Journal
of Achievements in Materials
and Manufacturing Engineering

VOLUME 31
ISSUE 2
December
2008

Control and path prediction of an Automate Guided Vehicle

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Received 22.08.2008; published in revised form 01.12.2008

Analysis and modelling

ABSTRACT

Purpose: In this paper a new architecture and control strategy of an AGV is proposed. It is organized as follows. The system architecture is explained in section 2. Section 3 deals with the kinematics model of the AGV path, prediction and control. Section 4 describes the experiments. The conclusion and recommendation are given in section 5.

Design/methodology/approach: It is a three wheels vehicle. The front wheel is used for driving and steering the AGV and the two rear wheels are free. The steering and driving are DC motor. Two encoders are individually attached on the two rear wheels in order to measure the vehicle displacement and then calculate its real time position and orientation. The choice of positioning the encoders on the free wheels provides to the vehicle an accurate measurement of its progression. A programmable logic control (PLC) is used for motion control.

Findings: In this paper, An Automate Guided Vehicle (AGV) is presented. The developed algorithm is based on memorised path and kinematics determination of the movement. The vehicle position and deviation are calculated from rear wheels rotation measurement. The steering and driving command are determined from this deviation. Localization of AGV by Kaman filtering algorithm is presented. Control of AGV motion is implemented by using PID control scheme. Displacement axis and steering axis are separated to implement the motion control. We proposed the localization system for estimation of AGV. Position and orientation are estimated by Kalman filtering in state-space model. Position and orientation of AGV are measured and used for simulation for localization system. We conclude that the vehicle can reach from the initial position moved along with generated path with accurate location. A Schneider PLC is used to implement this control. The tests reveal a smooth movement and convenient deviation.

Practical implications: The first prototype working, the next research steps will be development of a correction system to correct none detected errors. It will also be necessary to develop the fleet management strategy and software.

Originality/value: Future work is planed to increase the accuracy of the system by equip more sensors for observation technique. Treatment of dynamic model and machine vision application of automated vehicle are also planed to the next step.

Keywords: Automate Guided Vehicle (AGV); PID control

1. Introduction

Automate Guided Vehicles (AGV) has been applied for the flexible manufacturing system. Many factories were adopted it into assembly line or production line such as automobile, food processing, wood working, and other factories. Many researchers developed and designed in order to suite with their applications which are related to the main problem of factory. Automate Guided Vehicle (AGV) has firstly developed and conducted the research by [17, 18, 19] in the attempt to using at Jumbo Truck Manufacturing in Thailand. On the past of developed AGV, we surveyed several papers concerned the design and control aspects as following. The different structures were proposed in several cases as [1] proposed the architecture of AGV with two wheels driven by differential gear drive and parallel linkage steering, and the design and operation was also presented by [2]. This paper stated that the track layout and the number of AGVs in transportation control on a job-shop and a flow-shop were determined by using the queuing network theory. For entire FMS system, [3] proposed the operation control method by using two AGVs system. They solved the problem in scheduling method of AGVs model based on Petri nets. The formulation and heuristic search were used by global search in order to seek the optimal operation of the entire FMS. The operations of AGVs choice of guided path selection problem in FMS system was proposed by [4]. They proposed an approach for material flow modelling based on mathematical optimization method. With this approach, they obtained the guide path layout design with wire guided vehicles. The objective of optimization model is the minimization of the total distance travelled by vehicles to transport the material handing system. The route planning of AGVs in FMS was proposed by [5-7] presented the new approach for dynamics route planning and scheduling problem of AGVs. They applied the search algorithm and some heuristic rules to solve the route assignment in dynamic situations. [6] also proposed the path planning strategy of AGV to navigation, collision avoidance and docking to the target. The path planning was implemented on-board computer in order to avoid the wire-guided path. Not only the AGV was moved along the path with collision avoidance, but also it should be navigated with no deadlock condition as done by [8]. They formulated the control algorithm by digraph method in real-time path assignment to the vehicles. The deadlock control of AGV was controlled by colored resource-oriented Petri net model method to deal with the conflict free in real-time control as shown [7]. The AGV control approach was the important part for controlling the AGV actions. [9] applied the variable structure system techniques. The AGV was modeled by using kinematics and dynamic system. Sliding mode control by using Lyapunov design was applied for eliminating the chattering. They only implemented by simulation methods. The other paper proposed the control of AGV by using fuzzy logic control as shown in [10] and [11]. The AGV was guided by photoelectric guide way. The designed controller was the self-adjustment of control parameter by fuzzy controller. [11] proposed the steering control of AGV using fuzzy control. The AGV was guided by guide tape. They showed the response and energy saving in case of step change of guide tape. Fuzzy controller was achieved the reduction of steering energy more than the PI controller. [12] was presented the tracking algorithm of AGV navigation in container terminal. The multiple model algorithm based on multiple sensor detection in order to detect obstacle or other AGVs. Unscented Kalman filter was used to localization of AGV. They verified the propose algorithm by simulation methods. The adaptive control of AGV is also proposed by [13]. The nonlinear of dynamic model was developed for motion generation. The propose control was based on Lyapunov concept to ensure the control of AGV even if the dynamic parameter was not perfect. The intelligent of AGV was also worked on several methods. The integrate sensor and vision was applied for control AGV. [14] studied the intelligent path following and control for vision-based automated guided vehicle. They presented the control path following of AGV by vision control system, and multi-sensors was also applied in real time steering control. The hough transform algorithm was applied to detect the guideline of path as shown by [15]. The guideline of path was recognized by optical sensor as proposed by [16]. This paper proposed the array of optical sensor with 14 infrared (IR) emitter-detector pairs arranged in two columns. The trajectory recognition was based on neural networks.

