IoT Based Solar Smart Tackle Free AGVs for Industry 4.0

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Abstract. The emergence of Industry 4.0 has made a breakthrough by providing state of the art services when it comes to the manufacturing and material handling sectors. Continuous research and development are being made to ascertain efficiency. In spite of technological advancements, several bottlenecks still exist that require its mitigation to a great extent. Hence, in this paper, a strategy has been suggested which encompasses the fully automated Autonomous Guided Vehicles (AGV), Green energy, Automatic Storage and Retrieval Systems (ASRS) and the Internet of Things (IoT) to coordinate the status of the operation by acquiring data through a supervisory control in order to optimize vehicular paths with the help of a dynamic routing algorithm. Based on the operating area, the ZigBee protocol is seen to be best suited for this purpose. Thus, by formulating a prescribed working environment, manufacturers can conserve energy, reduce costs, eliminate machine downtime, and increase operational efficiency.

Keywords: AGV · ASRS · Industry 4.0 · IoT · Path routing · Solar photovoltaics · ZigBee

1 Introduction

A primitive man's simple life has given way to a modern man's more complex life. Wants have increased a hundredfold and have become more diversified in kind, thereby leading to automation [5]. Various operations are necessary which requires repetition and manifold material handling with high precision and accuracy, this has led to the development of automatic computer numerically controlled machines which can achieve the required tasks in shorter time period, hence opening more areas of research in the field of automatic machines which will lead to higher productivity and the ability of machines to complete more complex tasks [6]. Thus, the introduction of robotic manipulators in industries, such as AGVs, ASRS are widely used for tasks involving positioning, logistics etc. Parallel robots are lesser utilized in industries because of their lower popularity.

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Extensive research has been carried out in the last 15 years on six degree of freedom robots which are generally called Parallels. These manipulators are very efficient in moving heavy masses at higher speeds [7]. Thus, for a number of such manipulators, a need to coordinate correct pathways comes into play so as to ensure that no two manipulators interfere with each other's operation. Besides that, the fully automated vehicles should have the ability to drive safe and smooth in traffics. Path tracking, steering, obstacle avoidance and traffic laws must be considered in the driving goals [8–10]. Also, it includes positioning of vehicle or equipment onboard the relative vehicle to other objects. The docking stage was implemented by introducing a vital target of the current mobile robot position and the final target location [11]. Thus in this paper, an improved approach to path tracing for automated guided vehicles have been proposed that takes into account the position velocity and the presence of other vehicles in proximity along with the size of the obstacle. The objectives of the paper revolves around the implementation of a coordinated vehicular movement with the avoidance of hurdles in the path, elucidation of use in storage and retrieval purpose, the implementation of self-docking for battery charging without the dip in performance of the entire industrial functioning and lastly the aggregation of solar energy-based power supply to encourage a green and clean powering of material handling.

2 Automated Guided Vehicles (AGV)

Automated guided vehicles (AGV) are kind of transportable robots which follow a certain kind of marked lines to follow the path defined by them. AGV are mainly used in flexible management systems (FMS) for movement of materials from one place to another place. For path optimization, a number of different works has been implemented. One of the works proposed by Wenrong Lu et.al. which is mainly focused on order picking that has being applied in warehousing operations. A dynamic path routing algorithm has been implemented with multiple pick up points inside the factory settings [1].

Hybrid genetic algorithm has been implemented in AGVs in order to make integrated scheduling and detailed routing paths. The fitness function which is of multi-objective has been used for adaptive weight updates so that the weights can be assigned to each objective function for every generation [2].

A new approach has been made that mainly focused on integration of coordination between machine and scheduling problem of automated guided vehicle (AGV). A genetic algorithm in combination with Dijkstra algorithm has been proposed in order to solve the problems such as required number of minimum numbers of AGVS, minimum transportation time and conflict-free routing problem (CFRB) in flexible manufacturing systems (FMS) [3, 4].

Role of Autonomous Guided Vehicles (AGV) in Industry 4.0 has made sustainable development in reducing the cost of applicability and enhancing flexibility of the system. Regarding the safety standards, AGVs turn out to be a prominent figure head in enhancing the productivity consequently results in profitability. The most significant role of AGV in industry is to increase number of required additional AGVs as to evade from high investment costs.

However, in many industries reported a significant number of problems such as fixed path following path which has become a significant problem. This problem is still persisting from last decade and exact solution has not been available yet. For creating fully efficient vehicles with minimum investment cost, two solutions are being proposed to make fully automated vehicles.

