grasps the Insuboard and Insubox at its centre of mass, so that there are no moments that would tend to rotate the box in the gripper.
In using Eqn.(2) as a design formula, a factor of safety would typically be applied to provide a higher computed value of gripper force.
Safety Factor (SF) =1.5 would result 1.5 x 1.5 = 2.25kg and 1.5 x 0.8 = 1.2kg.as the required gripper force. This safety factor would help to compensate for the potential problem of the Insuboard and Insubox being grasped at a position other than its center of mass.

IV. Storage Rack Design

Conventional Storage Methods and Equipment
The following are the types: 1. Bulk storage, 2. Rack Systems, 3. Shelves and bins, 4. Drawer storage and 5. Automated storage systems. Sizing the AS/RS Rack structure:
Total storage capacity of one storage aisle depends on how many storage compartments are arranged horizontally and vertically in the aisle, as indicated in Figure 5.

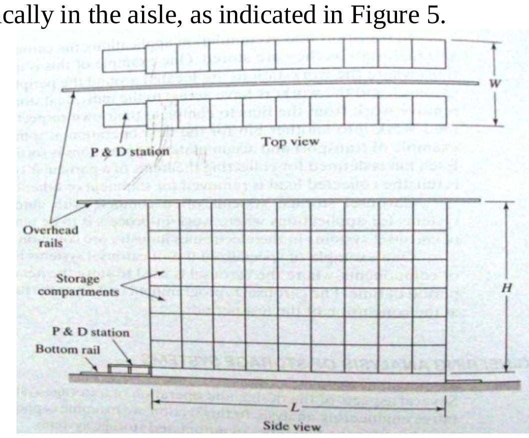

Figure 5. Sizing AS/ RS Rack Structure

Capacity per aisle = $2\, n_y n_z$ (3)
where n_y = number of load compartments along the length of the aisle.
n_z = number of load compartments that make up the height of the aisle.
The constant, 2, accounts for the fact that loads are contained on both sides of the aisle.

Assume a standard size compartment (to accept a standard size unit load),then the compartment dimensions facing the aisle must be larger than the unit load dimensions.
Let x = depth of a unit load (mm,in)
y = width of a unit load (mm,in)
z = height of a unit load (mm,in)
Width, Length and Height of one aisle of the AS/RS Rack Structure (mm,in)

$$W = 3\,(x + a) \quad (4)$$

$$L = n_y\,(y + b) \quad (5)$$

$$H = n_z\,(z + c) \quad (6)$$

Where a, b, c are allowances designed into each storage compartment to provide clearance for the unit load and to account for the size of the supporting beams in the rack structure (mm,in).

A. Storage Rack Data

For the case of unit loads contained on standard pallets, recommended values for the allowances are a = 150mm, b = 200mm and c = 250mm.
No. of aisles = 4, Storage compartment size is same.
Storage compartment, n_y = 60 in length direction. Storage compartment, n_z= 12 vertically.
Compartment accommodates standard size pallet of dimension:
x = 1050mm, y = 1200mm, z = 55mm
Now using the allowances a = 150mm, b = 200mm and c = 250mm.
The storage capacity = 2 n_y n_z
Capacity per aisle = 2 (60) (12) = 1,440 unit loads. With four aisles, Total AS/RS capacity = 4 (1440) = 5760 unit loads.
From eqn. 4,5 and 6 we can compute the dimensions of storage rack structure:
W = 3 (x + a) = 3 (1050+150) = 3600mm = 144 in = 12ft/aisle
Overall width of AS/RS = 4 (12) = 48ft.
L = n_y (y + b) = 60 (1200+200) = 84000mm = 3360 in = 280ft
H = n_z (z+ c) = 12 (55+250) = 3660mm = 146.4 in = 12.2ft/aisle
Standard pallet sizes commonly used in Factories and Warehouses used as reference.

TABLE I.
STANDARD PALLET SIZES

Depth = 'x' dimension	Width = 'y' dimension
800mm (32 in)	1000mm (40 in)
900mm (36 in)	1200mm (48 in)
1000mm (40 in)	1200mm (48 in)
1060mm (42 in)	1060mm (42 in)
1200mm (48 in)	1200mm (48 in)

V. INTELLIGENT STORAGE AND RETRIEVAL SYSTEMS

RFID and vision based intelligent storage and retrieval systems are shown in Figure 6. The system mainly includes two parts: RFID and vision systems. RFID technology is used to localize the target roughly, and onboard vision is used to localize the target precisely.

