CENTRALIZED FORMATION CONTROL OF NON-HOLONOMIC MOBILE ROBOTS

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***Abstract* — This work presents a control algorithm for a group of non-holonomic mobile robots that must attain coordinately a specific formation, which can be fixed or moving in the work space. The control error is defined in terms of location, size and shape of the constellation of points placed by the robots and the constellation of objective points. The stability analysis of the proposed control system is included along with the results from simulation and laboratory experiencies which validate the good performance of this robot formation control system.**

***Keywords* — Multi-agent robotic system, robot formations, centralized formation control, non-holonomic mobile robots, non-linear systems.**

I. INTRODUCTION

There is a steady growth of applications where the purpose is to coordinately control a group of robots assigned to a specific task. Examples of tasks that require the cooperation of several robots are: robot teams for games, surveillance operations, search and exploration, rescue, survey and mapping, and taks that need organized robot teams in specific formations such as moving objects, cooperative handling of objects, etc.

The research on coordinated robots starts after the introduction of the behavior-based control paradigm (Brooks, 1986). Basically, there are three approaches for robot coordination reported in the literature: leader tracking (Monteiro *et al*., 2004; Desai *et al*., 1998), behavior methods (Fredslund and Mataric, 2001; Balch and Arkin, 1998), and virtual structure techniques (Belta and Kumar, 2002; Lewis and Tan, 1997). Most of the proposed coordination control systems are not based on dynamic systems and control theory, largely on account of the complexity of multi-robot systems. This is more so when considering non-holonomic mobile robots. However, in order to ensure system stability, it is necessary to resort to using the tools from control theory and dynamic systems (Das *et al*., 2002; Yamaguchi *et al*., 2001).

Within the field of robot formation control, the control task could be either centralized when there is monitoring and control of all robots to make them be placed at the desired position, or decentralized when there is no supervisor and the feedback is only the detected relative positions of each robot respecting their neighbor robots. The centralized formation control could represent a good strategy for a small team of robots, when it is implemented with a single computer and a single sensor to monitor and control the whole team. However, when considering a team with a large number of robots, the need of greater computational capacity and a large communication bandwidth could make advisable to use the decentralized formation control. Yamaguchi *et al*. (2001) presents a distributed control scheme and shows simulations for final static formations. Fierro *et al*. (2002) proposes a hierarchical control structure that allows the switching of controllers in order to have a stable formation, based on sensing their relative positions to neighboring robots, under a strategy of distributed control.

This work considers a centralized control strategy by assuming as known information the sensing of the instantaneous relative position of each robot in the work space, for example, by means of a camera that watches and monitors the entire scene. Within this known context, a controller is designed to coordinate the simultaneous movement of a number of non-holonomic mobile robots to make them reach a pre-established desired formation that could be fixed or moving. The constellation of target points and the initial positions of the robots will be considered through the polygons formed by their positions. Using non-linear control theory, it is verified that the designed controller leads to reaching asymptotically the objective of robots formation.

The work is organized as follows. Section II defines the error model used for designing the controller. Section III presents the proposed controller and the stability analysis for the formation control system. Section IV shows the results from simulations and laboratory experiences, and Section V gives some conclusions on the work.

II. FORMATION ERROR MODEL

The first aspect that arises in the problem stated for this work is to define an error in the formation between the group of n robots (constellation of robots C_R, see Fig. 1) and the group of their n desired positions (desired constellation C_D).