3 Problem Description

In this paper, Flexible Manufacturing Services (FMS) has been considered where more than one AGV are being implemented here. At a particular decision point, there are about 8 different paths are being applied. These AGVs has been well operated through a single algorithm known as S P tackle free algorithm which can be applied for multiple operations or tasks assigned to these vehicles. The most interesting part of AGVs is, these vehicles are identical to each other. In starting point, multiple operations can easily be done with multiple AGVs so that there will be no collisions of AGVs. In addition to that, following assumptions are being made:

- Each AGV has been assigned a particular work for a particular time
- There are standby AGVs if any fails to work
- Single operation at a particular path for selected AGV
- AGVs are numbered on a particular task assigned on their priority basis
- AGVS are considered to have different velocities
- The path followed by AGVs may be linear as well as nonlinear curves

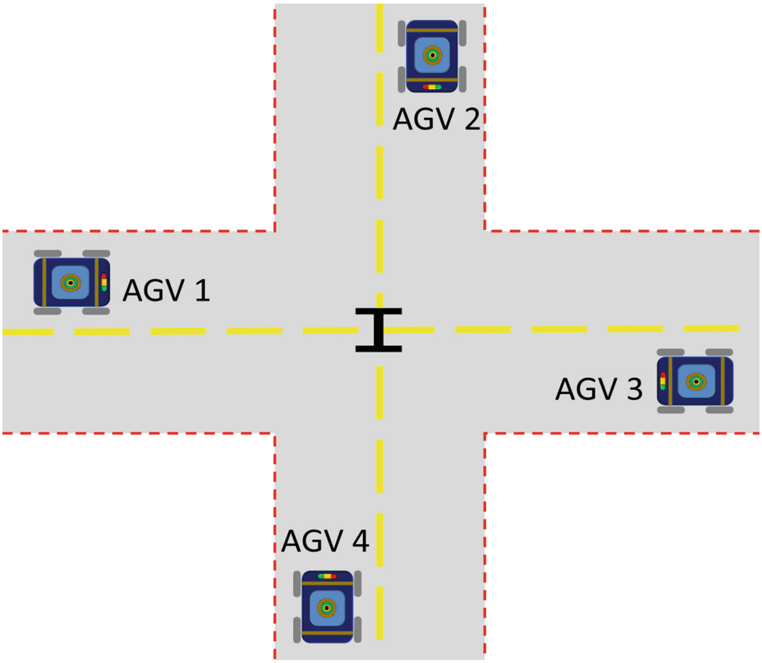

Fig. 1. Pictorial representation of 4 -point Decision of AGV

Here, both classical algorithm and optimization are applied to every AGV in order to get minimum time for any particular task so that the efficiency of the work can be enhanced and wastage of power can be minimized.

3.1 Algorithm for 4-point Decision for Free Collision of AGVs

Let V_1, V_2, V_3, V_4 symbols represents are vehicle 1, vehicle 2, vehicle 3 and vehicle 4 respectively (Fig. 1).

Let I = intersecting point of all the vehicles.

The path followed by the vehicle is of bidirectional where the materials are transported from one end to other end. The yellow lines indicate the path of the vehicle traversed whereas red lines indicate the minimum number of sensors are to be used.

STEP1: Considering the vehicle V_1, check whether the distance of V_2 to decision point (I), V_4 to decision point(I).

STEP2: If $V_2I=V_1I=V_4I$

then the input controller of V_1 is increased w.r.t. V_2 and V_4

Endif

STEP3: Considering the vehicle V_2, check whether the distance of V_1 to decision point (I), V_3 to decision point(I).

STEP4: If $V_3I=V_2I=V_1I$

then the input controller of V_2 is increased w.r.t. V_1 and V_3

Endif

STEP5: Considering the vehicle V_3, check whether the distance of V_4 to decision point (I), V_2 to decision point.

Step6: If $V_3I=V_1I=V_2I$

then the input controller of V_3 is increased w.r.t. V_2 and V_4

Endif

STEP7: Considering the vehicle V_4, check whether the distance of V_1 to decision point(I), V_3 to decision point.

Step8: If $V_4I=V_1I=V_3I$

then the input controller of V_4 is increased w.r.t. V_1 and V_3

Endif

Step9: We will be considering all the steps involved from step 1 to step 8 into a single step by considering all the positions of all vehicles V_1, V_2, V_3 and V_4

4 State Space Modeling of Automatic Guided Vehicles

The states of 4 AGVs are considered to be time dependent. The initial states and predicted states of vehicles are $X_{t|o}$, $P_{t|0}$ at time t = 0. The previous state and previous predicted states are given by $X_{t-1|o}$, $P_{t-1|0}$.

The generalized state space equation in terms of velocity is represented by

$$\dot{x}_{pn} = \mathrm{A}\, x_{pn} + \mathrm{B}\, a_{xn} + \mathrm{N} \tag{1}$$

where X = State matrix for i, j dimensions

a_{xn} = Control Variable Matrix
N = State noise matrix
n = No of vehicles ranging from 1, 2, 3, 4, ……………, N – 1.

Since, there is no interference in the relative positions of vehicle. As a result of this, N = 0.

The measurement of state that determines the position of the vehicle which is given by the equation

$$Y = C\, X_{\mathrm{pn}} \tag{2}$$

Here, some notations are to be made before proceeding for solution for above two equations,

ΔT = Time for the relative positions of the vehicle for an interval of 1 s
X_0 = initial state of the vehicle
$\dot{X}$ = velocity of the vehicle
$\ddot{X}$ = acceleration of the vehicle.