Position and orientation of vehicle must keep the precise navigation and known its positioning at each place during travelling. To known and maintain its position, the currently the localization is the key of research on mobile vehicle. AGV is one of the significance of the present research trend. In industrial application, manufacturing factory is brought the mobile vehicle to incorporate working with other machine in order to being the automated manufacturing system. Many applications were adopted the AGV in different tasks such as material handling system, AS/RS system, transportation system, etc. Thus the research on the localization of mobile vehicle has increasingly researched in different aspects for improving the ability of vehicle. For reviewing the past research, several methods have been reported the localization of mobile vehicle such as [21-22] was developed a system in which the basic localization algorithm is formalized as a vehicle-tracking problem, employing an extended Kalman filter (EKF) to match beacon observations to a navigation map to maintain an estimate of mobile robot location. Tong and Tang proposed the robot self-localization. They applied the sensor fusion algorithm, which is used ultrasonic and CCD sensors, to filter out unreliable the sensor data reading. Moreover Extend Discrete Kalman Filters (EDKF) used to design for raw sensor data fusion to obtain more reliable representation in environment perception procedures [23]. Modeling of ultrasonic range sensors was developed by [7], and they presented a probabilistic model of ultrasonic range sensors using back propagation neural networks trained on experimental data. Extend Kalman filter is used for update location from the prediction and observation matching as shown in [24, 25]. Self-localization techniques by using probabilistic for mobile robot that based on the maximum-likelihood estimation were also done by [26]. For outdoor navigation problem of mobile robot, [27] reported the localization with 2-D mobile robot localization based on observability analysis in order to determine the undergo difficulties. They developed the localization algorithm called multisensor localization system (MLS). Due to nonlinear system model obtained in state-space description, Extend Kalman Filter is applied for estimate the state X which is done in two steps, prediction and filtering, respectively. The use of GPS and inertial plate sensor for outdoor navigation also is presented by [28]. They presented the localization algorithm based on Kalman filtering that tries to fuse information coming from an inexpensive single GPS with inertial data and map-based data. And also [29] developed a localization system that employs two methods. The first method uses odometry, a compass and tile sensor, and global position sensor (GPS). An Extended Kalman filter integrates the sensor data and keeps track of uncertainty associated with it. The second method is based on camera pose estimation. Another localization method was implemented and based on vision sensor. As reported by [30], they proposed a new approach for determining the location of a mobile robot using image of a moving object. This scheme combines data from the observed position, using dead-reckoning sensors, and the estimated position, using images of moving objects captured by a fix camera to determine the location of a mobile robot. The proposed methods utilizes the error between the observed and estimated image coordinates to localize the mobile robot, and the Kalman filtering scheme is used for the estimation of mobile robot location. [31] applied the vision based localization, and used Monte Carlo for extracting each image in the database a set of possible viewpoints using a two-dimension map of the environment, but [32] used vision sensor to localize and build simultaneous three-dimensional map in global localization. Multiple robot formation is done by [33] to localize the group of mobile robots, a leader and follower control.

