An adaptive Control of the Nonholonomic Mobile AGV

Zhe-Yong Han* and Uk-Youl Huh*
*Dept. of Elec. Inha Univ. Inchon
Tel. +82-32-860-7394
Fax. +82-32-863-5822
e-mail: hanzy98@hotmail.com and uyhuh@inha.ac.kr

Abstract - Mobile AGV is one of the nonholon-omic systems. The integration of the kinematic adaptive controller for the dynamic in this pa-per introduction a motion control problem's dynamic state feedback as well as output feedback tracking control laws will be constructed with the adaptive extension of the controller is prop-osed. Feedback control strategies for mobile AGV are important to compensate for disturabances and errors in the initial condition. The problems of path following or tracking and of stabilization about a constant configuration have been treated as separate problems for nonholonomic mobile AGV.

1. Introduction

The mobile AGV is one of well-known system with nonholonomic constraints, and there are many works on its tracking control. Their objects are kinematic models, but recently one method for dynamic models has been proposed. This method integrates a kinematic controller and a torque controller for the dynamic model of a nonholonomic mobile AGV by using back-stepp-ing.The control input of the controller for the kinematic model is generally velocity, but it is more realistic that the input is torque. A kinem-atic controller is designed first so that the tracking error between a real position and a reference position converges to zero, and secondly a torque controller is designed by using back-stepping so that the velocitees of a mobile AGV converge to the desired velocities, which are given by kinematic controller designed at the first step. In the here, we present a method to design an adaptive tracking controller for the dynamic model of a nonholonomic mobile AGV with unknown parameters in its kisnematic part with two unknown parameters. The adaptive control methods, proposed so far nonholonomic.

2. A Mobile AGV control

2.1 A nonholonomic Mobile AGV

The mobile AGV system can be modeled with n-dimensional configuration space C with generalized coordinates ($q_1, \ldots, q_n$) and subject to m constraints. So it can be described by

$$M(q)\ddot{q} + V_m(q, \dot{q}) + F(\dot{q}) + G(q) + \tau_d = B(q)\tau - A^T(q)\blacksquare \quad (1)$$

where $M(q) \in R^{n \times n}$ is a symmetric, positive definite inertia matrix, $V_m(q, \dot{q}) \in R^{n \times n}$ is the centripetal and coriolis matrix, $F(\dot{q}) \in R^n$ denotes the surface friction, $G(\dot{q}) \in R^n$ is the gravitational vector, τ_d denotes bounded unknown disturbances including unstructured unmodelled dynamics, $B(q) = R^{n \times n}$ is the input transformation matrix, $\tau \in R^r$ is the input vector, $A(q) = R^{m \times n}$ is the matrix associated with the constraints, and $\lambda = R^m$ is the vector of constraint forces. We consider that all kinematic equality constraints are independent of time, and can be expressed as

$$A(q)\dot{q} = 0 \quad (2)$$

Let S(q) be a full rank matrix(n-m) formed by a set of smooth and linearly independent vector fields spanning the null space of A(q), i.e.

$$S^T(q)A^T = 0 \quad (3)$$

The involutivity properties of the distribution Δ spanned by the vectors of S(q) are closed related to the nature of the constraints as is pointed out. According to(2) and (3) it is possible to find an auxiliary vector time function $v(t)=R^{n-m}$ such that, for all t,

$$\dot{q}=S(q)v(t). \tag{4}$$

2.2 Mobile AGV with two Wheels

We consider a mobile AGV with two actuated wheels as an example which the theorem can be applied to an adaptive.

Tracking controller is designed for the kinem-atic model and the dynamic model, and some

simulation results are provided.We consider the mobile AGV with two actuated wheels, which is shown in Fig(1)

Let us consider a mobile AGV driven by two differential wheels. The center of motion

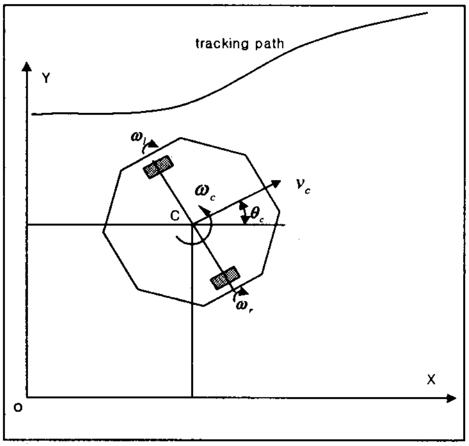

Fig.1 Mobile robot with two actuated wheels

denoted by C, is located at the midpoint between the left and right driving wheels. Assuming that the AGV moves on the planar surface without slipping, the tangential velocity V_c and angular velocity ω_c at the center C can be written as

$$v_c=\frac{r_w}{2}(\omega_r+\omega_l)$$
$$\omega_c=\frac{r_w}{d_w}(\omega_r-\omega_l) \tag{5}$$