Therefore, the state matrix is represented by position, velocity and acceleration variables with respect to time given by following equation

$$X = X_0 + \dot{X}\mathrm{t} + \frac{1}{2}\ddot{X}\mathrm{t} \tag{3}$$

Let x_{px} = position of vehicle in x direction
x_{py} = position of the vehicle in y direction
x_{pz} = position of the vehicle in z direction
$\dot{x}_{px}$ = velocity of the vehicle in x direction
$\dot{x}_{py}$ = velocity of vehicle in y direction
$\dot{x}_{pz}$ = velocity of vehicle in z direction
a_{x1} = acceleration of the vehicle in x direction
a_{y1} = acceleration of the vehicle in y direction
a_{z1} = acceleration of the vehicle in z direction

For AGV1,

$$\begin{bmatrix} \dot{x}_{px1} \\ \dot{x}_{py1} \\ \dot{x}_{pz1} \end{bmatrix} = \begin{bmatrix} 1\;0\;0 \\ 0\;1\;0 \\ 0\;0\;1 \end{bmatrix} \begin{bmatrix} x_{px1} \\ x_{py1} \\ x_{pz1} \end{bmatrix} + \begin{bmatrix} \frac{1}{2}\Delta T^2 & 0 & 0 \\ 0 & \frac{1}{2}\Delta T^2 & 0 \\ 0 & 0 & \frac{1}{2}\Delta T^2 \end{bmatrix} \begin{bmatrix} a_{x1} \\ a_{y1} \\ a_{z1} \end{bmatrix} \tag{4}$$

For AGV2,

$$\begin{bmatrix} \dot{x}_{px2} \\ \dot{x}_{py2} \\ \dot{x}_{pz2} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_{px2} \\ x_{py2} \\ x_{pz2} \end{bmatrix} + \begin{bmatrix} \frac{1}{2}\Delta T^2 & 0 & 0 \\ 0 & \frac{1}{2}\Delta T^2 & 0 \\ 0 & 0 & \frac{1}{2}\Delta T^2 \end{bmatrix} \begin{bmatrix} a_{x2} \\ a_{y2} \\ a_{z2} \end{bmatrix} \tag{5}$$

For AGV3,

$$\begin{bmatrix} \dot{x}_{px3} \\ \dot{x}_{py3} \\ \dot{x}_{pz3} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_{px3} \\ x_{py3} \\ x_{pz3} \end{bmatrix} + \begin{bmatrix} \frac{1}{2}\Delta T^2 & 0 & 0 \\ 0 & \frac{1}{2}\Delta T^2 & 0 \\ 0 & 0 & \frac{1}{2}\Delta T^2 \end{bmatrix} \begin{bmatrix} a_{x3} \\ a_{y3} \\ a_{z3} \end{bmatrix} \tag{6}$$

For AGV4,

$$\begin{bmatrix} \dot{x}_{px4} \\ \dot{x}_{py4} \\ \dot{x}_{pz4} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_{px4} \\ x_{py4} \\ x_{pz4} \end{bmatrix} + \begin{bmatrix} \frac{1}{2}\Delta T^2 & 0 & 0 \\ 0 & \frac{1}{2}\Delta T^2 & 0 \\ 0 & 0 & \frac{1}{2}\Delta T^2 \end{bmatrix} \begin{bmatrix} a_{x4} \\ a_{y4} \\ a_{z4} \end{bmatrix} \tag{7}$$

5 Integration with IOT

Internet of things (IOT) plays a crucial role in integrating the AGV vehicle to enhance the communication between them. IOT interfaces the object to the cyberspace which implies that each and every AGVs has the virtual identifiable entity of itself in cyberspace. A personal area network employing ZigBee comprises of a router, routing protocols and entities or objects to be interfaced. The underlying objective to employ ZigBee protocols relies on the fact that its data transfer rate requirement is low thereby making it energy efficient. In order to ensure the smooth functioning of the system the assemblage should be vendor independent. To ensure the real time control the embedded processor should be able to clock an appreciable speed such that the entire entities data can be collected for a short processing span, which implies that any change in data should be successfully captured by the system in a nutshell, the system have the capability to operate in real time, beside the compatibility data security is also a key factor hence ZigBee comes with robust AES (advanced encryption standard) for data encryption and security. The data is analyzed and transfer to the cloud from the production control. The intelligent gateway harmonizes the communication among various data sources. Moreover, this interface can be applied in both directions [12].

6 Conclusion

Although the significant developments have taken place in the fields of manufacturing areas, but there are several areas where certain issues such as data security, cost of implementing the systems still exists. The agglomeration of routing algorithm of AGV and IOT will lend a helping hand to resolve some of the potential areas of improvement not only in the manufacturing systems but also in the different areas of applications such as warehousing operations.

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