16 Intelligent Control of Autonomous Robotic Systems Using Interval Type-2 Fuzzy Logic and Genetic Algorithms

We develop a tracking controller for the dynamic model of unicycle mobile robot by integrating a kinematic controller and a torque controller based on Fuzzy Logic Theory. Computer simulations are presented confirming the performance of the tracking controller and its application to different navigation problems.

16.1 Introduction

Mobile robots are nonholonomic systems due to the constraints imposed on their kinematics. The equations describing the constraints cannot be integrated symbolically to obtain explicit relationships between robot positions in local and global coordinate’s frames. Hence, control problems involve them have attracted attention in the control community in the last years (Kolmanovsky and McClamroch, 1995).

Different methods have been applied to solve motion control problems. (Kanayama et al., 1991) propose a stable tracking control method for a nonholonomic vehicle using a Lyapunov function. (Lee et al., 1998) solved tracking control using backstepping and in (Lee and Tai, 2001) with saturation constraints. Furthermore, most reported designs rely on intelligent control approaches such as Fuzzy Logic Control (Bentalba et al., 1997) (Ishikawa, 1991) (Lee et al., 1999) (Pawlowski, 2001) and Neural Networks (Fierro and Lewis, 1998) (Song and Sheen, 2000).

However the majority of the publications mentioned above, has concentrated on kinematics models of mobile robots, which are controlled by the velocity input, while less attention has been paid to the control problems of nonholonomic dynamic systems, where forces and torques are the true inputs: (Bloch and Drakunov, 1991) and (Chwa, 2004), used a sliding mode control to the tracking control problem. (Fierro and Lewis, 1995) propose a dynamical extension that makes possible the integration of kinematic and torque controller for a nonholonomic mobile robot. (Fukao et al., 2000), introduced an adaptive tracking controller for the dynamic model of mobile robot with unknown parameters using backstepping.
In this chapter we present a tracking controller for the dynamic model of a unicycle mobile robot, using a control law such that the mobile robot velocities reach the given velocity inputs, and a fuzzy logic controller such that provided the required torques for the actual mobile robot. The rest of this chapter is organized as follows. Sections 16.2 and 16.3 describe the formulation problem, which include: the kinematic and dynamic model of the unicycle mobile robot and introduces the tracking controller. Section 16.4 illustrates the simulation results using the tracking controller. The section 16.5 gives the conclusions.

16.2 Problem Formulation

The model considered in this chapter is of a unicycle mobile robot (see Figure 16.1), it consist of two driving wheels mounted on the same axis and a front free wheel (Campion et al., 1996).

\[ q = \begin{bmatrix} \cos \theta & 0 & v \\ \sin \theta & 0 & w \\ 0 & 1 \end{bmatrix} \]

\[ M(q)\dot{v} + V(q, \dot{q})v + G(q) = \tau \]  \hspace{1cm} (16.1)

Where \( q = [x, y, \theta]^T \) is the vector of generalized coordinates which describes the robot position, \((x, y)\) are the cartesian coordinates, which denote the mobile center of mass and \( \theta \) is the angle between the heading direction and the \( x \)-axis (which is taken counterclockwise form); \( v = [v, w]^T \) is the vector of velocities, \( v \) and \( w \) are the linear