Where ω_r and ω_l denote the rotational velocities of the right and left driving wheels, respectively, r_w is the radius of the wheels and d_w

is the azimuth length between the wheels. The equation of the mobile robot is given by

$$\dot{x}_c=v_c\cos(\theta_c)$$
$$\dot{y}_c=v_c\sin(\theta_c) \tag{6}$$
$$\dot{\theta}=\omega_c$$

Where coordinates (x_c, y_c) indicate the position of the robot with respect to the robot. The trip-let (x_c, y_c, θ_c) is used for defining the robot pos-ture and represented by vector P. The posture of the robot can be estimated from integration of equations (3)-(5). The integration is impleme-nted by the following iterative algorithm called dead reckoning.

The configuration of the mobile AGV can be described by five generalized coordinates.

$$q=[x, y, \phi, \theta_r, \theta_l]^T \tag{7}$$

Where(x,y) are the coordinates of C, θ_c is the heading angle of the mobile AGV and θ_r, θ_l are the angles of the right and left driving wheels.

We consider the extension of the control law to the tracking control of the two-wheel driven mobile AGV on the plane kinematics(6). Due to the nonlinear and nonholonomic characteristics of the AGV kinematics, it is very difficult to get the control action determining the wheel accelerations.

These constraints can be rewritten in the form

$$A(q)\dot{q}=0 \tag{8}$$

where

$$A(q)=\begin{bmatrix} \sin\theta_c & -\cos\theta_c & 0 & 0 & 0 \\ \cos\theta_c & \sin\theta_c & b & -r & 0 \\ \cos\theta_c & \sin\theta_c & -b & 0 & -r \end{bmatrix} \tag{9}$$

Equations as the following:

$$\dot{q}=S(q)v(t) \tag{10}$$

$$\overline{M}(q)\dot{v}+\overline{V}(q,\dot{q})v=\overline{B}(q)\tau \tag{11}$$

where S(q) is selected as

$$S(q)=\begin{bmatrix} \frac{r}{2}\cos\theta_c & \frac{r}{2}\cos\theta_c \\ \frac{r}{2}\sin\theta_c & \frac{r}{2}\sin\theta_c \\ \frac{r}{2v} & -\frac{r}{2b} \\ 1 & 0 \\ 0 & 1 \end{bmatrix} \tag{12}$$

2.3 Adaptive Control of the Kinematic

We design an adaptive tracking controller for the kinematic part(10) modifying the method proposed by kanayama[4].Where $v(t)$ is considered as a control input the kinematic part(6). Since the real input of the mobile AGV driving motor's torques τ. The τ is designed to made $(v(t)-v_c(t))\mapsto 0$ as $t\mapsto\infty$ by using back-s tepping.

In this paper is shown that an adaptive contr-oller can be designed for the dynamic model with unknown parameters if it is possible to design an adaptive controller for the kinematic model with unknown parameters. Design an adaptive tracking for a nonholonomic

mobile AGV(1) in
order that

$$\lim_{t\to\infty}(\overline{q}(t)-q_r(t))=0 \tag{13}$$

Where $\overline{q}(t)=Cq(t), C\in R^{s\times n}$, and $q_r(t)\in R^s$ is its desired output and differentiable. Where we assumption the adaptive tracking controller:

$$v=v_c(q, q_r, \overline{a}) \tag{14}$$

We design an adaptive controller first set the v is the system input and construct the adaptive control system for the following kinematic model:

$$\frac{d}{dt}\begin{bmatrix} x \\ y \\ \theta_c \\ \theta_r \\ \theta_l \end{bmatrix}=\begin{bmatrix} \frac{r}{2}\cos\theta_c & \frac{r}{2}\cos\theta_c \\ \frac{r}{2}\sin\theta_c & \frac{r}{2}\sin\theta_c \\ \frac{r}{2v} & -\frac{r}{2b} \\ 1 & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \tag{15}$$

