

# IMPROVED DYNAMIC WINDOW APPROACH BY USING LYAPUNOV STABILITY CRITERIA

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**Abstract**— This paper presents improvements over the Dynamic Window Approach (I-DWA), used for computing in real time autonomous robot navigation. A novel objective function that includes Lyapunov stability criteria is proposed. It allows to guarantee a global and asymptotic convergence to the goal avoiding collisions and resulting in a more simple and self-contained approach. Experimental results with simulated and real environments are presented to validate the capability of the proposed approach. Additionally, comparisons with the original DWA are given.

**Keywords**— Autonomous Mobile Robot, Lyapunov Stability.

## I. INTRODUCTION

*Autonomous robot navigation* involves the real time achievement of user defined goal/s. The autonomy degree of a given robotic system fixes or defines both the capability of adaptation in front of environment changes and the abstraction level in which a given goal can be represented. For example, the achievement of a given goal in a static and known environment can be tackled with a *global planning strategy*. On the contrary, unknown or partially known environments, as well as dynamic environments, should be tackled by means of *reactive navigation strategies*. These reactive strategies allow solving unexpected events in real time by means of the use of sensors in order to capture the surrounding environment.

Several autonomous robot navigation approaches were proposed during the last decades. Early techniques were based on the use of an artificial potential field (e.g., Khatib, 1986; Khatib and Chatila, 1995; Borenstein and Koren, 1989; among others): an attractive force produced by the goal drives the robot to the objective, while at the same time, repulsive forces produced by the obstacles keep the robot away from

them. Since then, several improvements were introduced giving rise to more evolved techniques such as: *Virtual Field Histogram* (VFH; Borenstein and Koren, 1991), *Curvature-Velocity Method* (CVM; Simmons, 1996) and *Dynamic Window Approach* (DWA; Fox *et al.*, 1997). The CVM (Simmons, 1996) and DWA (Fox *et al.*, 1997) are widely used approaches since a high speed navigation can be reached. They search for *control commands* ( $v, w$ ) directly in the velocity space, rather than in the position space or in the configuration space (Latombe, 1991). Similarly, in Shimoda *et al.* (2005) a trajectory space is used for searching the control commands (*steering angle* and *velocity*). In these cases, control commands are selected by maximizing an objective function, which includes criteria such as: speed, goal-directedness and safety. At the same time that function incorporates constraints in velocity space from the obstacles and from the robot. In spite of these advantages, a hard constraint of these techniques is that they ignore the way in which the robot approaches the goal, so convergence criteria are not considered.

Extensions to the original DWA have been proposed in Brock and Khatib (1999), Arras *et al.* (2002), Philippsen and Siegwart (2003) and Ögren and Leonard (2005), to mention a few. Brock and Khatib (1999) present a Global-DWA to avoid the local minima problems by using connectivity information about the free space. However this global feature is never shown (Ögren and Leonard, 2005). A Reduced-DWA, to speed up the translational velocity selection, is proposed by Arras *et al.* (2002). As a result a *dynamic line* is obtained, which requires much less processing power. This velocity selection is not appropriate when the robot is not oriented towards the goal—for instance when the angle between the robot orientation with respect to the goal is higher than 90 degrees. A more elaborated method, which integrates three different approaches (DWA, elastic band and NF1), is