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Optical 센서를 갖는 AGV의 경로추적에 대한 연구

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A Study on the Path-Tracking of Optically Guided AGV

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Abstract-This thesis deals with study and implementation of a cross-coupling controller which can enhance the path-tracking performance of optically guided AGV (Automated Guided Vehicle). The AGV in this thesis is differential drive type and has front-side and rear-side optical sensors, which can identify the guiding path. When AGV from the path due to the inevitable error and the deviation must be corrected. It has been shown that compensation only the first term can lead to undesirable oscillatory results and even instability but compensating only the second term leads to a steady state offset error.

Cross-coupling control directly minimizes the error by coordinating the motion of the two drive wheels. The cross-coupling controller is analyzed to evaluate its performance. The cross-coupling controller enhances transient performance of the controller is demonstrated by simulation and is compared with that of individual loop controller.

1. Introduction

Mobile robots are utilized in a variety of applications, including defense, nuclear power plant maintenance, waste management, assistance to the disabled. Material handling security, and household service. A primary limitation of existing robots is their accuracy in trajectory tracking. One way to address this problem is by improving the accuracy of the low-level motion controller.

We deal with a low-level controlling comprised of the vehicle-level and wheel-level controllers. We are defined the error that has the largest impact on motion accuracy. In mobile robot control the important error is orientation. Note the individual error in each loop does not give a description of the other real motion error. The path tracking of the robot motion depends on how well the wheel velocities are coordinated. In the case of a differential-drive robot, there are two drive wheels driven by two different motors that are controlled independently.

In machine tool servo control, the main idea of cross-coupling control is based on calculation of the actual contour error multiplying it by a controller gain and feeding the result back to the individual loops. Cross-coupling compensation structures for two-axis machines. Through simulation results, we will discuss the cross-coupling and show how it can be used to improve the motion control performance. In the following section, we analyze the sources of trajectory errors in motion.

2. Motion Error Analysis

The motion error of the AGV can be decomposed into the components shown in Fig.1. The tangent to the trajectory at a general point (real robot location) is taken as the momentary *X*-axis and the normal to that is the Y-axis. The e_θ is a contour error and e_c is a orientation error and e_t is a tracking error.

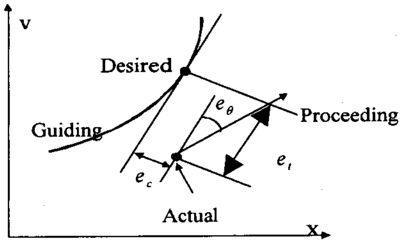


Fig.1. Motion error decomposition

A tracking error is the distance between the actual position and the desired position in the direction of travel.

The velocity of a differential drive mobile robot are given by

$$\dot{x} = \frac{v^L + v^R}{2}\sin\theta \qquad (1)$$

$$\dot{y} = \frac{v^L + v^R}{2}\cos\theta \qquad (2)$$

$$\dot{\theta} = \frac{v^L + v^R}{b_W} \qquad (3)$$

where x,y are the position in the world coordinate system(mm), θ is the orientation, $\dot{x},\dot{y}$ are AGV velocities(mm/s), $\dot{\theta}$ is the angular velocity of the AGV(1/s), v^L,v^R are the linear velocities output of the left and right wheels(mm/s), and b_w is the distance between the left and right wheels(wheel base)(mm).

We can largely classify the error sources into two categories: internal errors and external errors. The internal errors are the errors can only be detected by the wheel motion information. The external errors are the errors that only become apparent when the robot wheels interact with the environment; that is, external errors can only be detected by absolute robot motion measurements. In this paper, we deal with the control of internal errors

The tracking error does not have a significant effect on the motion accuracy of the AGV, and can be controlled by adjusting the AGV tracking speed as desired. The contour error is the direct result of the orientation error. We cannot control both error at the same time with a differential drive robot. Among these three errors, the orientation errors has the largest impact on the motion accuracy since it results in accumulation of contour and tracking errors.

2.1. Cross-Coupling control

The cross-coupling concept was introduced by Koren in [1]. The cross-coupling concept calls for construction of a contour error model in real time and utilizing it in the determination of a control law that reduce the contour error. A bolck diagram of a cross-coupling is show in Fig.2.

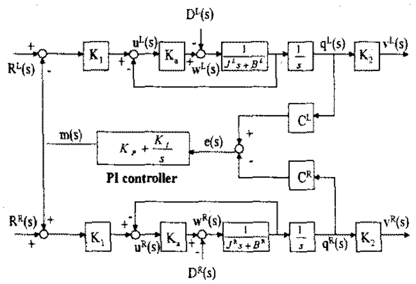


Fig.2. Cross-Coupling Controller

The task of the vehicle-level controller is to coordinate the motion of the drive loops. In the case of differential-drive robot, most conventional controllers consist of two individual control loops, one for each motor. Motion coordination is achieved by adjusting the reference velocities of the control loops, but one drive loop receives no information regarding the other. The error in each loop treated as the primary error, although it normally does not present the most significant motion error. An improvement in the path accuracy can be achieved by providing cross-coupling control,

Whereby the most significant error can be controlled directly.An improvement in the path accuracy can be achieved by providing cross-coupling control, whereby an error in either axis affects the control loops of both axes.