In this paper a new architecture and control strategy of an AGV is proposed. It is organized as follows. The system architecture is explained in section 2. Section 3 deals with the kinematics model of the AGV path, prediction and control. Section 4 describes the experiments. The conclusion and recommendation are given in section 5.

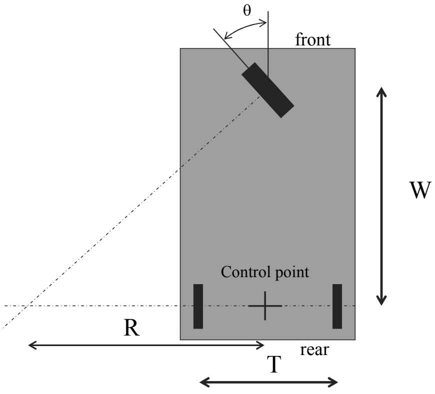


Fig. 1. AGV prototype architecture

2. System architecture

2.1. AGV design

It is a three wheels vehicle as shown in Fig. 1. The front wheel is used for driving and steering the AGV and the two rear wheels are free. The steering and driving are DC motor. Two encoders are individually attached on the two rear wheels in order to measure the vehicle displacement and then calculate its real time position and orientation. The choice of positioning the encoders on the free wheels provides to the vehicle an accurate measurement of its progression. A programmable logic control (PLC) is used for motion control.

2.2. Control structure

The parameters of the motion are driving speed and steering angle which determine the evolution of the position and orientation of the AGV. The input and output signal are interfaced with PLC module. The inputs are the encoder signal from left and right rear wheels. The driving speed and steering angle are calculated form these inputs and the digital output is converted to analog signal to drive amplifier of the driving motor and steering motor on front wheel as shown in Fig. 2

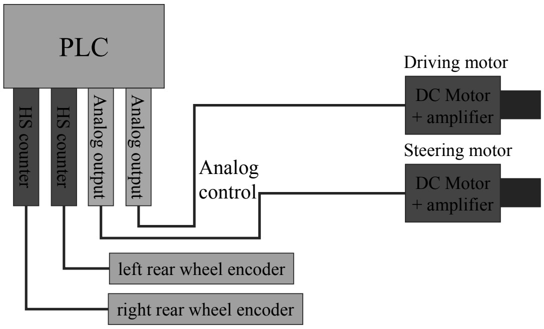


Fig. 2. AGV command architecture

2.3. Path determination

The required path of the AGV is be defined by line and circle as shown in Fig.3. The path is constructed in order to guide the vehicle movement and stored in the memory of the PLC. During the vehicle movement an error will occur between the actual position P(t) of the AGV and the defined path as shown Fig. 3.

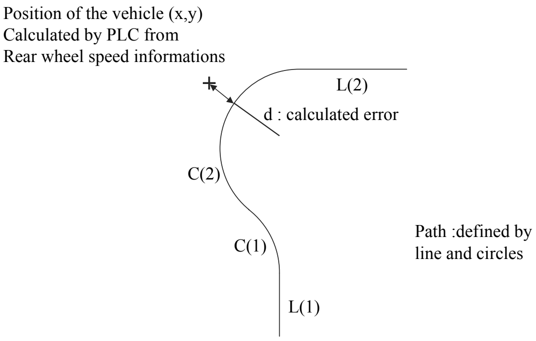


Fig. 3. Path description

AGV movement is modelled on the basis of the kinematics analysis. The position and orientation are defined at the instants t and t+dt by Fig. 4 below. Two coordinates systems are defined; AGV (X1,Y1) and world (X,Y) coordinates systems. The initial position P(t) at the point (X1,Y1) and the initial orientation β(t) are defined.

