AN EXPERIENCE ON STABLE CONTROL OF MOBILE ROBOTS

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***Abstract* — This paper is based on a previous work (Carelli *et al.*, 1999). In this paper, mobile robot control laws, including obstacle avoidance based on distance sensorial information are developed. The mobile robot is assumed to evolve in a semi-structured environment. The control systems are based on the use of the extended impedance concept, in which the relationship between fictitious forces and motion error is regulated. The fictitious forces are generated with the information provided by sensors on the distance from the obstacle to the robot. The control algorithms also avoid the potential problem of control command saturation. The paper includes the stability analysis of the developed control systems, using positive definite potential functions.**

***Keywords* — mobile robots; robot control; obstacle avoidance; stability analysis.**

I. INTRODUCTION

Mobile robots are mechanical devices capable of moving in an environment with a certain degree of autonomy. The environment can be classified as structured when it is well known and the motion can be planned in advance, or as partially structured when there are uncertainties which imply some on-line planning of the motions.

During the movement in partially structured environments, an obstacle can suddenly appear on the robot trajectory. Then, a sensorial system should detect the obstacle, measure its distance and orientation to calculate a control action to change the robot trajectory, thus avoiding the obstacle.

In this article, the concept of generalized impedance is used which relates fictitious forces to vehicle motion. Fictitious forces are calculated as a function of the measured distances. A similar concept for a generalized spring effect in robot manipulators is presented in (Sagués *et al.*, 1990). An application of the impedance concept to avoid obstacles with robot manipulators has been presented in (Mut *et al.*, 1992).

The control architecture here presented combines two feedback loops: a motion control loop (Secchi, 1998) and a second external impedance control loop (Hogan, 1985). This last loop provides a modification on target position when an obstacle appears on the trajectory of the mobile robot (Secchi *et al.*, 1994).

Most works in this area consider the motion control of the mobile robot avoiding obstacles (Khatib, 1985), (Newman and Hogan, 1987), (Borenstein, 1989), (Koren and Borenstein, 1991) and (Borenstein and Koren, 1991), but few of them (Aicardi *et al.*, 1995) study the stability of the control system problem. Main contributions of this paper are the design of stable motion control laws that include the actuators saturation problem; the design of a motion control structure for obstacle avoidance and its corresponding stability analysis; and the performance test of control algorithms through experiences on a mobile robot.

The paper is organized as follows. After this introductory section, Section 2 describes the kinematic equations of an experimental robot; Section 3 presents the control problem formulation; Section 4 defines the fictitious force for distance feedback; Section 5 presents the proposed control algorithms including their stability analysis; Section 6 is a brief survey of the mechanical characteristics and sensor capabilities of the experimental robot used; Section 7 describes the experimental results; and finally, Section 8 contains the main conclusions of the work.

II. KINEMATICS EQUATIONS

Consider the unicycle-like robot positioned at a non-zero distance from a goal frame <g>. Its motion towards <g> is governed by the combined action of both the angular velocity ω and the linear velocity vector $\boldsymbol{u}$, which is always on the same direction as one of the axes of the frame <a> attached to the robot, as depicted in Fig. 1.

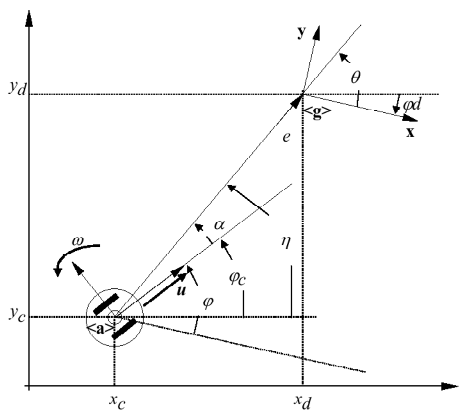

Figure 1. Position and orientation of the vehicle.

Then, the usual set of kinematic equations, which involves the Cartesian position (x,y) of the vehicle and its orientation angle φ, is

$$\begin{cases} \dot{x} = u \cdot cos\varphi \\ \dot{y} = u \cdot sin\varphi \\ \dot{\varphi} = \omega \end{cases} \qquad (1)$$

where u is the magnitude of $\boldsymbol{u}$, and x, y and φ are measured with respect to the origin of target frame <g> and to the orientation of the x-axis.

Now, by representing the vehicle position in polar coordinates, and by considering the error vector $\boldsymbol{e}$ with