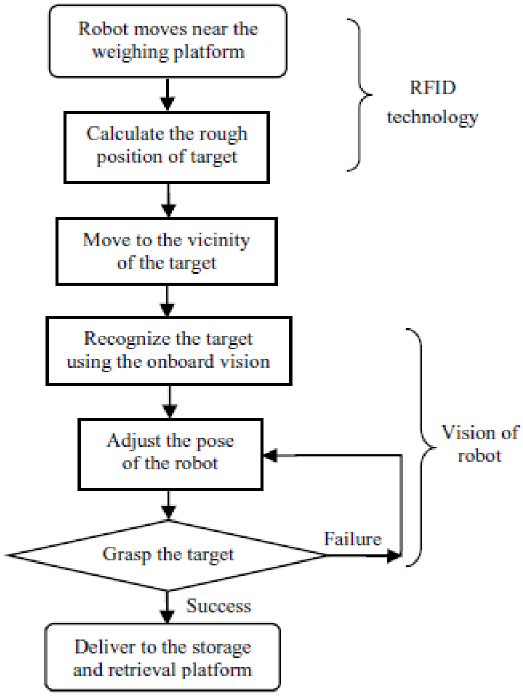

Figure 6. Flow Chart of intelligent storage and retrieval.

VI. STRUCTURE OF CONTROL SYSTEM

The RFID system mainly includes three parts: reader, antenna, and RFID tag. Because of the uniqueness of the RFID tag, the reader can locate and track the target once it is attached on an RFID tag. Passive tags are used to attach on the target object because they are much cheaper, long lived, lightweight and have a smaller foot print. The reader can communicated with host computer through RS232.

The control system of the automated warehouse include management/monitor computer, master PLC and lower PLC as shown in Figure 7.The whole automated warehouse system integrated cargo storage, retrieval, distribution and transportation together, realizes intelligent operations in the whole system, and is an intelligent warehouse without any manual operation.

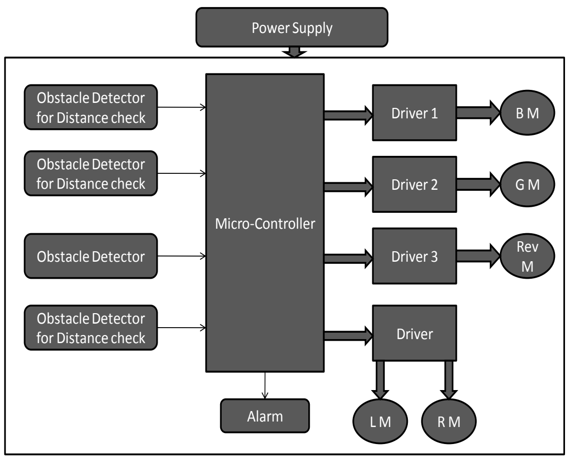

Figure 8. Control System of AGV

VII. Component Transfer Testing

In order to test the component transport system of AGV, the component transfer testing are carried out in the shop floor of The Supreme Industries Ltd. A closed path is laid out in the shop floor by specifying arbitrary initial position using programming. One component station is placed on a designated spot accurately beside the path, which is used as a component pickup workstation as well as a raw material placing workstation. Firstly, AGV starts at an arbitrary point of the path and moves towards the raw material component station-1. After it arrives at the accurate docking spot, it picks up the raw material from the station-1 automatically. Then it continues to run on the straight path and comes back to the raw material placing station-2 stand when it finishes the straight path. Afterwards it checks the finished component station-3 which is waiting for pick-up of component using RFID module and RFID tag attached at Station-3, it then picks-up the component from Station-3. The Loaded plate then turns by 180 degrees to place the component and move towards the initial arbitrary position for placing the component on to the designated storage rack automatically. After placing the finished component to the storage rack the loading plate again rotates by 180 degrees for the next cycle of operations.

In the component transfer testing, retrieving and depositing operations of AGV are executed continuously in a periodic way up to one shift. This satisfactory testing result can only be achieved when the material transport system already has two control capacities at the same time. One is that AGV can locate itself accurately on the same spot beside the pick-up station-1 at each time. The other is that the component-transfer mechanism, gripper, can arrive at the precise position to grasp the raw material as well as finished component, push the platform to the correct position of the pick-up and place station, and get ready for the next cycle of operations. It is seen that the performance of the component transport system can be guaranteed by the high repeatable accuracy of AGV and its component-transfer mechanism.

VIII. Conclusion

This paper designs a short-travel material pick and place system for a unit load AGV. AGV follows the path of the on board sensors, and locates itself according to the RFID tags beside the material stand. A material pick and place transfer methodology containing docking, retrieving and depositing is proposed firstly. A pick and place-transfer mechanism using grippers is then designed to pick up and down the material on both sides, including a lifting module that changes the vertical height of the platform and a translational module that moves their convex blocks in the lateral direction. Thirdly, a PLC-based control system is developed to detect the position of executive mechanisms and control their movements. Lastly, the component transfer testing of our AGV on both sides without any raw material and finished component by 180degree rotation of gripper testifies the performance of this material transport system.

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