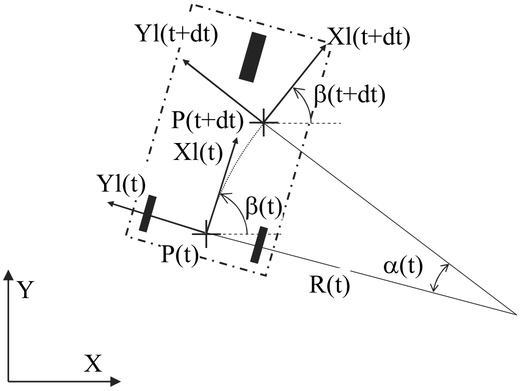


Fig. 4. Kinematics model of an AGV

The position and orientation at t+dt are calculated in vehicle coordinate system at instant t by Eq. 1.

$$\mathrm{P(t+dt)}_{(\mathrm{Xl(t),Yl(t)})}=\begin{bmatrix}\mathrm{R}\sin(\alpha)\\ \mathrm{R}\left(\cos(\alpha)-1\right)\end{bmatrix} \tag{1}$$

The position and orientation are transformed from vehicle coordinate to the world coordinate (X,Y) system in order to determine the new position of the AGV using Eq. 2.

$$\mathrm{P(t+dt)}=\begin{bmatrix}\cos(\beta(\mathrm{t})) & \sin(\beta(\mathrm{t}))\\ -\sin(\beta(\mathrm{t})) & \cos(\beta(\mathrm{t}))\end{bmatrix}\begin{bmatrix}\mathrm{R}\sin(\alpha)\\ \mathrm{R}\left(\cos(\alpha)-1\right)\end{bmatrix}+\mathrm{P(t)} \tag{2}$$
$$\beta(\mathrm{t+dt})=\beta(\mathrm{t})-\alpha(\mathrm{t})$$

Eq. 3 can then be written using the left encoder pulse increment (lpi) and right encoder pulse increment (rpi).

$$\mathrm{P(t+dt)}=\begin{bmatrix}\cos(\beta(\mathrm{t})) & -\sin(\beta(\mathrm{t}))\\ \sin(\beta(\mathrm{t})) & \cos(\beta(\mathrm{t}))\end{bmatrix}\begin{bmatrix}(\mathrm{lpi+rpi})\times\dfrac{\pi\times\mathrm{R_{wheel}}}{\mathrm{N_{pr}}}\\ -\left(\dfrac{\pi\times\mathrm{R_{wheel}}}{\mathrm{N_{pr}}}\right)^2\times\dfrac{(\mathrm{lpi+rpi})(\mathrm{lpi-rpi})}{\mathrm{T}}\end{bmatrix}+\mathrm{P(t)} \tag{3}$$
$$\beta(\mathrm{t+dt})=\beta(\mathrm{t})-2\pi\times\frac{(\mathrm{lpi-rpi})}{\mathrm{N_{pr}}}\times\frac{\mathrm{R_{wheel}}}{\mathrm{T}}$$

The actual position P(t) of the vehicle being determined the deviation error can be calculated. For linear path, the error is determined between the vehicle point P(t) and the line which is starting at point Ps and ending at point Pe as shown Fig. 5 a). For the circular path, the error is determined between the vehicle point P(t) and the circle of center Pc, starting point Ps and ending point Pe, as shown Fig. 5 b).
The error deviation of linear path is calculated by the Eq. 4 below.

$$d_l=\left(\frac{\overrightarrow{PsPe}}{\left\|\overrightarrow{PsPe}\right\|}\times\overrightarrow{PsP(t)}\right) \tag{4}$$

Where d_l is the error deviation of linear path, Ps is the starting point, Pe is the end point, and P(t) is the current position.