Where v_1 and v_2 represent the angular velocities of right and left wheels. We can get three state (x, y, θ). The relationship between (v, w) and (v_1, v_3) are like the following:

$$\begin{bmatrix} v_1 \\ v_2 \end{bmatrix}=\begin{bmatrix} \frac{1}{r} & \frac{b}{r} \\ \frac{1}{r} & -\frac{b}{r} \end{bmatrix}\begin{bmatrix} v \\ \omega \end{bmatrix} \tag{16}$$

We get the ordinary form of a mobile AGV with two actuated wheels the kinematics of the reference AGV is given as

$$\frac{d}{dt}\begin{bmatrix} x_r \\ y_r \\ \theta_r \end{bmatrix}=\begin{bmatrix} \cos\theta_r & 0 \\ \sin\theta_r & 0 \\ 0 & 1 \end{bmatrix}\begin{bmatrix} v_r \\ w_r \end{bmatrix} \tag{17}$$

Where x_r, y_r and θ_r are the configure of the reference AGV, and x_r, y_r are reference inputs. We
define the AGV moving error e_x, e_y, e_θ as following:

$$\begin{bmatrix} e_x \\ e_y \\ e_\theta \end{bmatrix}=\begin{bmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} x_r-x \\ y_r-y \\ \theta_r-\theta \end{bmatrix} \tag{18}$$

The e_x, e_y, e_θ describe the difference of position and direction of the reference AGV from the real AGV center are defined the inputs by the following:

$$v_f=v_r\cos e_\theta+K_1 e_x$$
$$w_f=w_r+v_r K_2 e_y+K_3\sin e_\theta \tag{19}$$

The mobile AGV with two actuated wheels satisfies assumptions. Therefre, we can designan design an adaptive tracking controller for the dynamic model(10). We can design an adaptive controller and perform some simulations. The adaptive tracking controller for the dynamic models applying the nonlinear feedback

$$\tau=f_c(q, \dot{q}, v, u)=\overline{B}^{-1}(q)\,[\,\overline{M}(q)u+\overline{V_m}(q, \dot{q})v+\overline{F}(v)+\overline{\tau_d}] \tag{20}$$

Considering that each on the basic navigation problems may be solved by using adequate smooth velocity control inputs, then tracking,path following and stabilization abut a desired posture may be solved under the same control structure.

The smooth steering velocity control, control, denoted by v_c can be found by any technique in the literature. The three basic navigation problems are solved as follows:

Tracking: given a reference AGV

$$\dot{x}_r=v_r\cos\theta_r,\ \dot{y}_r=v_r\sin\theta_r,\ \dot{\theta}_r=w_r$$
$$q_r=[x_r, y_r, \theta_r]^T,\ v_r=[v_r, w_r]^T \tag{21}$$

3. Simulation

The simulation was implemented in MATLAB. The controller gains were chosen so that the closed-loop system exhibits a critical damping behavior. Clearly, the mobile platform is able to track the reference trajectory. Furthermore, the actual velocities of the cart converge to the control velocities. This Simulation results on two distinct convergence characteristics is shown in Figure2. In this simulation, physical

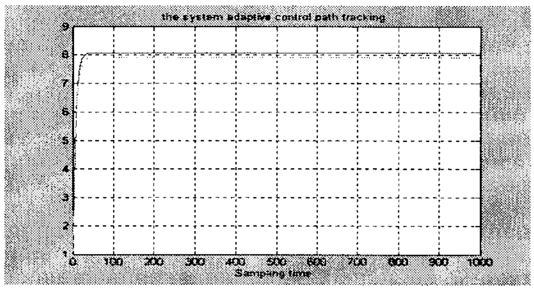

Fig.2 Transient Responsers (Simulation)

parameters and design parameters are a=35, b=2.35, d=0.3, K1 = K2 = K3 = kd=5. The initial values of the estimated parameters are about I/10---two times the real values.

6. *Conclusion*

In this paper, we proposed a design method of an adaptive tracking controller for a nonholonomic mobile robot with unknown parameters. It was proved that an adaptive tracking controller for the dynamic model can be designed by using adaptive tracking backstepping if an adaptive tracking controller for the kinematic model exists. We designed an adaptive controller of a mobile robot with two actuated wheels and provided some simulation results.

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