In this design the path error is calculated and fed as a correction signal to both loops.

A nonzero *E* indicates that one motor has been running faster than the other. The error signal generates a correction variable *M* which is used to reduce the speed to the faster motors are equalized. Absolute values of P1 and P2 are used in equation (8) in order to account for rotational motion, in which both motors run in opposite direction. But in the case of a differential-drive mobile robot, the two axes are parallel to each other motions are coupled through the robot body. The relations between the motion errors and the drive axes errors are not well known except for the orientation error.

Any temporary disturbance of the steady-state velocities will be successfully in corrected by a proportional (P) controller, in order to correct a continuous disturbance, as might be caused by different friction forces in the bearings (eg. due to an unsymmetric load distribution on the vehicle), an integral (I) action is required as well. The PI-controller provides not only equal velocities but also an equal overall pulse count from the beginning of each motion. Therefore, this controller guarantees a zero steady-state orientation error of the vehicle for any constant continuous disturbance (except for slippage).

The equations of the PI-controller are

$$S(i) = S(i-1) + E(i) \quad (4)$$

$$M(i) = KcS(i) + KpE(i) \quad (5)$$

Where Kc is the integration gain and Kp is the proportional gain. The ranges of Kc and Kp that guarantees stability of the system have been determined as described below. In this equations the parameters have the following values:

K_a=0.02V/pulse,H=3pulses/rev,

Kc = 1 ; Kp = 15; T = 0.03; Kb = 16;

The block diagram of the entire control loop is shown in Fig.2.

In the DAC the signal is held constant during the interval T, and therefore its transfer function is :

$$\frac{E(z)}{\Delta D(z)} = \frac{z^2(z-1)HK_b\omega}{(z-1)^2(z-r)+z(z-1)KK_p(1-r)+z^2KK_C(1-r)} \quad (6)$$

where *K* is open-loop gain given by *K=KaKbH.* The control algorithm may be represented with the aid of the Z-transform as

$$P_j(z) = \frac{z}{z-1}F_j(z) \qquad j = 1,2 \quad (7)$$

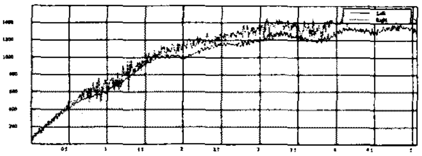
$$E(z) = P_1(z) - P_2(z) = \frac{z}{z-1}(F_1(z) - F_2(z)) \quad (8)$$

$$M(z) = [K_p + K_c\frac{z}{z-1}]E(z) \quad (9)$$

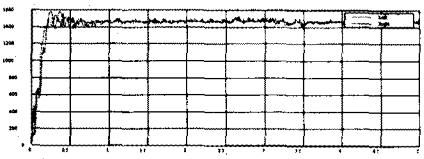
$$F_1(z) - F_2(z) = -K(\frac{1-r}{z-r})(K_p + \frac{z}{z-1})E(z) + HK_b(\frac{z\omega}{z-r})\Delta D(z) \quad (10)$$

2.2 Simulation Results

Through computer simulation results, we are showed difference in the encoder and speed error and position error between the cross-coupling controller and the individual control. Cross-coupling control has been used for linear motion path-tracking control and results are very encouraging.

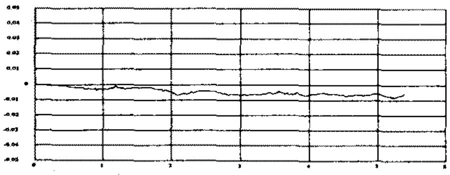


(a) conventional

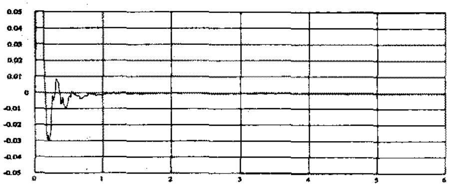


(b) CCC

Fig.4. Simulation encoder

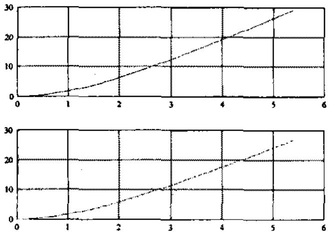


(a) conventional

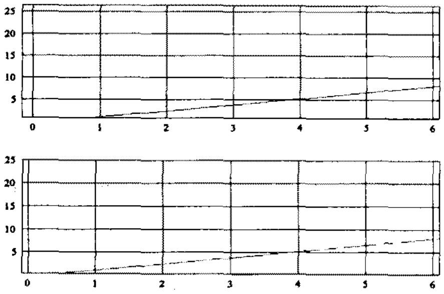


(b) CCC

Fig.5. Comparison of speed error



(a) conventional



(b) CCC

Fig.6. Comparison of position error

3. Conclusion

In this paper, to improve tracking performance and contour performance a cross-coupling control scheme for mobile robots was presented. The position accuracy of our mobile robots is mainly affected by mechanical disturbances. A variable-gain cross-coupling controller that reduces the contour errors has been proposed. The method is based on building in real time the instantaneous contour error, feeding it into a PID controller, and decomposing the signal into axial components through multiplying it by gains that are calculated at each interpolation step. These variable gains have to be computed in real time, which obviously slows down the possible sampling-rate of the controller.

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