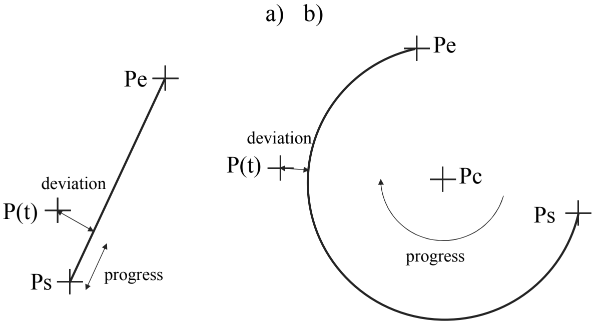


Fig. 5. Path deviation evaluation: a) error evaluation of a line; b) error evaluation of a circle

The error deviation of circular path is calculated by the Eq. 5 below.

$$\mathrm{d_c}=\pm\mathrm{distance(Pc,P(t))}-\mathrm{radius} \tag{5}$$

Where d_c is the error deviation of circular path, Pc is the center point of curve, and P(t) is the current position. The sign is plus (+) when turning left and minus (-) when turning right.

3. Prediction and control

3.1. Prediction

AGV mobile vehicle is needed to move with the precision position and orientation along the defined path. Vehicle must keep the command trajectory generated by path definition. Due to the error sources occurred during moving, then mobility would estimate and adjust position and orientation itself with knowledge of system estimation known as Kalman filter [20]. The localisation technique of AGV has shown in Fig. 6 as described in block diagram.

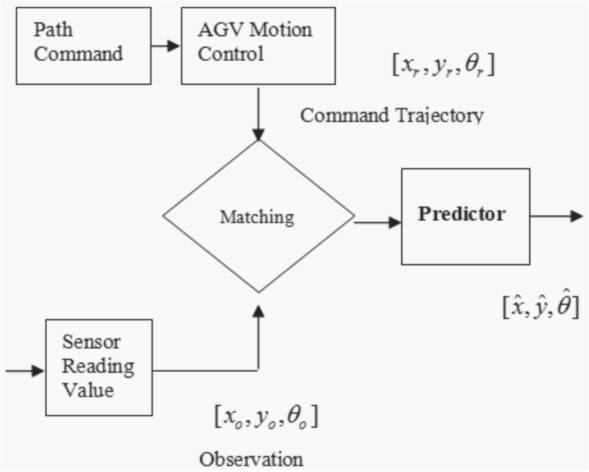


Fig. 6. Path prediction of AGV

From block diagram in Fig. 6, the localization can be done for maintaining the AGV movement along with the given path. Observations are measured by using encoder attached on wheels of AGV in translational and rotational exes. Estimation is performed by Kalman filter, the matching uses for comparing the current observer and trajectory command, the error is occurred during this process. The estimation of AGV position will correct and update its positioning by Kalman filter estimator algorithm.

3.2. Controller implementation

The deviation error being evaluated, the steering and driving command signal can be calculated and converted to analog signal by the PLC. The steering and driving control strategy are showed by the to simple block diagram Fig 7. The correction applied to the command signal is a proportional one for the driving signal and proportional derivative for the steering signal.

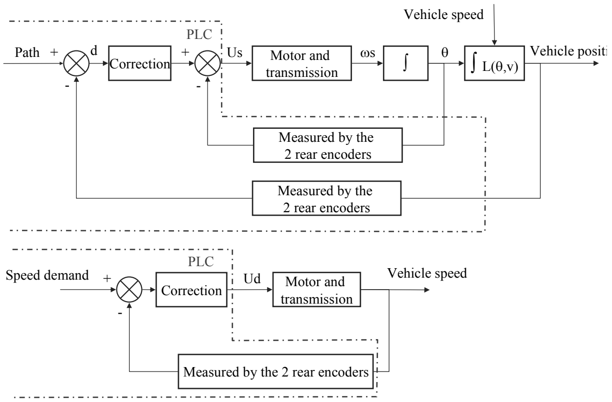


Fig. 7. Block diagram of steering and driving control

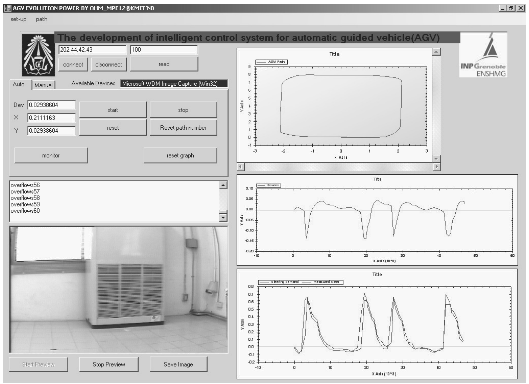
The proposed control structure is shown in Fig. 7. Information is derived from encoder sensor attached on each axis of vehicle, displacement and steering axis. PID control output is obtained bdifferential equation used in this research is:

$$u(t)_{pid} = K_p e(t) + K_D[e(n) - e(n-1)] + K_I \sum_{k=1}^{n} e(k) \qquad (6)$$

Where $u(t)_{pid}$ is the output signal, $e(t)$ is the error signal between the actual and the desired output, $K_D[e(n)-e(n-1)]$ is a signal proportional to the time derivative of the error, and $K_I \sum_{k=1}^{n} e(k)$ is the signal proportional to the time integral of the error at any time t, K_p, K_D and K_I are tunable and they are to be determined on the basis of specifications of plant.

4. Experiment

Command window illustrated in Fig. 8 uses for control AGV movement operation through PC in long distance area. There are two types of command such as positioning command (x,y position) and jog mode command which is tested motion control in each axis such as go, turn left, turn right etc. In positioning command, set of x,y coordinated position are sent to AGV with the design path of movement. Experiments are conducted in several tests, for example, Fig. 9 is shown the design path with S-curve shape of AGV moving on PC. The position pairs are sent to AGV with wireless communication channel. AGV receives the command of two axes, steering and driving axes, to control AGV with regarding to specified path. The result of AGV moving with the specified path have is shown in Fig. 10.


AGV EVOLUTION POWER BY OHM_MPE12@KMIT'NB

The development of intelligent control system for automatic guided vehicle(AGV)

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Available Devices: Microsoft WDM Image Capture (Win32)

Dev 0.02938604
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Fig. 8. AGV command window

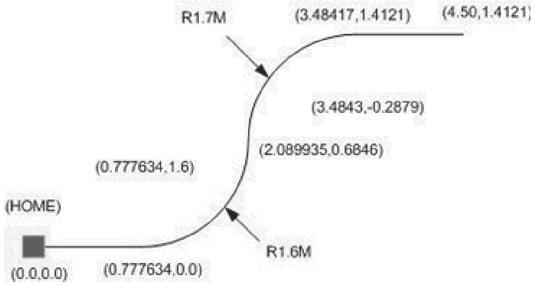

Fig. 9. S–curve path of command motion from window

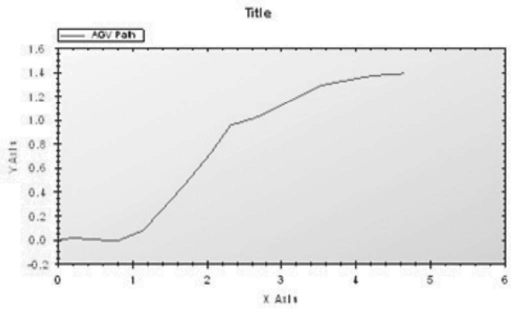

Fig. 10. Result of AGV motion with S–curve path

5. Conclusions

In this paper, An Automate Guided Vehicle (AGV) is presented. The developed algorithm is based on memorised path and kinematics determination of the movement. The vehicle position and deviation are calculated from rear wheels rotation measurement. The steering and driving command are determined from this deviation. Localization of AGV by Kaman filtering algorithm is presented. Overall structure of designing AGV is described. Control of AGV motion is implemented by using PID control scheme. Displacement axis and steering axis are separated to implement the motion control. We proposed the localization system for estimation of AGV. Position and orientation are estimated by Kalman filtering in state-space model. Position and orientation of AGV are measured and used for simulation for localization system. We conclude that the vehicle can reach from the initial position moved along with generated path with accurate location. A Schneider PLC is used to implement this control. The tests reveal a smooth movement and convenient deviation. The first prototype working, the next research steps will be development of a correction system to correct none detected errors. It will also be necessary to develop the fleet management strategy and software. Future work is planed to increase the accuracy of the system by equip more sensors for observation technique. Treatment of dynamic model and machine vision application of automated vehicle are also planed to the next step.

Acknowledgements

The authors would like to thank the Schneider electric for Automation solution and JUMBO, industrial trucks manufacturer, to support the AGV prototype construction.

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